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From the Desk of Editor-in-Chief

It gives me immense pleasure to present this edition of our journal, which continues to serve as a platform for advancing knowledge, encouraging academic discourse, and fostering innovation in the field of Forensic Medicine and Toxicology. Each manuscript featured herein reflects the dedication, expertise, and curiosity of our contributors, addressing pressing issues and emerging trends that shape the practice and research of our discipline. As always, our commitment remains to ensure scientific rigor, ethical standards, and relevance to both academic and applied forensic settings.

In this issue, we bring together diverse articles that not only enhance our understanding of technical and investigative aspects but also highlight the social, legal, and public health implications of forensic science. It is my hope that these contributions will inspire further inquiry, collaboration, and practical application among our readers. I extend my sincere gratitude to our authors, reviewers, and editorial team for their invaluable efforts, and to our readership for their continued engagement and trust in our publication. My special thanks go to Joint Editor Dr. Harvinder Singh Chhabra and Assistant Editor Dr. Rattan Singh for their unwavering support and sincere efforts in the publication and release of this issue. Together, we move forward in our shared mission to expand the frontiers of forensic knowledge.

Thank you for being a part of this journey.

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Editorial

Forensic Medicine in the Era of Artificial Intelligence: Protecting Human Rights in India

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2. **Jyoti Barwa,** Additional Professor, Department of Forensic Medicine and Toxicology, AIIMS, Bathinda

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INTRODUCTION

The convergence of forensic medicine and artificial intelligence (AI) marks a transformative era in India's justice and healthcare systems. With the rising demand for faster, more accurate investigations, AI tools are increasingly being integrated into forensic pathology, toxicology, facial reconstruction, crime scene analysis, and even post-mortem interval estimations as these advancements promise unprecedented efficiency and objectivity.[1] Yet, they also bring profound challenges, particularly concerning human rights.

India, as the world's largest democracy, is at a crucial crossroads. Its use of AI in forensic contexts has begun to accelerate, often outpacing the development of legal safeguards and ethical frameworks. While AI has the potential to strengthen human rights through quicker case resolution, reduced wrongful convictions, and more equitable investigations, if misused or left unregulated, it could exacerbate existing inequalities, violate due process, and infringe on the right to privacy and dignity.[2]

Artificial Intelligence (AI) is increasingly being integrated into modern autopsy techniques also, particularly in the development and enhancement of virtual autopsy, or "virtopsy." Unlike traditional autopsies, which involve invasive surgical procedures to examine the body, virtopsy uses advanced imaging technologies such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) to create detailed, three-dimensional visualizations of the deceased's internal structures.

AI plays a critical role in this process by automating and improving various aspects of image analysis. For instance, machine learning algorithms can detect and classify anomalies, such as internal bleeding, fractures, tumors, or organ damage, with high precision and consistency. AI can also compare post-mortem imaging results with clinical and forensic databases, helping pathologists identify causes of death more quickly and accurately.[3]

While this innovation can reduce invasiveness and help in mass disaster identifications, questions remain about consent, data privacy, and the handling of sensitive post-mortem information. With no national forensic AI regulation in place, there is a potential for the risk of its misuse. In the Indian scenario, the foundation for acknowledging electronic communications and recordings as legitimate kinds of evidence was established by the Information Technology Act of 2000 (IT Act).

The statutory foundation for the admissibility of electronic records is provided by Section 65B of the Indian Evidence Act (IEA), now replaced by Section 63 in the new Bhartiya Sakshya Adhiniyam, 2023 (BSA). This provision stipulates that any digital record must be accompanied with a certificate attesting to the fact that it was created by a trustworthy computer system and unaltered, guaranteeing the integrity of the evidence that is offered.[4] Anvar P.V vs P.K. Basheer & Ors (2014) was a landmark case that highlighted the significance of this aspect of Indian law. The Supreme Court of India decided that digital evidence, including phone records and emails, must strictly adhere to the procedural requirements of this section in order to be admissible in court.[5]

In this context, equally concerning is the lack of standardized protocols for AI-generated evidence in courts as the Indian law has yet to fully adapt to the complexities of machine-generated forensic interpretations. Without robust admissibility standards, chain-of-custody protocols, and algorithmic transparency, such evidence may compromise the right to a fair trial.

Several state police departments in India have adopted AI-

based surveillance tools, sometimes without clear oversight or legislative backing. These technologies, when used in forensic identification or crowd analysis, may result in wrongful targeting especially of marginalized communities who already face systemic discrimination. Algorithmic bias, combined with flawed or incomplete forensic data, could lead to serious miscarriages of justice.[6]

Despite these risks, AI if developed and applied responsibly also presents a tremendous opportunity to protect human rights as enshrined in the Indian constitution and Universal declaration of Human rights. It can help reduce human error, identify patterns in custodial deaths, improve documentation of injuries in assault cases, and support medico-legal professionals in overburdened systems. However, the core principle must remain clear: AI must assist, not replace, human judgment.

India stands at a critical juncture. As the world's largest democracy and a digital economy on the rise, the choices it makes today in AI governance will set the tone for decades to come. Yet, unlike the European Union's General Data Protection Regulation (GDPR) implemented in 2018 or the recent AI Act which entered into force on August 1, 2024, and will be fully applicable from August 2, 2026,[7] India lacks a dedicated legal framework to govern the ethical deployment of AI. The absence of comprehensive data protection legislation despite the introduction of the Digital Personal Data Protection Act, 2023 leaves significant gaps in safeguarding citizens' rights against algorithmic decision-making.[8]

India urgently needs a rights-based AI governance framework specific to forensic applications. This includes legal reforms, ethical guidelines, effective implementation of data protection laws, algorithm audits, and strong judicial oversight. Furthermore, forensic professionals must receive interdisciplinary training in AI ethics, data privacy, and bias awareness. The Indian Council of Medical Research (ICMR), National Human Rights Commission (NHRC), and legal institutions must come together to shape this regulatory landscape.

India's judiciary, civil society, and academic institutions have a vital role to play in shaping this conversation. A robust ecosystem of ethical AI development, independent audits, and public consultation must be fostered; technology must remain subordinate to the rule of law and not the other way around.

In the era of digital forensics and algorithmic investigations, the true test of progress lies not just in technological capability, but in our commitment to uphold constitutional values. In forensic medicine, where decisions touch the most fundamental aspects of life and liberty, the protection of human rights must never be optional, it must be absolute.

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Original Research Paper

Understanding Motivational, Symbolic and Forensic Significance of Tattoo-Marks

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ABSTRACT

Introduction: Tattoos are a non-verbal form of expression with significant cultural, symbolic, and personal meaning across diverse societies. While prior research has explored the historical, cultural, and forensic significance of tattoos, gaps remain in understanding their role as identifiers in forensic anthropological contexts.

Objectives: The main objectives of the present research were: to explore the motivations and choices of individuals to get their body/body parts tattooed; to analyze the symbolic meaning of tattoos, and to investigate how tattoos can be helpful in personal identification for criminal investigations.

Materials and Method: This exploratory study was conducted in Chandigarh, India, involving 100 tattooed individuals, five tattoo artists, and 50 non-tattooed participants. Data was collected through self-administered schedules, interviews, non-participant observation, and secondary data sources. Participants were selected using purposive, convenience, and snowball sampling.

Results: The findings revealed that motivations for tattoos varied widely, including personal storytelling, social media influences, idolization, individuality, and spiritual beliefs. Symbolically, tattoos served as expressions of personal identity and cultural affiliation. Forensic applications of tattoos were explored, highlighting their potential as secondary identifiers in situations where other forms of identification were not possible.

Conclusion: The findings highlighted diverse motivations for getting tattoos, with the primary reasons being personal storytelling (27%), spiritual beliefs (27%), and fashion (16%). Tattoos were found to be deeply intertwined with an individual's personal, cultural, and social identity, with significant implications for forensic identification. Participants often chose tattoos to reflect personal milestones, memorialize loved ones, or express individuality, with many citing social media influences and idolization as key motivators. Tattoos, such as those on the lower arm, were more common among individuals from lower socioeconomic backgrounds, often acquired in informal settings like fairs or religious festivals.

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INTRODUCTION

Tattoo is a non-verbal form of expression, hold deep cultural, symbolic, and personal significance across diverse societies. The intentional alteration of the body known as tattooing entails introducing pigmented materials into the subcutaneous tissues, creating coloured patches that stand out from the surrounding skin. The Polynesian Tahitian word "ta-tau" is the source of the word "tattoo." The oldest known tattoos, which date to approximately 5300 years ago, were discovered on the preserved mummified body of Otzi, the so-called "Ice Man," a Neolithic hunter discovered in the Swiss/French Alps.[1] Since ancient times, people have been altering their bodies by marking them. Additionally, there is evidence of tattooing all across the world[2] and dating back at least to the Neolithic era, according to archaeological evidence found in the form of figurines and preserved skin.[1] Anthropology, the holistic study of humans, also comprehensively studies tattoos.

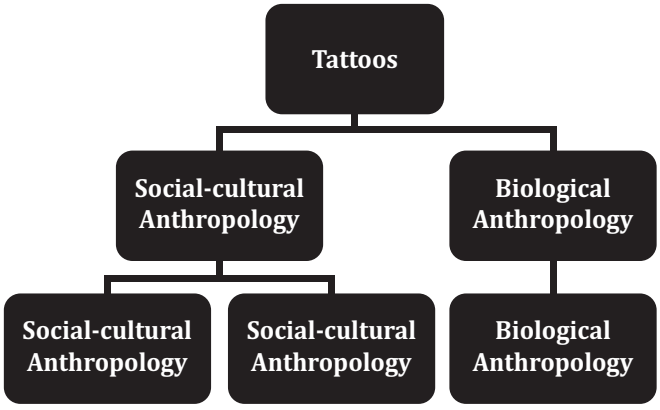
As highlighted by Boruah and Nilendu[3], tattoos are deeply tied to both personal and cultural identities, can serve as valuable forensic markers, especially in cases involving

decomposed or unidentified bodies. They offer insights into an individual's social background, religious beliefs, and community affiliations, making them essential tools in forensic investigations. Through real case studies, we can see how tattoos have been instrumental in identifying individuals, establishing criminal affiliations, determining timelines of events, and aiding in the resolution of criminal cases. As technology and forensic techniques continue to advance, tattoos will remain an essential tool in the arsenal of forensic experts and law enforcement agencies worldwide.

The primary objective and scope of the present study are to explore the art of tattooing from a multidimensional perspective, encompassing motivational, symbolic, and forensic aspects, through the lens of forensic anthropology. Tattoos, as a form of body modification, serve not only as expressions of personal and cultural identity but also hold significant forensic value. By examining tattoos in the context of human identification, this research integrates the fields of motivational psychology, symbolic anthropology, and forensic science. This forensic anthropological study emphasizes the application of forensic anthropology methods to investigate tattoos as potential tools for human identification in legal and criminal investigations.

The present study aims to understand the motivation factor behind getting tattoos and the different perceptions attached to them. Tattoos, which vary regionally, can also play an important role in forensic science as they may serve as a secondary or circumstantial form of identification.[1] The objectives of this study are threefold: to explore the motivations behind individuals' decisions to get tattoos, analyze the symbolic meanings attached to tattoos, and investigate their role as tools for personal identification in criminal investigations. By achieving these objectives, this study bridges the gap between cultural, personal, and forensic understandings of tattoos, contributing valuable insights to the field of forensic anthropology.

Figure 1: Classification of Tattoos



CLASSIFICATION OF TATTOOS

The American Board of Dermatology (ABD) has identified five categories under which tattoos fall: Professional, cosmetic, medical, traumatising, and amateur tattoos are all possible.[1] Trained artists make professional tattoos with uniform depth and vibrant colours that reach the dermis, cosmetic tattoos mimic makeup (e.g., eyeliner, lipstick) and aid in personal identification for forensic use, medical tattoos provide some essential health information (e.g., allergies, conditions), commonly used by the military and, traumatic tattoos are accidental tattoos from some incidents like road accidents or shootings, aiding in crime scene reconstruction.[1]

MATERIALS AND METHOD

The authors conducted interviews with 100 tattooed individuals, 5 tattoo artists, and 50 non-tattooed participants. From these, 20 of the most comprehensive interviews with tattooed individuals were analyzed for themes including motivations, symbolism, societal perceptions, and forensic aspects like age, gender, and tattoo location. The rationale for using only 20 participants was based on data saturation, where additional interviews were unlikely to yield significantly new insights. This allowed for a focused, in-depth analysis within the time constraints of the study. Time constraints limited coverage of some areas. The study explores tattoo culture in Chandigarh region, examining motivations for tattoos among adults (18+ years) through perspectives of both tattooed and non-tattooed individuals and insights from five local tattoo artists.

DATA ANALYSIS

Data collection methods included interviews, self-administered schedules, non-participant observation, and photography, supported by secondary data from university libraries and online databases. (Self-administered schedules were used for tattooed individuals and tattoo artists, with questions based on the themes and topics of the study). The schedules were validated by the supervising professor to ensure alignment with the study's objectives. Non-probability sampling techniques-convenience, purposive, and snowball sampling were employed.

I. MOTIVATION FOR TATTOOS

Nowadays, people view tattoos as a way to express

themselves. Following trends, becoming more motivated, prioritising psychological well-being, feeling good about reaching life satisfaction, enduring emotional agony, and concealing scars are some of the reasons why people get tattoos. The driving force underlying all human behaviour is motivation. All goal-oriented behaviours are guided and maintained by it. Extrinsic (originating from outside) and intrinsic (originating from within) motivation are the two primary categories. Tattoos alter motivation even though they have an impact on how it is perceived.[4]

III. Social perception and Stigma:

Social perceptions and stigma around tattoos vary widely across cultures and contexts. While tattoos are celebrated in certain cultures like Maori Ta Moko[5] and are increasingly accepted as personal expression in modern

i. Personal Tale (Tattoos Often Symbolize Personal Beliefs or Significant Life Events)

Participant	Statement	Picture
A	"Pataka" tattoo to express bold personality and resilience post-breakup. After breaking up with her boyfriend, she got this tattoo to cope with the situation. She felt that the tattoo symbolized her resilience and vibrant character, helping her embrace her individuality and move forward from the breakup. This tattoo serves as a reminder of her strength and ability to overcome personal challenges.	
B	Nandi Bail tattoo to remind him of positivity and strength. During his coaching time, saw Nandi Bail every day. Whenever he saw this bull, his day would become very positive. For that reason, he decided to get a tattoo of Nandi Bail. This tattoo symbolizes the positivity and strength he drew from seeing the bull, serving as a constant reminder of the positive influence it had on his daily life and mindset.	
C	Dopamine molecule tattoo for mental well-being and positive emotions. which held deep personal significance. He had chosen this tattoo because dopamine, often referred to as the "feel-good" neurotransmitter, symbolized his journey towards finding happiness and balance in life. For him, the tattoo was a constant reminder of the importance of mental well-being and the role that positive emotions played in his daily life. It represented his commitment to maintaining a positive outlook and his appreciation for the science that explained the human experience.	

ii. Social Media (Influences from Movies or TV Can Inspire Tattoo Choices)

Participant	Statement	Picture
D	Inspired by Sunny Deol's character in Narasimha to get a Narasimha tattoo for strength. In this movie, Actor Sunny Deol's character had a tattoo of Narasimha (Lion), which left a significant impression on Individual D. Captivated by the character's strength and courage; he decided to get a similar tattoo.	

Western society, they still face stigma in conservative settings. Negative associations with tattoos often stem from historical biases and stereotypes, especially in professional and generational contexts. Case studies highlight discrimination in workplaces, generational differences in acceptance, and the empowering role tattoos can play in personal recovery. Efforts to combat stigma include education, diverse representation, inclusive workplace policies, and open dialogue.

iii. Idolizing Someone (Tattoos can Reflect Admiration for Artists, Writers, or Celebrities)

Participant	Statement	Picture
E	Atticus quote tattoo as a reminder to live fully. The quote, "Spoiler: We die in the end," is inked on his arm. This quote resonates deeply with Individual E, serving as a stark reminder of life's impermanence and the importance of living fully in the moment. He explained, "Atticus's words remind me to embrace life with urgency and not to take anything for granted. This quote, in particular, push me to live authentically and make the most out of every day.	

iv. Individuality (Tattoos as Unique Expressions of Identity and Personal Milestones)

Participant	Statement	Picture
F	Tattoo representing love for mountain travel. His tattoo is on right lower leg.	

v. Fashion: Tattoos as a Fashion Statement or for Self-Expression

Participant	Statement	Picture
G & H	Chose tattoos to stay trendy, focusing on appearance.	

vi. To Hide a Scar (Tattoos Used to Cover Scars from Past Experiences)

Participant	Statement	Picture
I	Om tattoo on ring finger to cover self-inflicted scars. She opted to tattoo the symbol of _Om' on her ring finger to cover up severe cut marks. These marks were a result of self- inflicted injuries caused by emotional distress, particularly related to a past relationship.	

vii. In Memory of Someone (Memorial Tattoos Keep Loved Ones' Memories Close)

Participant	Statement	Picture
J	Tattoo for her late grandfather (Daddu).	

viii. Religious Belief (Tattoos Representing Spirituality or Lucky Charms)

Participant	Statement	Picture
K & L	Shiva-related tattoos expressing deep spiritual beliefs.	

II. Symbolism and Meaning of Tattoo:

Participant	Statement	Picture
M	Zodiac Sign Tattoos- **Gemini (Individual M)** **Personal Traits:** Duality: Reflects adaptability and versatility in personality. Communication: Signifies love for conversation, learning, and sharing ideas. Curiosity and Intellect: Represents a quest for knowledge and a dynamic approach to life **Cultural and Symbolic Significance:** Astrological Symbolism: Depicted as Roman numeral II or twins, symbolizing balance between opposing forces. Mythological References: Linked to Castor and Pollux, twin brothers symbolizing themes of brotherhood, protection, and eternal life.	

IV. Forensic Identification:

Identifying unidentified bodies is essential for upholding the rule of law. It provides closure for families and loved ones, allowing them to grieve properly, while also ensuring legal security within society and offering peace of mind to those affected. Additionally, it is for the satisfaction of a last legal and moral duty to the deceased.[6] Tattoos can be important in forensic science because they can be used as a secondary or circumstantial form of identification.[1]

When it comes to identifying one's ethnicity, nationality, occupation, and religion, tattoos can be extremely significant. Name of the individual or loved ones; Drug usage or misuse; Membership in a criminal or social group; Socioeconomic status, all can be derived from the tattoos.[7] Any tattoo marks on the body may be used as a form of identification in certain criminal situations where the victim's face is destroyed to hide their identity. The significance of tattoos in cases when a body was discovered in a state of advanced putrefaction is detailed in a case

vii. In Memory of Someone (Memorial Tattoos Keep Loved Ones' Memories Close)

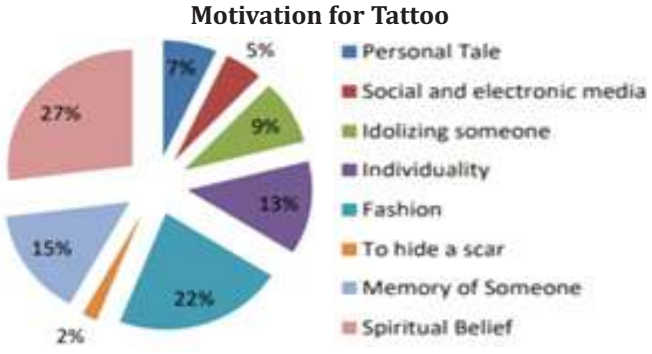
Participant	Statement	Picture
N	**Virgo** **Personal Traits:** Practicality and Reliability: Reflects grounded nature and dependability. Meticulousness and Attention to Detail: Symbolizes an appreciation for detail and perfectionism. Health and Well-being: Represents dedication to a healthy lifestyle. **Cultural and Symbolic Significance:** Astrological Symbolism: Depicted as the Virgin or "M" with a loop, representing purity, modesty, and strong work ethic. Mythological References: Linked to Demeter (goddess of harvest) and Astraea (goddess of justice), symbolizing themes of nurturing, justice, and purity.	
O	Professional Discrimination Individual W, a corporate employee, faced professional discrimination due to his visible sleeve tattoos. Despite his qualifications and performance, he encountered biases during job interviews and promotions. Colleagues and employers often perceived him as unprofessional or unconventional. This experience highlights the ongoing stigma in conservative professional environments, where tattoos are not fully accepted.	

study by Mukhopadhyay et al[8]. A secondary identifier, a tattoo mark that read "R + K," was discovered, aiding law enforcement in identifying the person.

RESULTS

a) Motivation factors among individuals for getting tattoos

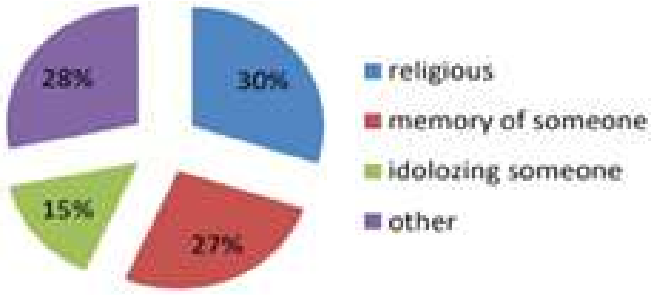
Figure 2: Motivation for Tattoos



The primary motivation for tattoos among participants was spiritual belief (27%), while the least common was the scar concealment (2%). This highlights spirituality's influence on tattoo choices and the variety of personal reasons behind them.

b) Motivation factors among non-tattooed participants and planning for tattoo

Figure 3: Motivation for Tattoos in Non-Tattooed Participants

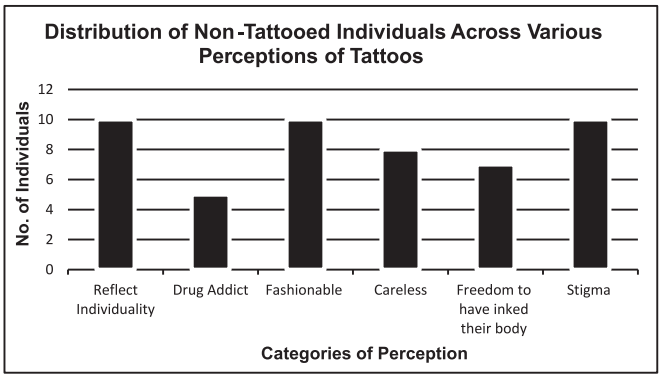


Among non-tattooed participants, 30% expressed that religious themes would motivate their future tattoos, highlighting the strong influence of spirituality on body art choices.

c) Social perception and Stigma Related to Tattoos

Tattoos have been generally inked to reflect individuality, drug addiction, fashion/adornment, social stigma, carelessness or personal freedom of an individual to get tattoos etc.

Figure 4: Distribution of Non-Tattooed Individuals\ Across Various Perceptions of Tattoos



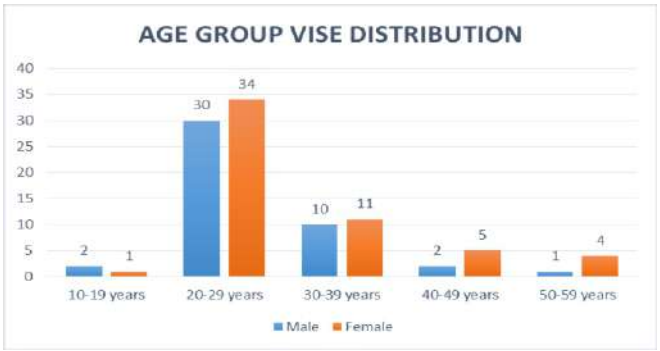
b) Forensic Identification

Tattoos are invaluable in identifying unknown bodies, especially when other methods like fingerprints or dental records aren't available, aiding legal investigations and providing closure to families. Any tattoo mark on the body may be used as a form of identification in certain criminal situations where the victim's face is destroyed to hide their identity. The significance of tattoos in cases when a body was discovered in a state of advanced putrefaction is that tattoos, due to their pigments being embedded deep within the dermal layers, often remain visible or can be detected with specialized techniques even when other identifying features are lost, thereby serving as valuable secondary identifiers for human identification when visual recognition, fingerprints, or dental records are not possible.[9]

Sex

Out of the 100 participants surveyed, 45% were male and rest were female, each with at least one tattoo. This distribution indicates a nearly balanced representation of genders in the study, allowing for diverse insights into the motivations, symbolism, and social perceptions associated with tattoos among both men and women. The study's gender balance provides a comprehensive understanding of how tattoos are experienced and perceived across different demographic groups.

Figure 5: Sex and Age based Distribution of the Tattooed Participants



Religion & Caste

Out of the 100 participants interviewed, 31% (n = 31) identified as belonging to Sikhism and had tattoos, while the remaining 69% (n= 69) participants identified as Hindum and also had tattoos. The majority of participants who had tattoos belonged to the general category, comprising 52% (n =52). Additionally, 39% (n = 39) of participants identified as belonging to the Scheduled Caste category, while 9% (n = 9) of participants were from the Other Backward Classes (OBC) category and had tattoos.

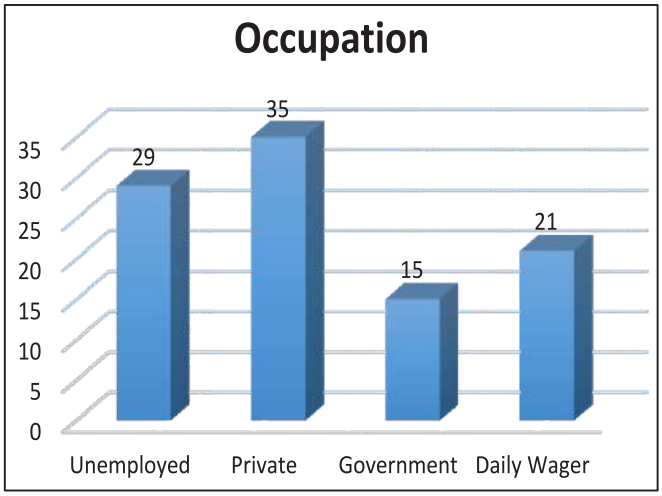
Type of Tattoo

Amateur tattoos are preferred by daily wage workers, who often get them at fairs (16%, n = 16). This trend reflects a cultural practice where individuals from certain socioeconomic backgrounds opt for less expensive and more accessible tattooing options, often seeking them out in informal settings like fairs or religious sites from amateur tattoo artists While maximum of the participants get their tattoo from trending tattoo studio (84%, n = 84).

Occupation

Out of 100 participants, 35% (n =35) of them are employed in the private sector and have tattoos, while tattoos are restricted in the government sector, 15% (n =15) only. This disparity in tattoo acceptance between private and government sectors underscores the influence of workplace policies and cultural norms on individuals' decisions to get tattooed. Additionally, it highlights the potential impact of occupational considerations on tattooing practices among different segments of the population.

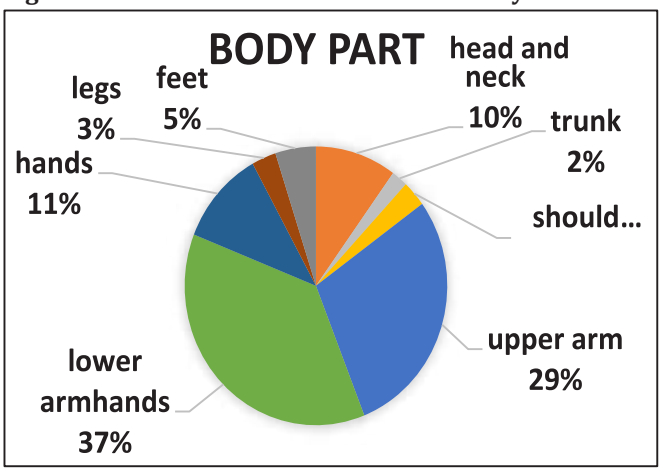
Figure 6: Occupation of Tattooed Participants



Body Part

37% (n =37) participants preferred tattoos on lower arm followed by upper arm, which is visible easily. Maximum of the female prefer tattoo on the lower arm.

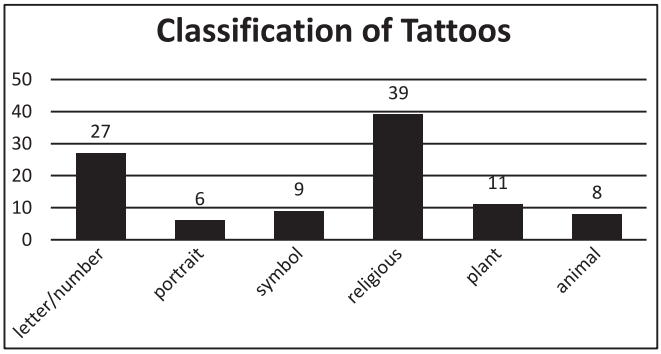
Figure 9: Distribution of Tattoos across Body Parts



Classification of Tattoos

The high proportion of tattoo is of letter/number that is 39% (n = 39) participants having tattoos which included the name of that individual, his/her lover, parents name etc.

Figure 10: Classification of Tattoos



DISCUSSIONS

Tattoos are a non-verbal form of expression wherein an indelible mark, figure, or pattern of ink or pigment is inserted under the skin of a person. These inked patterns hold utmost cultural, symbolic, and personal significance across diverse human societies as such intricate patterns, symbols or motifs communicate personal narratives, societal roles, and group affiliations. While existing research has delved into the historical, and cultural importance of tattoos, there remains a gap in understanding how these inked-symbols serve as identifiers in forensic anthropological contexts and can be used as a secondary or circumstantial form of identification like name of the individual or loved ones; drug usage or misuse; membership in a criminal gang or social group; socioeconomic status. Through personal symbols, tattoo culture has given people a way to express who they are while also fostering a sense of belonging and community.[10] Tattoos can help in tracing individuals' origins, migrations, and affiliations, rich histories, kinship structures, and social hierarchies of the communities. The present article addresses with the presentation of results in the light of the finding obtained by other researchers in the same field.

MOTIVATION FOR TATTOOS

Over the last twenty years, people's views on tattoos and tattooing have changed a lot. Tattoos, which used to be associated with fringe groups, are now a big part of mainstream culture and fashion. Researchers have noted the importance of personal motivations behind getting tattoos. Researcher finds out different sub themes which lead the motivation for getting tattoos. This include: personal tale, motivation from social media, idolizing someone, individuality, fashion, to hide a scar, in the memory of someone, religious belief. Dey and Das[2] studied the motivation behind being tattooed. They conducted their study in the Kolkata metropolitian and included tattoo artists and tattoo owners covering both sexes of various age groups who were selected by using snowball sampling technique. People get tattoos for various reasons, such as telling personal stories, expressing their individuality, finding spiritual significance, or following fashion trends. Tattoos can also mark significant life events like births, coming of age, marriages, divorces, or deaths, and can commemorate important memories related to love or loss. Some believe that tattoos are used for personal advertisement, attracting others' attention and interpretation, although this is considered a myth. According to Rohith et al[1] study, television and movies have a strong influence on people, leading them to get tattoos that connect them emotionally to characters they admire, rather than just copying their physical appearance. Both the studies have showed similar motivation for being tattooed. This data can be used for further studies and identification purposes.

SYMBOLISM OR MEANING OF THE TATTOOS

Tattoos are more than just physical marks; they carry personal, social, and cultural significance. For example, a tattoo of Lord Shiva may represent spiritual devotion and community ties. By using thick description, we can

understand tattoos as symbols of identity, social affiliation, and cultural narratives. However, the researcher lacks tattoos from specific communities that share similar meanings. Tattoos are a unique form of self-expression, symbolizing commitment and permanence. Conducting research across different groups could help develop a model for identifying cultural symbols through tattoos. Throughout human history and across the cultures, tattooing has evolved from a traditional practice deeply embedded in specific communities to a global phenomenon influenced by modernization and westernization. This evolution reflects broader social changes and highlights the dynamic interplay between cultural heritage and contemporary influences.[11]

FORENSIC IDENTIFICATION

Identifying unknown bodies is crucial for ensuring a well-functioning rule of law. This process helps maintain legal security in society and provides relatives and friends with the certainty needed for closure and mourning. It also fulfills a final moral and legal duty to the deceased. Studying demographic variables like age, marital status, caste, religion, and occupation helps understand tattoo trends, including their cultural impact, and which groups are most influenced by tattoo culture. In Mexico, tattoos are often used to identify missing persons, with a significant percentage of missing individuals having tattoos.[6] Tattoos are valuable identifiers, especially during autopsies, where they can be documented and revealed using special techniques. The study suggests a classification system for tattoos, which, combined with other methods, can assist in identifying unknown bodies. It also provides a framework for interpreting tattoos in criminal investigations.

When it comes to identifying one's ethnicity, nationality, occupation, and religion, tattoos can be extremely significant. Prioritising psychological well-being, feeling good about reaching life satisfaction, enduring emotional agony, and concealing scars are some of the reasons why people get tattoos. Examination of these inked-markings coupled with advancements in imaging technology facilitate the establishment of individualized profiles for forensic purposes. Tattoos may help in tracing individuals' origins, migrations, and affiliations, rich histories, kinship structures, and social hierarchies of the communities.

Forensic analysis of tattoos emerged as a pivotal theme in the study, particularly in the context of identifying victims in mass disasters, criminal investigations, and cases involving decomposed or disfigured bodies. Tattoos were recognized as secondary identifiers, essential when traditional methods like fingerprints or dental records are not available.

The integration of advanced radiological tools, such as MSCT, MRI, CBCT, and micro-CT, can complement tattoo analysis by improving the precision of forensic identification in cases of disfigurement or decomposition.[12,13]

LIMITATIONS

The lack of a standardized tattoo database and variability in cultural interpretations of tattoo symbols was one of the limitations of the study. While time constraints limited the scope of certain areas, the study successfully captures key themes and provides a solid foundation for future, more extensive investigations.

CONCLUSION

Tattoos serve as powerful tools for personal expression, cultural representation, and social communication. They are not merely decorative but also encapsulate complex narratives and embody the intersection of individual and collective identities. The findings highlighted diverse motivations for getting tattoos, with the primary reasons being personal storytelling (27%), spiritual beliefs (27%), and fashion (16%). Tattoos were found to be deeply intertwined with an individual's personal, cultural, and social identity, with significant implications for forensic identification. Participants often chose tattoos to reflect personal milestones, memorialize loved ones, or express individuality, with many citing social media influences and idolization as key motivators. The study illustrated that tattoos, such as those on the lower arm, were more common among individuals from lower socioeconomic backgrounds, often acquired in informal settings like fairs or religious festivals. This trend suggests that tattoos can also reflect cultural and social affiliations, offering further avenues for forensic experts to link individuals to specific communities or regions.

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Original Research Paper

Sternal Components as Predictors of Stature: A Forensic Anthropology Study in the Prayagraj Region

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ABSTRACT

Introduction: An important component of forensic anthropology is identifying people through estimating their total height based on skeletal remains. Out of all the bones analysed, the sternum has been identified as one of the more well-preserved and stronger bones suitable for height estimation. This research seeks to explore the predictive potential of the sternum for stature estimation.

Materials and Method: A total 100 participants (50 males & 50 females) aged 20 to 70 years from the Prayagraj region underwent thoracic thin-section computed tomography scans. The scans were performed, using a 384 Multi-Detector Computed Tomography (MDCT) Scanner, the images with a slice thickness of 1 mm were utilised. Structural images analysis were conducted to estimate stature by measuring different components of the sternum through three dimension CT imaging.

Results: The investigation revealed verifiable sexual dimorphism, as male sternal dimensions and stature surpassed that of females. In all the variables studied, height correlated most closely with TSL (r=0.891), which further increased with height regression in males (r=0.932). Also, regression analysis corroborated that manubrium length, body of sternum length, and total sternal length were significant predictors of stature. The predictors accounted for 72% of the variance (R^2=0.72). Males, unlike females, were more precise (R^2=0.75 vs. R^2=0.68). Over the years, ageing has had a cumulative effect on reducing stature owing to spinal compression.

Conclusion: The present study validates the use of sternal measurement for estimating stature, enhancing their relevance in forensic practice. Being a scientific reliable, non-invasive and tailored to both sex and age, these measurements offer a practical and accurate tool for anthropological and forensic application. This adds considerable value to forensic identification methods, especially in scenario where traditional techniques may not be feasible or available. The study supports that sternal lengths strongly correlate with stature particularly in males.

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INTRODUCTION

Some medico-legal practitioners deal in cases in which the decomposition, dismemberment, or mutilation of a body is so extreme that it is nigh impossible to identify them. There is no question that in every medico-legal case, a very important goal is the identification of unknown human remains. In order to do that, it is important to outline the biological profile of the subject which involves determining their age, height, sex, and other anthrop-ological attributes. In some circumstances, human skeletal remains are studied due to the extensive decomposition of soft tissue, charring, or mutilation. Different bones such as femur,[1] scapula,[2] sacrum,[3-4] skull,[5] vertebrae,[6] ribs,[7] Talus,[8] calcaneum[9] have been examined previously for the estimation of a person's stature, age, sex and other anthropometric features.

In cases involving mutilation and dismemberment, the sternum is often recovered intact due to its relatively protected position within the body.[10] As a result, this bone may prove more valuable for identification purposes than other skeletal elements. Anthropologists have long utilised the sternum and its components, to estimate sex,[11-15] age,[16-19] and stature[20-29] across different populations. The present study specifically focuses on the population of Prayagraj city. To the best of the authors' knowledge, no prior study has been conducted on this population. Additionally, the present study is based on CT scans performed on living individuals. The sternum was completely isolated using three-dimensional Virtual Reality (VR) tool within Digital Imaging and Communications in Medicine (DICOM) Viewer. In addition to anthropometric measurements, various morphological characteristics and other straightforward traits have also been employed in stature estimation.[30]

Although some research has explored stature estimation from the sternum and its components in India, the available literature remains limited and shows contradictory findings. Studies by Muam et al[20] and Chandrakanth et al.[21] conducted on South Central Indian populations reported only a minimal correlation between sternal dimensions and stature. In contrast, Menezes et al[27,29] demonstrated a significant association in a South coastal Indian sample. These inconsistencies, combined with the absence of population-specific data from North-Central India, particularly the Prayagraj region, highlight the need for further research. Additionally, previous studies predominantly relied on cadaveric specimens, whereas the present study utilizes advanced CT imaging techniques, offering a novel, non-invasive approach to stature estimation.

Prayagraj is a significant region for forensic anthropology research due to its diverse population, which aids in developing population-specific biological profiles. The present study set out to determine the stature of the people in the Prayagraj region by employing radiological samples of the sternum and its parts, namely the manubrium body of the sternum, also known as mesosternum.

The studies reviewed have utilized linear regression equations to estimate sternal measurement-based stature estimation. Unlike the methods that have been outlined, all preceding studies have been conducted with the skeletal remains of humans and have avoided Radiological techniques.

We have progressed well with utilizing CT scans as our sternum measuring tool instead of using the more traditional cadaver bone length measuring techniques. Therefore, this study aims to develop reliable, population-specific regression models for stature estimation using high-resolution CT-derived sternal measurements in the Prayagraj region.

MATERIALS AND METHOD

The ethical approval LPU/IEC/LPU-IEC/2023/1/2 was collected in December 2023 from the Institutional Ethics Committee (IEC) at Lovely Professional University, Phagwara, Punjab.

In this study, we used the Thoracic thin-section CT images of 100 Participants (50 males and 50 females), aged between 20 and 70 years, from the Prayagraj region, Uttar Pradesh from February 2024 to August 2024. Subjects included in the study were natives of the Prayagraj region from more than three generations. Informed consent was obtained from all participants. These patients underwent CT imaging for diverse clinical indications, with none having a prior history of thoracic trauma or surgery. The CT images were collected in the axial orientation with a slice thickness of 1mm. Furthermore, sagittal and coronal reformatted images were generated at the workstation for comprehensive evaluation. The scanning was done in the Kriti Scanning and Research Centre Pvt Ltd, Prayagraj; all patients were scanned using a 384 Multi-Detector Computed Tomography (MD-CT) Scanner. Structural image analysis was performed to estimate stature by measuring the different components of the sternum utilising 3D CT imaging. The measurements were obtained using mouse-driven techniques within the Radiant DICOM viewer software. All CT examinations conformed to a standardised protocol. A single breath-hold was used to scan patients from the thoracic intake to the lung bases. The beam pitch coefficient used for the scans was 1.2, a collimation width of 384 mm, and a scanner rotation time of 0.8 seconds per slice at 120kv.

Measuring the Stature of Participants:

The stature of the participants was measured with a stadiometer positioned in anatomical posture. The participants were asked to inhale maximally and then to maintain that breath while the sliding horizontal rod touched their head

Precautions in Measuring Stature:

i. The participants were asked to keep their body erect with their heads in the Frankfort plane (FH).

ii. All reading was taken by the author only so as to prevent any observer bias.

iii. Participants with any sternum-related trauma were not included in the study.

Radiological Assessment:

The measurements of various sternum parameters were recorded for analysing the stature (Shown in **Figure 1**):

- **Length of Manubrium [ML]:** Total length from jugular notch to the manubriosternal joint.
- **Body Length [BL]:** Length from manubriosternal joint to the xiphisternal joint.
- **Complete length of the sternum [TSL]:** Distance from the manubrium and body of the sternum.

Figure 1: Parts of Sternum Measured for Analysing the Stature.

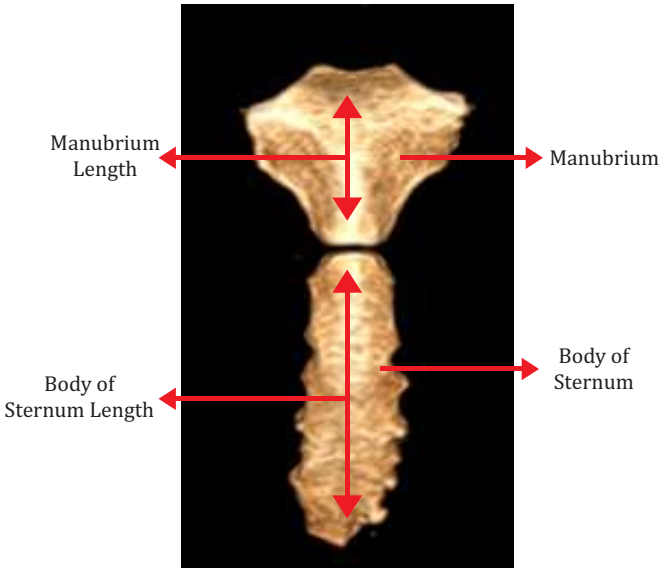


Figure 2 and **Figure 3** shows how measurements were taken using RADIANT DICON viewer software.

Figure 2: Measurement of Female Sternum by Using Radiant DICOM Viewer Software.

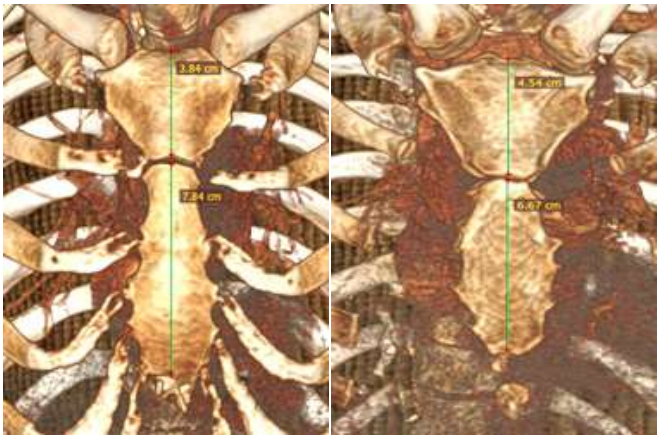
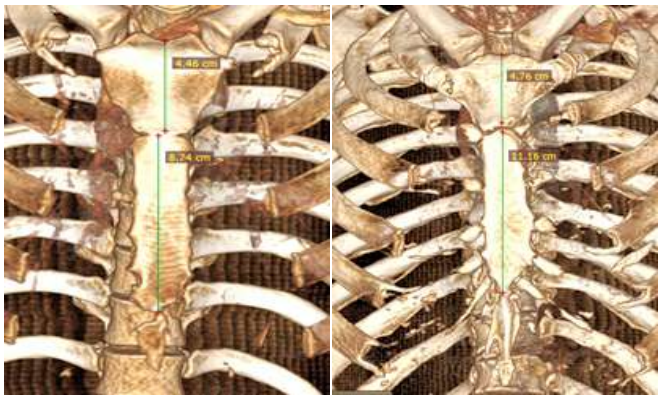


Figure 3: Measurement of the Male Sternum by Using Radiant DICOM Viewer Software.



Inclusion and Exclusion

The subjects strictly belong to Prayagraj region and the age ranged between 18-70 years. The subjects with sternal trauma, developmental anomalies or surgical modifications were excluded from the study. CT scans of subjects showing artefacts were also excluded from the present study.

Analysis of the Data was done using SPSS version 16.0. A two-tailed Student's t-test was conducted to evaluate the differences between the sexes for the various observations made during the study. The relationship between stature and sternal measurements was studied and regression estimation models for sternal measurements were developed. p-value equal to or less than 0.05 was regarded as significant.

RESULTS

The study investigates the estimation of stature using sternal measurements, presenting a detailed statistical analysis across multiple parameters. **Table 1** shows female sternum measurements, which include manubrium length, body length, and total sternum. A scatter plot presentation for females is shown in **Figure 4**. Likewise,

Figure 4: Scatter Plot Showing Age Vs Height (Female)

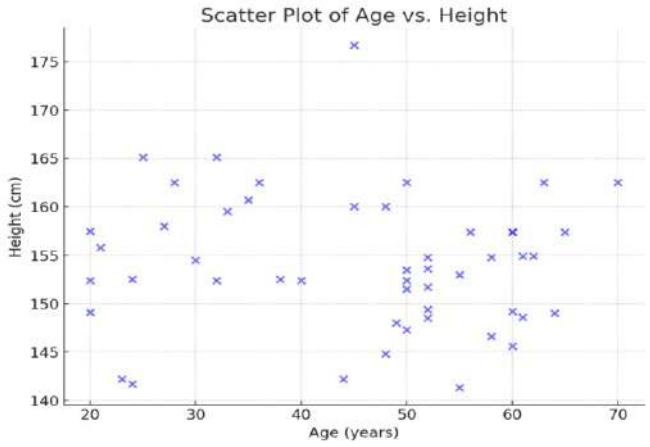


Table 1: Measurements of Females' Sternum

No. of Participants	Manubrium Length (ML)	Body of Sternum (BL)	Manubrium + Body od sternum length (TSL)	Age	Sex	Stature
1	3.84	7.84	11.68	20	female	149.1
2	5	7.66	12.66	20	female	152.4
3	4.08	7.63	11.71	20	female	157.5
4	3.89	8.08	11.97	21	female	155.8
5	4.27	7.78	12.05	23	female	142.2
6	4.05	6.69	10.74	24	female	141.7
7	4.17	8.53	12.7	24	female	152.5
8	4.21	8.18	12.39	25	female	165.1
9	3.41	7.37	10.78	27	female	158
10	3.66	6.95	10.61	28	female	162.5

Table 2: Measurements of Males' Sternum

No. of Participants	Manubrium Length (ML)	Body of Sternum (BL)	Manubrium + Body od sternum length (TSL)	Age	Sex	Stature
1	4.69	9.86	14.55	20	male	167.4
2	4.13	8.58	12.71	22	male	179.8
3	4.75	9.28	14.03	23	male	146.3
4	5.24	8.7	13.94	23	male	171.4
5	4.46	8.74	13.2	24	male	170.9
6	5.26	8.69	13.95	25	male	177.8
7	5.15	8.27	13.42	26	male	163.3
8	4.94	7.66	12.6	28	male	167.6
9	4.62	9.5	14.12	28	male	170.1
10	4.31	9.63	13.94	29	male	167.7

Table 3: Descriptive Statistics

Variables	Mean	Median	Standard Deviation	Range
Age (years)	4.12	4.05	0.48	2.91–5.26
Manubrium length (cm)	8.62	8.35	1.25	5.96–12.19
Body of sternum length (cm)	12.72	12.45	1.91	8.87–16.66
Manubrium + Body of sternum lengths (cm)	44.5	45	15.3	20–70
Stature (cm)	159.8	157.4	10.2	141.3–182.9

Table 4.1: Descriptive Statistics by Sex (Females)

Variables	Mean	Median	Standard Deviation	Range
Manubrium Length	3.78	3.72	0.42	2.91–4.68
Body of Sternum	8.02	7.97	1.05	5.96–10.52
Manubrium + Body of Sternum Lengths	11.54	11.38	1.28	8.87–14.68
Stature (cm)	152.9	152.4	6.3	141.3–176.7

Table 4.2 Descriptive Statistics by Sex (Males)

Variables	Mean	Median	Standard Deviation	Range
Manubrium Length	4.57	4.43	0.38	3.33–5.26
Body of Sternum	9.21	9.09	1.12	7.14–12.19
Manubrium + Body of Sternum Lengths	13.68	13.52	1.45	10.97–16.66
Stature (cm)	167.2	167.7	9.1	146.3–182.9

Table 2 show the same parameters for the male sternum, and its scatter plot presentation is shown in **Figure 5**. An overview of the descriptive statistics for the key variables is shown in **Table 3**, including age, manubrium length, body of sternum length, the combined length of these structures, and stature. The findings highlight variations in skeletal features, with a mean stature of 159.8 cm and a standard deviation of 10.2 cm. The data is further categorised by sex, illustrating notable differences between females and males shown in **Table 4.1** and **Table 4.2**. Males exhibit larger sternal measurements, with a

Table 5: Correlation Matrix

Variable	Manubrium Length	Body of Sternum	Manubrium + Body of Sternum Length	Age	Stature
Manubrium length	1.00	0.82	0.78	0.10	0.65
Body of sternum	0.82	1.00	0.85	0.15	0.70
Manubrium + Body of Sternum Lengths	0.78	0.85	1.00	0.18	0.73
Age	0.10	0.15	0.18	1.00	-0.12
Stature	0.65	0.70	0.73	-0.12	1.00

Table 6: Regression Analysis

Parameter	Description
Dependent Variable	Stature (cm)
Independent Variables	Manubrium length(ML), Body of Sternum (BL), Complete Length (TSL), Age
Regression Equation	Stature = 100.34 + 3.21(ML) + 1.84(BL) + 2.15(TSL) − 0.25(Age)
R^2 Value	0.72 (Indicating the Model Explains 72% of Height Variance)
Significant Predictors	ML ($p < 0.001$), BL ($p = 0.002$), TSL ($p < 0.001$)

**ML-Manubrium length, BL-Body of sternum, TSL-Complete length(manubrium and body of sternum)*

Table 6.1: Regression Analysis (Females)

Parameter	Description
Dependent Variable	Height (Female)
Independent Variables	Manubrium length(ML), Body of Sternum (BL), Complete length(TSL), Age
Regression Equation	HEIGHT (female) = 95.28 + 2.85(ML) + 1.65(BL) + 2.03(TSL) - 0.30(AGE)
R^2 Value	0.68 (indicating the model explains 68% of height variance in females)
Significant Predictors	ML($p < 0.01$), BL($p = 0.03$), TSL($p < 0.01$)

**ML-Manubrium length, BL-Body of sternum, TSL-Complete length(manubrium and body of sternum)*

mean stature of 167.2 cm, whereas females average 152.9 cm, emphasising sex-based anatomical variations.

To explore relationships among variables, **Table 5** presents the correlation matrix, revealing strong positive correlations between sternal dimensions and stature. The combined length of the manubrium and body of the sternum shows the strongest correlation with stature (r = 0.73), followed by the body of the sternum (r = 0.70) and manubrium length (r = 0.65). Age, however, demonstrates a weak negative correlation with stature (r = -0.12),

Table 6.2: Regression Analysis (Males)

Parameter	Description
Dependent Variable	Height (Male)
Independent Variables	Manubrium length(ML), Body of Sternum (BL), Complete length(TSL), Age
Regression Equation	HEIGHT (male) = 102.67 + 3.42(ML) + 1.98(BL) + 2.28(TSL) - 0.18(AGE)
R^2 Value	0.75 (indicating the model explains 75% of height variance in males)
Significant Predictors	ML($p < 0.001$), BL($p = 0.01$), TSL($p < 0.01$)

**ML-Manubrium length, BL-Body of sternum, TSL-Complete length(manubrium and body of sternum)*

indicating a slight height reduction with increasing age, likely due to skeletal changes.

Regression analysis, detailed in **Table 6**, confirms that sternal measurements significantly contribute to stature estimation. The overall regression model explains 72% ($R^2 = 0.72$) of height variance, with the regression equation:

Stature = 100.34 + 3.21 (ML) + 1.84 (BL) + 2.15 (TSL) − 0.25 (Age)

where ML ($p < 0.001$), BL ($p = 0.002$), and TSL ($p < 0.001$) are significant predictors.

Sex-specific regression models further refine the analysis. Table 6.1 presents the female-specific model, which explains 68% ($R^2 = 0.68$) of height variance, using the equation:

Stature (female) = 95.28 + 2.85 (ML) + 1.65 (BL) + 2.03 (TSL) − 0.30 (Age)

with significant predictors ML ($p < 0.01$), BL ($p = 0.03$), and TSL ($p < 0.01$).

In contrast, **Table 6.2** shows that the male-specific model has the highest predictive accuracy, explaining 75% ($R^2 = 0.75$) of height variance with the equation:

Stature (male) = 102.67 + 3.42 (ML) + 1.98 (BL) + 2.28

Figure 5: Scatter plot showing Age vs Height (Male)

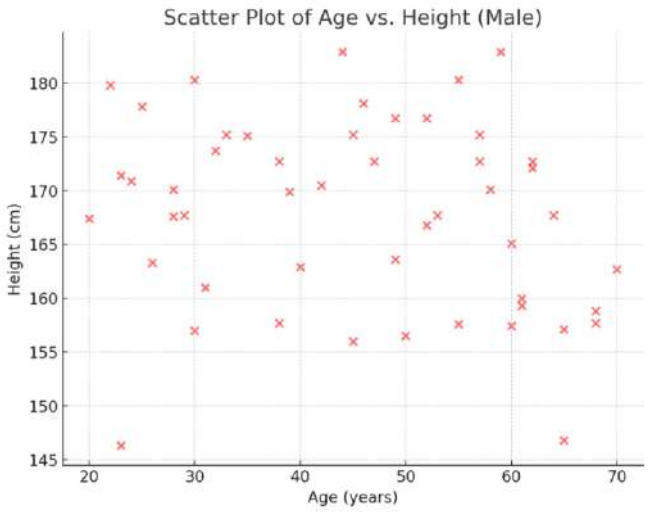
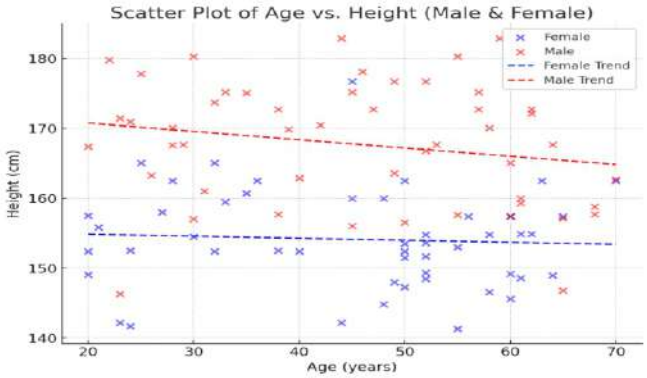


Figure 6: Scatter Plot Comparing Age and Height for Both Males and Females. The Dashed Lines Represent The Trend Lines for Each Sex.



***Blue:** Female data and trend line*
***Red:** Male data and trend line.*

(TSL) – 0.18 (Age)

where ML ($p < 0.001$), BL ($p = 0.01$), and TSL ($p < 0.01$) are significant predictors.

Overall, the study confirms that sternal dimensions serve as reliable predictors of stature, with stronger correlations in males. The sex-based differences in predictive accuracy highlight the importance of tailored regression models for forensic and anthropological applications. These findings validate the use of radiographic sternal measurements for stature estimation, offering a more advanced and non-invasive alternative to traditional cadaver-based methods.

DISCUSSION

The goal of this research is to estimates height based on the separate and combined lengths of the manubrium, sternal body, and total sternal length. The results have revealed that there is a high correlation between the dimensions of the sternum and the height of the individual, especially in terms of combined length ($r = 0.73$). This research also develops sex-specific regression equations, which contribute to the accuracy of the estimated height. While conducting this research, a comparison was made with available literature focusing on measurements of height using different sternal measurements shown in **Table 7**.

Studies using different populations for studying the association between sternal length and stature. Baraw R et al., (2017), analysed samples of cadaver sternums from Delhi, India, and obtained R^2 values of 0.770 and 0.731 employing linear regression on fresh and dry sternum samples pertaining to posterior curve length of the sternum and posterior curve length of the individual's stature, which meant a high correlation.[12,34] This hints at the reliability of the methods for estimating stature in the North Indian population. On the other hand, Bista et al., (2024) studied Nepalese samples employing combined manubrium and mesosternum length and found in their study $r = 0.320$, indicating some degree but no major correlation.[33] Yonguc et al., (2014) studied Turkish cadavers and found length of manubrium and body to be the most useful parameter for estimating stature, reporting R^2 values of 0.521 and 0.547 for males and females, respectively, with further improvement to 0.640 in females when combining length of body and length of manubrium and body.[25]

Tumram et al., (2015) focused on Indian males in Central India, estimating total sternal length yielded a moderate correlation ($R^2 = 0.55$) after Baraw, yet placing these findings in the context of practical applications.[20] Lastly, Venkatesh (2020) worked with 210 cases from South India and claimed that length of manubrium and body yielded the most reliable estimates of statistical correlation, particularly in males ($R^2 = 0.490$), with a combined R^2 of 0.611.[35]

This study builds on past work by incorporating CT-based sternal measurements and creating appropriate regression models for each sex. Its strong correlation values along with other methodological improvements demonstrate the study's contributions to forensic science, especially for contemporary forensic practices by providing a non-invasive method of stature estimation that is accurate and reliable.

Influential Effects of the Technique Used for Measuring

Perhaps the most important difference between this study and most earlier ones is the use of computed tomography CT instead of some form of direct anthropometric physical

Table 7: Comparison of Previous Studies on Sternal Measurements for Stature Estimation with the Present Study.

S. No.	Authors, Date	Population	Samples used	Samples Size	Statistical Analysis	Sternal Length	R^2 Value	References
1	Yonguc et al., 2014	Turkey	Cadavers	65 males, 30 females	Linear & Multiple Regression; ROC Analysis	LMB (manubrium + body)	0.521 (males), 0.547 (females); 0.640 (females, multiple)	14
2	Tumram et al.,2015	Central India	Cadavers	92males	Linear regression	Total sternal length	0.55	20
3	Bista et al., 2024	(67 males, 33 females), 6, Nepal	Autopsies	67 males, 33 females	Linear regression	Combined manubrium and mesosternum	0.32	33
4	Baraw et al., 2017	Delhi	Cadavers	50 males, 50 females	Linear regression	Posterior Curve Length (PCL)	0.770 (fresh), 0.731 (dry)	34
5	Venkatesh J. et al., 2020	South India	Cadavers	160 males, 50 females	Linear regression	LMB (males), LB (females)	0.490 (LMB, males), 0.472 (LB, females), 0.611 (total LMB)	35
6	Present Study, 2025	Prayagraj	Radiological samples (CT scans)	100 living individuals (50 males, 50 females)	Linear regression, Correlation	ML,BL and TSL	0.75 (males) 0.68 (females)	

**LMB-Length of Manubrium + Body, LB-Sternal Body Length, ROC-Receiver Operating Characteristic*

measurement. The previous studies made use of sternal lengths derived from dissecting cadaveric specimens, and there are issues concerning drift due to the conditions of preservation and contact with the specimen. On the other hand, radiographic measurement is direct and simple, and above all unique because it is taken in the living subject, which explains the reasons for the higher correlations established in this study.

Moreover, Chandrakanth et al., 2021 studied how the sternal fusion status affects the accuracy of stature estimation.[21] Their results indicated that sternal incompleteness can be a defect to some extent. As the focus of this study is not on the fusion status, the difference in correlation coefficients between males and females may be, at least partially, a result of the difference in sternal ossification.

Differences of The Sexes in Relation to Stature Estimation

Several studies including Dwight (1890) and Ashley Montagu (1935), have repeatedly established that sternal measurements are not the same in males and females, with sternal components of males being larger in size and more robust than those of females.[31,32] This study also found that men have greater sternal length in comparison to their female counterparts. Therefore, the male-specific regression equation ($R^2 = 0.75$) is more accurate than the female-specific equation ($R^2 = 0.68$). With these results, we emphasise the salient point that the regression model of stature estimation should consider sex as a variable.

Strengths and Limitations

The strongest point of this study is the use of CT scan-based radiographic measurements, which offer greater precision

and accuracy compared to traditional physical measurement methods. Moreover, the creation of distinct regression models for men and women increases the accuracy of the equations

Despite advancement there were several weaknesses persist in this study, i.e. lack of the complete analysis for fusion status, which may affect accuracy of stature estimation in particular among the older age groups, population specific limitation, which create population specific regression model which is not suitable for broader diverse population, limited sample size, using different measurement techniques (manual, radiological, autopsy) and postmortem changes, research involving cadavers may contain errors because of decomposition, shrinkage, or any posture-related distortions with sternal length. Future studies should include sternal fusion analysis and use larger, diverse samples to improve accuracy. Standardized imaging methods and consideration of morphological traits can enhance the reliability of stature estimation models.

CONCLUSION

The present study concurs with those that argue that there is a close relationship between sternal length and height, especially in males. This conclusion is different from previous studies wherein only cadaveric measurements were performed, and which reported weak correlations. The sternum bone showed excellent correlation i.e. (>0.90) with stature that justify the application of sternal measurements for stature estimation that heightens the application value in forensic practice. Since it is scientifically credible and non-invasive, as well as specific to sex and age. Therefore sternum is ideal for forensic stature estimation. Future research should incorporate sternal fusion status and expand sample diversity to enhance the applicability of these models across populations. CT-based sternal measurements offer a superior, non-invasive, and population-specific method for stature estimation, enhancing forensic investigations in cases of decomposition or dismemberment.

Conflict of Interest/Funding: Nill

There is no conflict of interest regarding the publication of this research. All data and findings are presented transparently and without any external influence.

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Original Research Paper

Stature Estimation by Ulnar Length in Medical Students of Tamil Ethnicity using Linear Regression Analysis in a Tertiary Care Hospital, Chennai

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ABSTRACT

Introduction: Many tools help in establishing the identity of a person, of which height or stature plays a key role. One such tool is the estimation of height from the percutaneous length of the ulna. Anthropometry is especially helpful in establishing the identity of mutilated, skeletonized and amputated body parts. Height not only plays a vital role in Forensic Medicine but also in Clinical Medicine, where height enables the calculation of BMI, basic energy needs and tidal volume. Height cannot be measured directly in bedridden patients. Moreover, regression equations are ethno-specific. Hence, the main aim of this study is to derive a linear regression formula for determining the stature of right and left ulnar length. Ulnar length is measured between the tip of the olecranon and styloid processes with the help of a digital caliper in a population of Tamil ethnicity between the age group of 18–23 years. Tamil ethnicity was determined based upon their native language and their ancestral history. Within the study population, it was found that the average height of adult males was significantly higher than that of adult females. The mean height in males was 175.03±8.97 cm, in females were 159.51±6.21 cm and in all the subject (N=181), the mean height calculated was 166.11±11.79 cm. The linear regression equations for estimation of stature would be of high practical value for medical and forensic experts in identifying a person from stature for civil and criminal purposes as per the need.

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INTRODUCTION

The assessment of height plays a crucial role in forensic medicine and anthropometry. Assessing height from different parts of a human skeleton can be helpful and plays a vital role in identifying the unknown and disfigured human bodies. Identification of unknown human corpses involves the measurement of various physical parameters, including stature. In numerous instances, only human body parts are used to establish identification while determining the height of a person. There is a positive correlation between a person's height and the dimensions of different body parts, especially this correlation serves as a foundation in estimating the stature. Particularly long bones are used for this purpose.[1]

Stature estimation, as a vital parameter of personal identity, plays an important role in establishing individuality of an unidentified dead body or any mutilated part of the body by medico-legal experts.[2] Among all techniques that use metrics, the regression equation for height based on the length of long bones provides the most accurate outcomes. Calculations from upper limb long bones are just as trustworthy as those from lower limb long bones.[3] The measurement of the ulna is often utilized to determine stature. Different regression equations that depend on the length of ulna are available.[4] It is widely accepted that a formula suitable for one specific population may not provide accurate estimates for other populations.[5]

Distinct sexual dimorphism was observed in stature and length of ulna and positive linear correlations observed between height and length in males and females and linear regression models for stature estimation have been

derived in accordance.[6] Professor Karl Pearson (1898-99) was the first to introduce correlation calculus for stature prediction from long bones.[7] From the size of a few skeletal remains, he sought to reconstruct the size of organs and the general stature of prehistoric races. With the aim to estimate missing dimensions, this method included creating mathematical correlations between various bodily elements.

However, height can differ based on factors such as race, age, gender, genetics, climate, and nutritional health. Consequently, any research related to height estimation must be tailored to the specific population and sex.[8] Numerous researchers have identified the existence of dissimilarity between different populations when it comes to estimating the height. Hence the importance of using a population-specific regression equation for determining the stature has been reiterated. Thus, this study focuses on deriving a regression equation using ulnar length to predict height in adult individuals particularly of Tamil ethnicity.

MATERIALS AND METHODS

The present study was conducted on undergraduate medical students at ACS Medical College, Chennai, Tamil Nadu, India. Their ages ranged between 18 and 24 years and this study was done in 2023-2024 over a period of 6 months. The total sample size was 181. n = 77 males and n = 104 females. Ethical clearance was obtained from the Institutional Ethical Committee and, after obtaining informed written consent from the participants of the study, the data were recorded in the proforma.

Individuals with major systemic illnesses, past fractures, skeletal abnormalities, developmental issues, any surgical procedures affecting height and metabolic disorders that may impact bone growth were not included in the study. Measurements were conducted at a specific time of day to remove diurnal fluctuations. The right and left ulna were measured percutaneously using a digital Vernier caliper from the olecranon tip to the ulnar styloid process tip with the arm flexed at the elbow and the hand positioned on the other shoulder, while the individual's vertical height was measured in barefoot with a stadiometer from head to heel facing in Frankfurt's horizontal plane.

The data were examined with the statistical software SPSS version 28.0. The T test was utilized to determine the relationship between the right and left ulna in relation to gender. ANOVA was conducted to determine the relationship. The linear regression equations were calculated and a p value < 0.05 was deemed significant.

RESULTS

There was a positive correlation between ulnar length and height and as the ulnar length increases, height tends to increase as well.

Table 1: Distribution of Subjects According to Age and Gender

Variables	Frequency	Percentage
Age	-	-
18	7	3.9
19	31	17.1
20	43	23.8
21	70	38.7
22	25	13.8
23	4	2.2
24	1	0.6
Gender		
Male	77	42.5
Female	104	57.5
TOTAL	**181**	**100.0**

Table 2: Mean and S.D for All the Parameters – Both Sexes Together

Variables	Mean	SD
Age	20.50	1.14
Height	166.11	11.79
Length of Ulna (Right)	26.92	1.98
Length of Ulna (Left)	26.81	1.96

Table 3: Mean and S.D for All the Parameters in Male and Female Cases

Variables	Male		Female	
	Mean	SD	Mean	SD
Age	20.48	1.14	20.52	1.15
Height	175.03	8.97	159.51	6.21
Length of Ulna (Right)	28.48	1.70	25.77	1.25
Length of Ulna (Left)	28.38	1.68	25.66	1.21

There was a positive correlation between ulnar length and height and as the ulnar length increases, height tends to increase as well

Table 4: Comparison of Length of Right and Left Ulna \ between the Gender

Variables	t-value	p-value	95% CI
Length of Ulna (Right)	12.399	0.000	2.28–3.14
Length of Ulna (Left)	12.671	0.000	2.30–3.14

Table 5: Pearson's Correlation Coefficient Between Ulna Length and Height.

Variables		Correlation Coefficient (r)	Coefficient of Determination (%)	p-value
Length of Ulna (Right)	Both the Sexes	0.739	54.6	0.000*
	Male	0.498	24.8	0.000*
	Female	0.761	57.9	0.000*
Length of Ulna (Left)	Both the sexes	0.731	53.5	0.000*
	Male	0.488	23.8	0.000*
	Female	0.731	53.4	0.000*

Table 6: Regression Equation for Height with Length of Ulna.

Variables		Correlation Coefficient (r)	p-value
Length of Ulna (Right)	Both the Sexes	4.782 * X + 37.39	0.000*
	Male	4.101 * X + 58.23	0.000*
	Female	3.791 * X + 61.82	0.000*
Length of Ulna (Left)	Both the sexes	4.770 * X + 38.20	0.000*
	Male	4.064 * X + 59.71	0.000*
	Female	3.742 * X + 63.51	0.000*

Independent Sample T-test. p-value <0.05 is regarded as statistically significant. Both left, and right ulnar lengths show statistically significant differences between the groups being compared. There is a significant difference in both left and right ulnar lengths between males and females, with males likely having longer ulnas on average than females. The significant results of both the t-tests and Levine's test suggest that gender plays a key role in the variation in ulnar length.

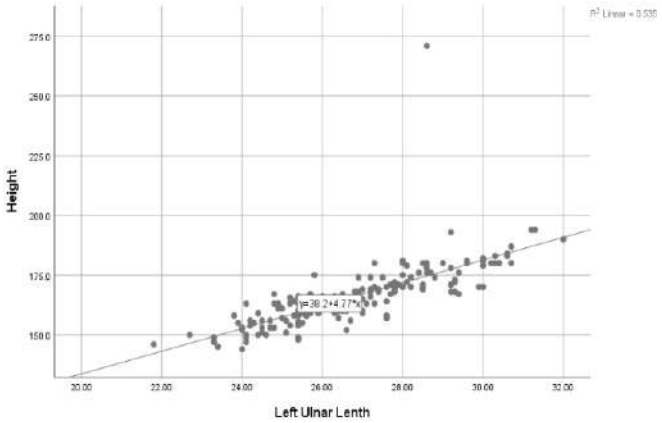
Correlation was Significant at the 0.001 Level

The correlation coefficient® between stature and right ulna in males and females were 0.498 and 0.761, respectively, whereas, the r values between stature and left ulna in males and females were 0.488 and 0.731, respectively. This showed strong positive correlations between stature and ulnar lengths **(Table 5)**, that were statistically significant in both the sexes. Also, the r values were higher in females, implying that females have better correlation between stature, and ulna and tibial lengths than males.

Regression equation for estimation of stature was derived using the formula y= a + bx ± S.E.E., where y= estimated stature, a= intercept, b= regression coefficient, x= length of the variable and S.E.E. = Standard Error of Estimate.

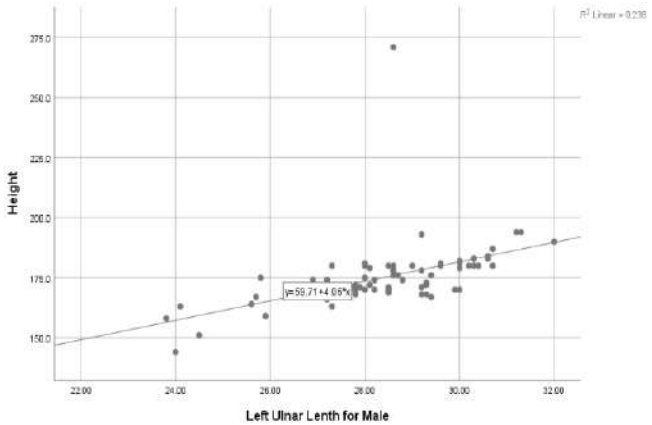
The **Graph 6** shows the relationship between two variables: height (on the y-axis) and right ulnar length (on the x-axis) in females. Each dot represents an individual female's right ulnar length and the corresponding height. The trendline (line of best fit) represents the linear

Graph 1: Linear Regression Coefficient for Left Ulna Length and Height in Both Sexes.



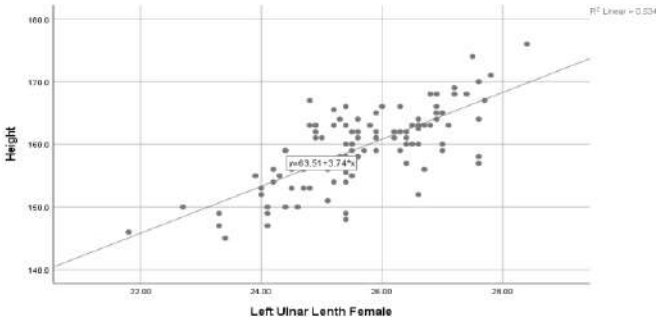
The equation of this line is given as: y=38.2+4.77 X. where [X = length of left ulna in cm in male]*

Graph 2: Linear Regression Coefficient for Left Ulna Length and Height in Males.



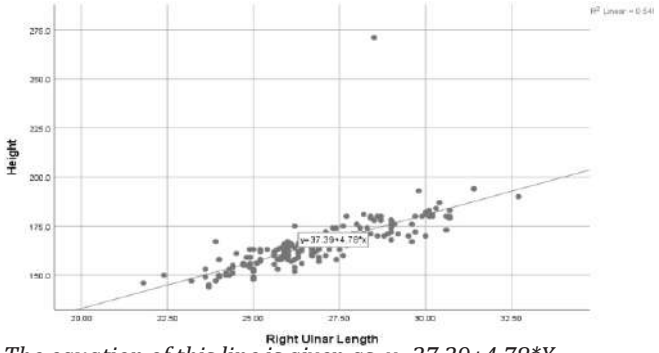
*The equation of this line is given as: y=59.71+4.06*X. where [X = length of left ulna in cm in male]*

Graph 3: Linear Regression Coefficient for Left Ulna Length and Height in Females.



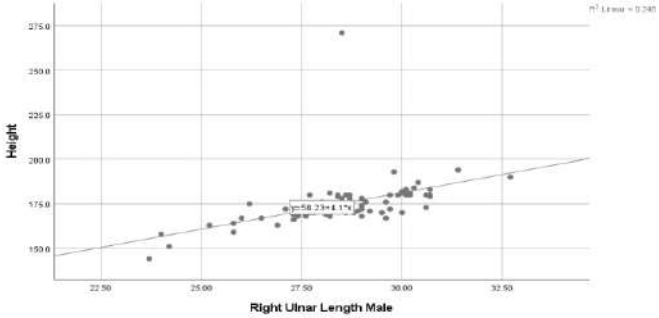
*The equation of this line is given as: y=63.51+3.74*X. where [X = length of left ulna in cm in females]*

Graph 4: Linear Regression Coefficient for Right Ulna Length and Height in Both Sexes



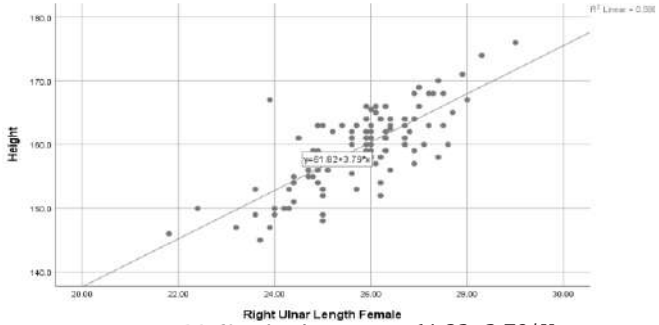
*The equation of this line is given as: y=37.39+4.78*X. where [X = length of right ulna of any gender in cm]*

Graph 5: Linear Regression Coefficient for Right Ulna Length and Height in Males.



*The equation of this line is given as: y=58.23+4.1*X. where [X = length of right ulna in cm in male]*

Graph 6: Linear Regression Coefficient for Right Ulna Length and Height in Females.



*The equation of this line is given as: y=61.82+3.79*X. where [X = length of right ulna in cm in female]*

relationship between ulnar length and height. The equation of this line is given as: y=61.82+3.79*X.

where, Y = Height/ Stature (cm)

X = Length of right ulna (cm)

61.82 is a constant for female.

3.79 is a regression coefficient for female

The R^2 value (0.58) tells us that approximately 58% of the variability in height can be explained by the ulnar length. This suggests a moderate positive linear relationship between the two variables.

Interpretation of Data:

- There is a positive correlation between ulnar length and height. As the ulnar length increases, height tends to increase as well.
- However, there is some variability, as shown by the spread of the dots around the trendline, and 42% of the variation in height is not explained by the ulnar length alone.
- In both sexes, there was insignificant difference in the mean lengths of ulna between the right and left sides (P>0.05). Thus, left ulna and right ulna lengths for both sexes were employed for additional statistical analysis. Each of these measures showed a significant difference between the sexes (P<0.001).

DISCUSSION

Anthropometric analysis of bones is very significant since it gives valuable information on a person's age, stature, sex, and race. Estimating a person's stature aids in their identification. Estimating a person's stature in a living subject is simpler because it is typically measured by their standing height; however, it becomes challenging when only fragmented remains are available.[9] A study by Meena MK et al.[10] had tried to establish the statistical correlation between stature and pre-cutaneous tibial length (PCTL) by formulating a simple regression equation and multiplication factor (MF) for the people of Jhalawar region of Rajasthan. It was carried out on 200 subjects (100 male and 100 female) among the people of Jhalawar and it was revealed that there is a positive correlation exists between the stature and percutaneous tibial length. The present study has intended to estimate stature from percutaneous measurement of length of ulna on which the data gathered and analyzed and would be available for comparison with other studies.

The observations were individually analyzed for both ulna

bones of each gender in all cases and the outcome was summarized in tables. There was a significant difference in both left and right ulnar lengths between males and females, with males likely having longer ulnas on an average than females. The age of the participants ranged from 18 to 25 years with 91% falling between 19 to 22 years of age. The mean ages of males and females were 20.48 ±2.73 years and 20.52 ±2.34 years, respectively, which was comparable. **(Table 1, Table 2)**

The total stature of subjects ranged from 147 to 194 cm with the mean stature of males, 175.03 ±8.97 cm and females, 159.51 ±6.21 cm. **(Table 3)**

In this study, differences in mean height and ulnar length between genders were found to be statistically significant ($p<0.05$). **Table 3** suggests the mean lengths of the right and left ulna in males (28.48±1.70and 28.38±1.68) were noticeably greater than those of females (25.77±1.25and 25.66±1.21) across all age groups. This study suggests that gender plays a key role in the variation in ulnar length. This was consistent with a study by Lemtur M et al.[6] (*) where the mean ages of males and females were 23.22 ±3.93 years and 23.12 ±3.34 years, respectively and mean stature of males was 168.12±5.48 cm and females was 157±5.41 cm. Mean ulna and tibial length in males were significantly longer than that of females and a positive correlation between height and both the length of long bones was observed in both the sexes in that study.

Table 5 suggests correlation of height with length of ulna is 0.498 and 0.488 in males and is 0.761 and 0.731 in females, which are positive and statistically highly significant ($P < 0.01$) i.e. if length of ulna increases or decreases, the height of the subject also increases or decreases and vice versa.

Table 6 infers that an increase of 4.101 in height for males is associated with each additional unit of length in the right ulna, with a statistically significant p value of 0.000. Similarly, an increase of 4.064in height for males is associated with each additional unit of length in the left ulna, with a statistically significant p value of 0.000.

Each additional unit of length in the right ulna is correlated with a 3.791 increase in height for females, with a p value of 0.000 indicating statistical significance. Likewise, each additional unit of length in the left ulna is correlated with a 3.742 increase in height for females, with a p value of 0.000 indicating statistical significance

The average height of adult males within a population is significantly higher than that of adult females.[11] The results of this research coincide with the assertion.

It has been argued by Trotter and Gleser[12] that a regression formula tailored to a population's size must be developed. The primary explanation for this should be because different populations have varying height proportions of different body parts, which are known to be influenced by factors such as race, environment, diet and socio-economic stand.[13] Hence before using a regression equation to predict stature specific to a certain locality, it is necessary to identify race, gender, and age. Afore mentioned reason justifies, that different population-specific regression formulae must be developed to determine the stature in various population within India. For instances, Thummar B et al.[13] developed a regression equation to predict height based on the length of the right and left ulna in both men and women. The regression equation for the right ulna in males was Y = 81.11 + 3.117X, while for the left ulna is Y = 65.76 + 3.667X. The formula for the right ulna bone in females was Y = 17.10 + 5.34X, while for the left ulna it is Y = 18.95 + 5.33X.

In another study by Singh JP et al.,[14] an anthropometric attempt was made to correlate between stature and measurements of hand & finger length, where stature was observed as significantly related to hand length, width and length of fingers. In that study, the mean height in males was 174.3690±6.18 cm, in females it was 159.50±6.22 cm and in all the subjects (N= 200), the mean height calculated was 166.94±9.68 cm. The regression equation formulated for height for all the subjects (n= 200) was Y= 36.734+(4.994* LHL) +(2.683* RHW) +(5.023* RMFL) -(3.489* LRFL).

As determination of sex and estimation of stature are important aspects of forensic identification, it becomes a challenge to conclude in absence of pelvis and skull. Hence, long bones become handy in such cases. A study was conducted in Turkey[15] where radial and ulnar lengths were used for the same purpose, and it was revealed that, in the study sample of 127 corpses, the average male stature was 170 cm, i.e. 140 mm taller, and radial and ulnar bone lengths are 30 mm longer than the female group. And, regression analysis was used in stature estimation from these two bones. Another study at Punjab University, Patiala,[16] measured hand length and breadth as well as stature for 300 subjects between the ages of 18-30 years and both univariate and multivariate linear regression equations were developed to predict stature based on hand dimensions, which showed a positive and significant correlation between hand dimensions and stature.

On similar lines, many others have derived regression

equations for the estimation of stature, observing the inconsistencies existing between populations of different ethnicities within India. This is one such study reiterating the importance of stature estimation in the population of Tamil ethnicity. Thus, using the data and regression equations obtained from the current study, the stature of a deceased individual whose only forearm bones are available can be determined with a reasonable degree of accuracy.

CONCLUSION

The present research signifies that males exhibit a higher average height and ulna length than females. It also suggests that height and ulnar length were directly correlated. In addition to that gender plays a vital role in the variation of ulnar length.

The linear regression equation which we derived in this study can be reliably applied for predicting the height of individuals of Tamil ethnicity. If either the ulna length or total height is provided, the other measurement can be easily calculated. The regression equation for height based on the length of ulna, thus provides the most accurate outcomes in terms of stature estimation. This can be of practical applicability in certain forensic investigations, clinical assessments and anthropometry.

Limitations

Since the linear regression equation derived in this study is specific for individuals of Tamil ethnicity, applying equation for predicting the height of individuals of other ethnicity may not give accurate estimations.

Exclusion of individuals above the age of 24 from the analysis due to insufficient sample size is another limitation of this study. Also, it is a well-known fact that stature can decrease with age. Thus, a validation test for the other age individuals should be another topic for the future research with additional data

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Original Research Paper

Profile of Sudden Cardiac Deaths: A Five-Year Autopsy-Based Retrospective Study at a Tertiary Care Center in Northern Haryana, India

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ABSTRACT

Introduction: Sudden deaths happen in those individuals who have an unknown or undiagnosed disease. Sudden cardiac death (SCD) is the most prevalent worldwide cause of sudden death, and its cause and epidemiology are still being studied in different regions in India.

Materials and Method: This retrospective study analyzed 41 (5.2%) SCDs of the 779 autopsies conducted at a tertiary healthcare center in Northern Haryana, India, over five years (January 2019 to December 2023).

Results: Males were majorly affected with 33 (80.5%) SCDs. Most SCDs were in the 41-50 years age group, with 10 (24.4%) followed by 9 (22.0%) cases each in the 21-30 and 31-40 years age groups. Most hearts (29.3%) weighed between 351 and 400 g; in 75.6% of SCDs, the heart weighed more than 300 grams. Among the causes of death observed, the most common was acute coronary insufficiency (ACI) due to coronary atherosclerosis, with 29 (70.7%) cases, and hypertrophic cardiomyopathy was observed in the rest. Among the 29 cases of SCDs due to ACI, single and double coronary vessel narrowing was observed equally, with 13 cases each, and 3 cases had triple vessel involvement. Most commonly involved was the left anterior descending artery in 23 (56.1%) cases. The most common risk factor was obesity, observed in 26 (63.4%) SCDs, followed by hypertension, three (7.3%) cases.

Conclusion: The findings emphasize the need for early cardiovascular risk assessment, especially for middle-aged men, and the urgent need for public health initiatives to lower the prevalence of SCDs in this region.

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INTRODUCTION

The World Health Organisation describes sudden death as "when an individual dies within 24 hours of the onset of symptoms without any known preceding disease or injury."[1] Predominantly, the cardiovascular system is involved in sudden unexplained deaths. Sudden cardiac deaths (SCDs) are due to anomalies and abnormalities that affect several cardiovascular structures.

Coronary atherosclerosis is the main culprit among cardiovascular causes.[2] Many authors prefer 'unexpected' or 'unexplained' instead of sudden as these terms describe death's suspicious nature and warrant postmortem examination. The natural causes are particularly cardiovascular, followed by the respiratory, central nervous, gastrointestinal, and other systems.[1-2]

According to the National Crimes Record Bureau, in 2022, heart attacks claimed the lives of 32,457 Indians, accounting for a substantial portion of the 56,450 sudden deaths that were reported, a 10.1% rise from the previous year. Lifestyle variables, including stress, poor diets, and inactivity, also have a major impact.[3] Recent data on SCD in India highlight its growing burden.

According to an analysis in 2023, SCDs claimed the lives of over 5-6 lakh Indians per year.[4] In the United States, annually 180,000 to 450,000 SCDs are reported. The SCDs increased with age and were notably higher in men. The majority of SCD cases, approximately 75-80%, are attributed to CAD.[5] Arrhythmias, undetected heart diseases, and hypertrophic cardiomyopathy have also been found to be significant factors in autopsy-based research. Genetic predi-spositions, lack of awareness, and restricted access to healthcare exacerbate the problem in urban and rural communities.[4]

Coronary artery disease (CAD) is a leading health issue that results in insufficient blood supply to the heart muscle, manifesting as ischemic heart disease. Acute coronary syndrome, which includes unstable angina, myocardial infarction, and SCDs, is largely caused by CAD.[6] CAD is the most frequent cause of death in nations across all income brackets despite variations in mortality and prevalence.[7]

When thrombus is absent in the coronary artery, death can be opined due to acute coronary insufficiency as a consequence of coronary atherosclerosis if atherosclerotic deposition causes more than 75% narrowing of the vessel.[8] An adult heart typically weighs 250 to 300 grams.[9] When unexplained left ventricular hypertrophy (LVH) and other causative cardiac or systemic conditions, such as hypertension or aortic stenosis, are absent, it is a hallmark of Hypertrophic cardiomyopathy (HCM), characteristic of genetic disorder.

Mutations in sarcomeric protein genes primarily cause HCM, leading to clinical manifestations, including arrhythmias and heart failure, particularly in young individuals and athletes. Left ventricular hypertrophy (LVH) is due to more mass and thickness of the left ventricle, which may arise from physiological adaptations (e.g., athletic training) or pathological conditions such as hypertension, aortic stenosis, or genetic disorders like hypertrophic cardiomyopathy. In genetic cardio-myopathies, LVH occurs independently of loading conditions and is a hallmark feature of hypertrophic cardiomyopathy.[10]

The present study aimed to identify the patterns and trends of SCDs reported in postmortem examinations at the mortuary of a tertiary care hospital in Northern Haryana to find out the most vulnerable age groups, gender, date, and time of incidence, survival period, pre-existing disease condition and survival period involved to obtain a better perspective of such sudden deaths.

The cases were labeled SCD if autopsy findings confirmed coronary atherosclerosis with >75% luminal narrowing or evidence of HCM, etc.

MATERIALS AND METHOD

This retrospective study includes 41 SCDs brought to the mortuary of a tertiary hospital in Mullana, Ambala, Haryana, for postmortem examination from January 2019 to December 2023. The study aimed to determine the profile of SCD cases in this region. The study was conducted with prior approval from the Institutional Ethics Committee, MMIMSR, Mullana, Ambala, Haryana (IEC-3146/MMIMSR).

Inclusion Criteria

All cases with conclusive postmortem findings consistent with sudden cardiac death (e.g., acute coronary insufficiency, coronary atherosclerosis with >75% luminal narrowing, or evidence of HCM, etc) were included.

Exclusion Criteria

Unknown dead bodies, decomposed bodies, and cases with a history suggestive of SCDs, but autopsy findings suggested otherwise.

Data were collected from the postmortem examination reports, police inquests, histopathology examination reports, and chemical analysis of viscera reports. Data was compiled in an anonymized data collection proforma, then tabulated in Microsoft Excel 2021 and analyzed for descriptive statistics.

RESULTS

During the study period of five years from 2019-2023, 779 autopsies were conducted, of which 41 (5.2%) were SCDs. Maximum numbers of SCDs were observed in 2021, with sixteen (39.0%) cases each in this year. The lowest number of SCDs was recorded in 2019, with two (4.9%) cases **(Table 1)**.

Table 1: Shows Sudden Cardiac Deaths Among Total Autopsies Conducted in The Respective Year of the Study Period.

Year (n= 41)	% (n)
2019	4.9 (2)
2020	22 (9)
2021	39 (16)
2022	14.6 (6)
2023	19.5 (8)

Most, 36 (87.8%), were residents of rural areas, whereas only five (12%) lived in urban locality. The study revealed a

preponderance of male cases, where males were 33 (80.5%) and females were eight (19.5%). SCDs ranged in individuals from 21 to 68 years. The mean age was 42 years, with 12.8 years of standard deviation. Ages 41 to 50 years were the most affected, with 10 (24.4%) SCDs, all males. Between the ages of 21 to 30 years and 31 to 40 years, 9 (22.0%) SCDs each were observed.

Age group 31 to 40, half of the females had SCDs. The age categories of 21–40 and 41–60 years had an equal distribution of SCDs, with 18 (44.0%) cases each. No cases were found between 0 to 20 years old, and above 70 years old. **(Table 2)**

Table 2: Shows Age Group and Gender Distribution Among Sudden Cardiac Deaths.

Age Group	Male (n=33)	Female (n=8)	% (n)
21 - 30	6	3	22 (9)
31 - 40	5	4	22 (9)
41 - 50	10	0	24.9 (10)
51 - 60	7	1	19.5 (8)
61 - 70	5	0	12.2 (5)

The data on the onset of symptoms in SCDs revealed that most SCDs (24, 58.5%) occurred between 06:00 AM to 02:00 PM, indicating a higher incidence early in the day; 12 (29.3%) cases occurred from 02:00 PM to 10:00 PM. Only a small proportion of five (12%) of cases occurred between 10:00 PM and 06:00 AM. These findings suggest that SCDs are more likely to occur during daytime hours, particularly in the morning and early afternoon.

While observing the occupation of the individuals who died due to SCD, most of them, 24 (58.5%) cases were labor, followed by five (12.2%) employed in a private job, and four (9.8%) cases each who were homemakers and employed in government service, farmers constituted three (7.3%) cases and student, one (2.4%) case. **Table 3** depicts the weight of the heart observed among the SCDs. **Table 4** shows the involvement of coronary arteries noted in the SCDs.

The causes of SCDs were acute coronary insufficiency (ACI) due to coronary atherosclerosis (accounting for 29 (70.7%) of cases), or HCM was observed in 12 (29.3%) cases **(Figure 1)**.

Most of the SCDs were brought dead to the hospital, 37 (90.2%), whereas only four (9.8%) cases were hospitalized before death. The most common risk factor was obesity, seen in 26 (63.4%) SCDs, followed by three (7.3%) cases of known pre-existing hypertension. Among the hypertensives, two died due to coronary atherosclerosis and one due to HCM.

Table 3: Shows the Weight of the Heart in Sudden Cardiac Deaths.

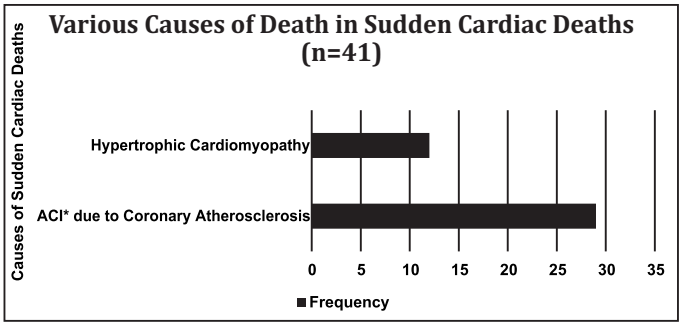
Weight of Heart in Grams (n = 41)	% (n)
200-250	7.3 (3)
251-300	17.1 (7)
301-350	17.1 (7)
351-400	29.3 (12)
401-450	9.8 (4)
451-500	9.8 (4)
501-550	7.3 (3)
551-600	2.4 (1)

Table 4: Shows Involvement of Coronary Arteries in Sudden Cardiac Deaths.

No. of Critically Stenosed Coronary Arteries* (n = 41)	% (n)
Single Vessel	31.7 (13)
Double Vessel	31.7 (13)
Triple Vessel	7.3 (3)
None	29.3 (12)
Involved Coronary Vessels	
Left Coronary Artery	
Left Anterior Descending	56.1 (23)
Left Circumflex	46.3 (19)
Right Coronary Artery	
Involved	19.5 (8)
Not Involved	80.5 (33)

**Critical stenosis is considered where more than 75% of the narrowing of the coronary artery is present.*

Figure 1: Shows the Distribution of Various Causes of Death in Sudden Cardiac Deaths (*ACI = Acute Coronary Insufficiency).



DISCUSSIONS

It is challenging to compare published autopsy research on SCDs because they differ in how they define SCD, how they

define gender inclusion criteria, age, demographics, and the examined causes of mortality. However, a reasonable effort has been undertaken to compare with the autopsy reports on sudden cardiac deaths that are currently available. The SCDs constituted 5.2% of all autopsies performed. Similar to the findings of Zanjad et al., Ahmad et al. observed a higher percentage of SCDs among the autopsies conducted at their center.[11-12] In contrast, studies by Sarkioja et al. and Montagnana et al. observed a minimal percentage of SCDs compared to the present study.[13-14]

In the present study, most SCDs, 80.5%, occurred in males, similar to other studies.[11,13,15] Male predominance may result from smoking, higher levels of stress, and a lack of the cardio-protective hormone estrogens.[16] In this study, most SCDs, 10 (24.4%) of cases, belonged to the 41-50 age group. Studies by Naneix et al. and Shreedhar et al. had similar susceptible age group for SCDs.[17-18] Studies of Garg et al. and Gaiwale et al. showed maximum SCDs in the 51-60 years age group.[15-16] The study by Khan et al. had a higher frequency of SCDs in the 61-70 years age group.[19]

The study revealed a clear pattern of the onset time of symptoms in SCDs. Most SCDs, 58.5%, occurred between 06:00 AM and 02:00 PM, indicating a higher incidence in the early part of the day, same as findings in the study done by Khan et al. and Chaudhari et al., where most of the cases were associated with the early part of the day.[19-20] SCDs occurring in the morning might be connected to life's stressors, such as carrying out obligations, getting around, and other work-related tasks.[14] Any atherosclerotic plaque susceptible to SCDs produces hemodynamic stress to the cardiovascular system, which seems to be higher in the morning. Higher catecholamine levels in the morning seem to be exacerbating the condition. Additionally, studies have shown that platelet agreeability tends to be higher in the morning.[21-22]

A high frequency of SCDs was observed in hearts weighing 351-400 grams. In contrast, Khan et al. reported higher SCDs at heart weight lower than 350 grams.[19] The most common risk factor observed in 63.4% of our study was obesity. Similarly, Prasanna et al. also observed obesity as the major risk factor.[23] Whereas, the study by Chaudhari et al. found hypertension as the most common risk factor for CAD.20 The majority of the SCDs, 90.2%, were declared dead on arrival at the hospital. This finding is the same as Chaudhari et al. on sudden deaths.[20]

In the present study, the most common cause of SCDs was acute coronary insufficiency as a consequence of coronary atherosclerosis. A similar finding was observed in most of the other studies on SCDs.15-25 According to the involvement of coronary arteries, 31.7% of cases had single and double-vessel disease, and 7.3% had triple-vessel disease. The studies by Suri et al. and Sharma et al. showed single-vessel involvement as the most common.[26-27] The study by Prasanna et al. observed double vessel disease as the most common occurrence in more than half of the cases.[23] In contrast, studies by Ahmad et al. and Kasthuri et al. showed triple vessel disease as the common finding.[12,22] The involvement of the LAD artery was higher, followed by the LCX and RCA. Similarly, studies by Virmani et al. and Farb et al. showed LAD as the most involved vessel in deaths due to acute coronary insufficiency.[28-29] Studies by Ahmad et al. and Saidi et al. had the right coronary artery was predominantly involved in causing SCDs.[12,30]

CONCLUSION

This five-year study from a tertiary healthcare institute in Northern Haryana highlights that SCD is a significant public health challenge, particularly among middle-aged males living in rural areas. Most SCDs were due to acute coronary insufficiency as a consequence of coronary atherosclerosis followed by hypertrophic cardiomyopathy. The data revealed SCDs being higher in the daytime and most being brought dead at the hospital, showing the unpredictable nature of these tragedies. The predominant risk factors were obesity, followed by hypertension. These findings underscore the importance of timely access to health care services, public education regarding risk factors, and screening for cardiovascular anomalies, especially in underserved areas.

Limitations

- The study was limited to 41 SCDs over five years, which may not represent the broader population in Haryana or India. Data were collected from a single tertiary care hospital, which may introduce selection bias and limit the applicability of findings to other regions or healthcare settings. Larger multicentre studies are required for more generalizable conclusions.
- This retrospective study relied solely on available records, which might lack detailed clinical history, circumstances of death, and prior diagnostic evaluations.
- Information on lifestyle-related risk factors such as smoking, alcohol consumption, stress-related factors, dietary habits, and physical activity was not uniformly available in all cases, limiting assessment of their impact.

- The study did not rule out hormonal factors such as a lack of cardioprotective hormones like estrogen.
- The study did not involve genetic testing, which could have revealed hereditary cardiac conditions leading to SCD.

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Original Research Paper

A Study On The Relationship Between Hand Dimensions And Stature Among Individuals Aged 21–25 Years: A Cross-sectional Study At Tertiary Care Centre In Kota

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ABSTRACT

Introduction: In recent times, the occurrence of dismembered human remains has become more common due to the increasing frequency of both natural disasters—such as earthquakes and landslides—and human-induced events like stampedes, structural collapses, traffic accidents, mining incidents, fires, and explosions. In many post-mortem examinations, only partial or mutilated remains are available.

Aim: This study was undertaken to assess the potential of using hand length as a tool for estimating stature and to evaluate the applicability of regression equations separately for males and females.

Materials and Method: This descriptive cross-sectional research was carried out in the Outpatient Department of Forensic Medicine and Toxicology at Government Medical College, Kota. Hand length was measured from the tip of the middle finger to the wrist crease, while hand breadth was recorded at the widest point where the fingers connect to the palm. Stature was measured to the nearest centimetre using a stadiometer, with participants standing barefoot, arms at their sides, and fingers pointing downward.

Results & Conclusion: The findings revealed a strong positive correlation between hand dimensions and stature in both sexes. These results support the use of hand measurements as reliable indicators for estimating height, especially in forensic anthropology where complete skeletal remains may not be available.

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INTRODUCTION

Forensic anthropometry is a specialized branch of forensic anthropology focused on identifying human remains using precise body measurements. In today's world, the discovery of dismembered body parts has become increasingly common, largely due to the rising frequency of both natural disasters-such as earthquakes and landslides-and human-induced incidents, including stampedes, structural collapses, road and rail accidents, aviation crashes, mining mishaps, fires, and explosions. Dismembered body parts are also often encountered in criminal cases, particularly in homicides where perpetrators mutilate the corpse to eliminate identifying features and simplify disposal. In such cases, forensic anthropometrists play a crucial role by helping establish a preliminary identification of the remains. This is done through the development of a biological profile, which includes estimating key characteristics such as stature, sex, age, and ancestry. Among these, determining stature from various body parts is especially valuable in the identification process.[1] Stature estimation can be derived from various measurements such as hand length, foot length, length of the long bone, and length of the skull.

Kota is a region with a lot of tiger and forest reserve areas, with the Chambal River the chances are higher for concealing the crime with natural decaying of bodies. Many times we receive only mutilated bodies in the form of body parts for postmortem examination.

Most body parts maintain a relatively consistent proportional relationship with an individual's height. The present study aimed to explore the potential of using hand dimensions to estimate stature by developing and applying regression equations specific to males and females within the Hadoti population.

MATERIALS AND METHOD

Study Design

The study was conducted from 01/01/2025 to 31/03/2025 as a Descriptive cross-sectional study in the Outpatient Department, Department of Forensic Medicine and Toxicology, Government Medical College, Kota. Ethical approval was obtained from the Institutional Ethics Committee of Government Medical College, Kota (Approval No.- F.3()/Acad /Ethical clearance/43 Dated- 31.12.24) A total of 100 male and 100 female participants aged between 21 and 25 years were included in the study.

Inclusion Criteria

Subjects of the age group between 21-25 years, presented to the OPD of the forensic Department, who gave consent for participating in the study till the sample size was met.

Exclusion criteria

- Individuals aged 21–25 years who refused to participate in the study were excluded.
- Participants were excluded from the study if they had missing limbs, chronic illnesses, poorly defined wrist creases, deformities of the spine or limbs, a history of hormonal therapy, contractures, previous trauma to the hands or feet, or features indicative of dysmorphic syndromes or musculoskeletal diseases.

Data Collection Procedure

After obtaining informed consent and completing consent forms for all enrolled participants, data collection commenced. Measurements were consistently taken between 1:00 and 2:00 pm each day to minimize diurnal variation. Each measurement was recorded three times, and the average value was used for analysis. Several methods exist for measuring hand dimensions; however, this study will follow the approach outlined in the research by Rai A et al. (2023).

Hand Length: Measured from the tip of the longest finger to the wrist crease.

Hand Breadth: Measured across the widest area where the fingers join the palm.

Height of the Individual: Height was measured to the nearest centimetres (cm) using a stadiometer, with the participant standing upright on a flat surface, barefoot, with the palms facing inward and fingers pointing downward. The measurement was taken from the sole of the feet to the top of the head, as per the guidelines of the International Biological Program.

Data Collection Tools: Vernier calipers and a stadiometer were used for measurements. The collected data were organized, presented in graphical form, and analysed statistically.

MATERIALS AND METHOD

Hand length was recorded by measuring the distance from the tip of the longest finger to the wrist crease. Hand breadth was taken across the widest part of the hand, where the fingers meet the palm. Stature was measured to the nearest centimetre using a stadiometer, with participants standing barefoot, arms at their sides, palms facing inward, and fingers pointing downward. The height was measured from the bottom of the feet to the top of the head, following the protocol of the International Biological Program. All measurements were subjected to statistical analysis using Microsoft excel and multiplication factors were derived accordingly. A p-value was considered statistically significant.

RESULTS

The observed ranges for height and hand dimensions **(Table 1)** align well with those reported in earlier studies, suggesting that the sample accurately reflects the broader population. The average values for stature, right-hand length, right-hand breadth, left-hand length, and left-hand breadth were comparable between male and female participants **(Table 2)**. Results from the t-test showed no statistically significant differences between the sexes for any of these measurements, indicating that gender does not substantially influence these parameters. The multiplication factors derived for estimating height from hand dimensions **(Table 3)** were also similar for both groups, supporting the use of hand measurements as a reliable predictor of stature. The study revealed a positive and significant correlation between stature and both hand length and hand breadth on the right and left sides. While no significant difference was found between the hand lengths of both sides ($p > 0.05$), the right-hand breadth was notably greater than the left ($p < 0.05$). Additionally, males showed significantly higher values for stature, hand length, and hand breadth compared to females ($p < 0.05$). The study concluded that both hand length and hand breadth

Table 1: The Range of Height and Hand Length and Hand Breadth Observed Among the Participants.

Gender	Height Range	Right Hand Length Range	Right Hand Breadth Range	Left Hand Length Range	Left Hand Breadth Range
Male	165-184 cm	17.4 – 20.7 cm	8.4 – 10.2 cm	17.3 – 20.6 cm	8.4- 10 cm
Female	158-178 cm	14.6- 19.2 cm	6.9 – 9.6 cm	14.8- 19.2 cm	6.9 – 9.6 cm

Table 2: Representing Mean, T Value (Anova) and P Value for the Variables

Variable	Mean Male	Mean Female	T value	P Value
Height	174.4	174.2	0.23	0.82
Right Hand Length	18.5	18.4	0.53	0.60
Right Hand Breadth	8.8	8.8	0.0	1.0
Left Hand Length	18.6	18.5	0.63	0.53
Left Hand Breadth	8.8	8.8	0.0	1.0

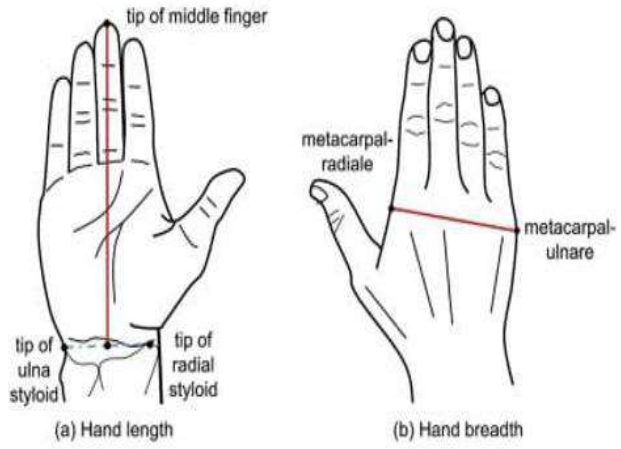
Table 3: Mean Multiplication Factor to Estimate Stature

Variable	Male	Female
Right Hand Length	9.4	9.4
Right Hand Breadth	19.8	19.7
Left Hand Length	9.3	9.4
Left Hand Breadth	19.8	19.7

Table 4: Pearson Correlation Coefficient (r)

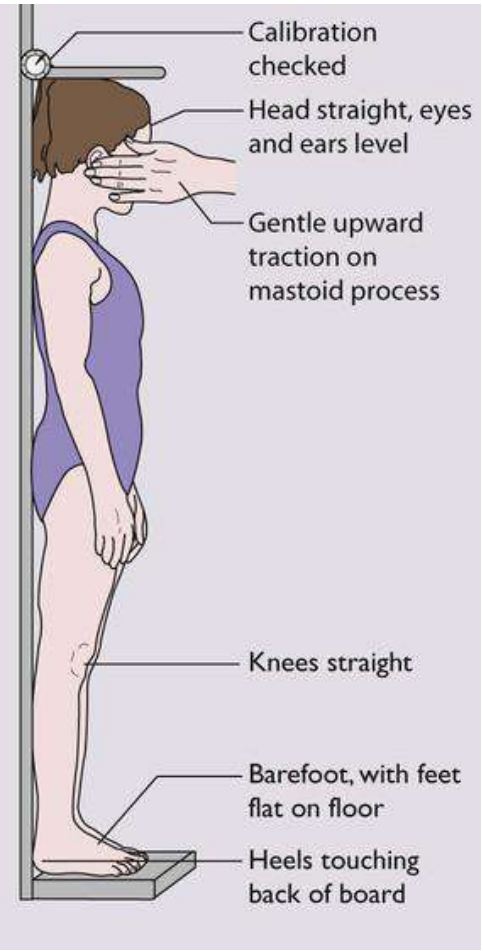
Variable	Male	Female
Height Vs Right Hand Length	0.916	0.854
Height Vs Right Hand Breadth	0.821	0.761
Height Vs Left Hand Length	0.923	0.859
Height Vs Left Hand Breadth	0.813	0.753

Figure 2:



serve as reliable indicators for estimating stature. The Pearson correlation coefficients **(Table 4)** demonstrated strong to very strong positive associations between stature and hand measurements, indicating that taller individuals generally possess larger hand dimensions. These correlations were consistent across both sexes, suggesting

Figure 1:



a similar pattern of relationship between height and hand dimensions in males and females.

DISCUSSION

The outcomes of this study hold valuable relevance in the field of forensic anthropology, particularly in cases where stature estimation is required from incomplete skeletal remains. The findings indicate that hand dimensions can

serve as dependable indicators for estimating stature, especially when other bones are not available for analysis.

The multiplication factors derived for estimating height from hand dimensions were also similar for both groups, supporting the use of hand measurements as a reliable predictor of stature. These findings are consistent with those reported by Varu P.R. et al. (2015)[2], who conducted the study to determine the stature from hand dimensions.

Our results align with those reported by Rai A et al. (2023)[3], who examined the relationship between palm length, palm width, and hand length with stature. Their study found that hand length had the strongest correlation with height (r = 0.5), while hand breadth showed the weakest. They concluded that stature could be reliably estimated from hand measurements alone, given the strong positive association.

Similarly, Narayan H et al. (2018)[4] conducted a comparable study in the Bihar population, deriving significant regression equations and multiplication factors for stature estimation. Patel P.N. et al. (2012)[5] also investigated the use of arm span, hand length, hand breadth, foot length, and foot breadth in height estimation, identifying hand length as having the highest correlation with stature (r = 0.908), followed by foot length. The correlation coefficients from our research are consistent with these findings.

Additional studies by Laila S.Z.H. et al. (2009)[6] and Krishan K. et al. (2007)[7] also support the conclusion that measurements of the hands and feet show a statistically significant positive correlation with stature.

Garg A. et al. (2022)[8] studied on estimation of stature from palm length in regional population of Sonipat and observed a significant positive correlation between the stature and measured palm length.

CONCLUSION

This study highlights a strong positive correlation between hand dimensions and stature in both male and female participants. The results support the use of hand measurements as dependable predictors of height, particularly in forensic anthropology where such estimations are often critical. The outcomes align with previous research that also identified significant associations between hand dimensions and stature.

Additionally, the similarity in multiplication factors between males and females suggests that hand measurements can estimate height with reasonable accuracy across sexes. These findings reinforce the value of incorporating hand dimensions into stature estimation protocols. Future research can further explore this relationship in varied populations and settings to enhance its applicability in forensic and anthropological contexts.

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Original Research Paper

Estimation of Stature from Foot Length in Eastern Uttar Pradesh: A Prospective Cross-Sectional Study

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ABSTRACT

Introduction: Stature estimation significantly contributes to forensic anthropology, particularly when complete skeletal remains are unavailable. Foot length, frequently preserved even in fragmented remains, has emerged as a dependable anthropometric measure for stature prediction, yet specific data for the Eastern Uttar Pradesh population in India are limited. This prospective observational study, conducted from April 2023 to September 2024 in Varanasi, aimed to assess the correlation between foot length and height and to establish regression models for accurate stature estimation. A total of 500 healthy adult volunteers (250 males, 250 females), aged between 25 to 55 years, participated, providing measurements of stature using an anthropometric rod and bilateral foot lengths via spreading calipers. Analysis using SPSS version 25.0 indicated a mean stature of 160.99 ± 9.81 cm, with males significantly taller (168.06 ± 7.21 cm) compared to females (153.92 ± 6.37 cm, $p < 0.0001$). Mean foot lengths were 24.21 ± 1.70 cm (right) and 24.25 ± 1.70 cm (left), both strongly correlated with stature (right foot $r = 0.85$, left foot $r = 0.86$, $p < 0.0001$). Derived linear regression equations demonstrated stature predictions: 4.9408 × right foot length + 41.388, and 4.9818 × left foot length + 40.239. Multivariate regression models incorporating variables such as age, gender, religion, and education further enhanced predictive accuracy ($R = 0.898–0.899$). A slightly stronger correlation with the left foot suggests minimal bilateral asymmetry. Observed sexual dimorphism, with males having greater stature and longer feet, aligns with global findings. Females exhibited lower correlations ($r = 0.63–0.66$), reflecting greater anthropometric variability potentially influenced by hormonal and morphological differences. Age-related stature decline beyond 40 years and the positive link between stature and educational status highlight physiological and socioeconomic influences. Despite limitations, including convenience sampling and exclusion of younger populations, this study underscores the importance of population-specific anthropometric equations in forensic identification.

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INTRODUCTION

Stature estimation is a pivotal element in forensic anthropology, contributing to the biological profile—comprising sex, age, ancestry, and height—that aids in identifying unknown human remains. This process is particularly valuable in medico-legal investigations, where establishing identity can assist in resolving cases of missing persons, mass disasters, or criminal dismemberment.[1]

The identification process is based on the notion that each person has a distinct biological profile consisting of age, sex, stature, and ethnicity. When a fully intact and non-decomposed body is recovered, identification is relatively simple. Historically, long bones such as the femur, tibia and humerus have been the preferred skeletal elements for stature determination due to their robust correlation with overall height.[2] However, these bones are often unavailable in fragmented, decomposed, or deliberately altered remains, necessitating the use of alternative skeletal or anthropometric measurements.[3]

The human foot, as the body's primary weight-bearing structure, has adapted for balance, support, and

propulsion, differing from its grasping function in other primates. The human foot, a weight-bearing structure integral to locomotion, has emerged as a reliable alternative for stature estimation.

Its proportional relationship with body height, coupled with its frequent preservation in forensic contexts (e.g., when footwear protects it), makes it a practical choice.[4] On average, males have a larger body size and weight than females, leading to sexual dimorphism in the foot and other parts of body, as well as variations in their relationships with stature between the sexes. Global studies have consistently reported strong linear correlations between foot length and stature, with correlation coefficients ranging from 0.65 to 0.90 across diverse populations.[5-7]

These correlations, however, vary due to genetic, environmental, and socioeconomic factors, emphasizing the need for population-specific regression models to optimize forensic accuracy.[8] In India, regional studies in Assam, Rajasthan, and Kerala have demonstrated such variations, yet no comparable data exist for Eastern Uttar Pradesh, a region with distinct demographic and cultural traits.[9-11]

This study addresses this research gap by examining the correlation between foot length and stature in a cohort from Varanasi, Eastern Uttar Pradesh. By establishing correlation coefficients and deriving regression formulae tailored to this population, the research aims to enhance the precision of stature estimation in forensic investigations involving fragmented remains from this region.[22] The findings are intended to contribute to the growing body of population-specific anthropometric data, supporting forensic practitioners in India and beyond.[23]

MATERIALS AND METHOD

This prospective cross-sectional observational study was designed to investigate the correlation between foot length and stature and to develop regression equations for stature estimation in a population from Eastern Uttar Pradesh, India. Data collection occurred at :Provincial Armed Constabulary (PAC) Headquarters, located in Varanasi, Eastern Uttar Pradesh. The study spanned from April 2023 to September 2024. A convenience sample of 500 healthy volunteers was recruited, comprising 250 males and 250 females aged 25-55 years. Participants were drawn from the PAC headquarters.

Inclusion Criteria

- Age between 25 and 55 years, irrespective of gender.
- No history of skeletal abnormalities affecting stature.

Exclusion Criteria

- Presence of congenital or acquired skeletal deformities (e.g., scoliosis, kyphosis).
- Post-traumatic conditions causing apparent or true limb shortening (e.g., fractures, amputations).

The study protocol was approved by the Institutional Ethics Committee of the Institute of Medical Sciences, BHU (Approval No. [Dean/2023/EC/6088,Dated-28-07-2023]). Written informed consent was obtained from all participants, ensuring they understood the study's purpose, procedures, and voluntary nature. Stature was measured to the nearest centimeter using a standard anthropometric rod. Participants stood erect, barefoot, on a flat surface, with their head aligned in the (eye-ear horizontal plane).

The measurement extended from vertex (highest point of the skull) to the floor, with heels, buttocks, shoulders, and occiput contacting the vertical backboard. Bilateral foot lengths were measured using a spreading caliper with a globular head. The length from pternion (most posterior heel point) to acropodion (tip of the longest toe-hallux or second toe) was recorded to the nearest 0.1 cm. Participants were seated to prevent weight-bearing distortion, and each foot was measured twice by the same observer, with the average value used for analysis. A standardized proforma collected demographic details, including age, gender, religion (Hindu/Muslim), and educational attainment (High School, Intermediate, Graduate, Postgraduate).

Statistical Analysis

Data entry utilized Microsoft Excel, with analyses in Excel, GraphPad Prism 8.4.2, and SPSS v25.0. Continuous variables underwent descriptive statistics; categorical data were summarized by frequencies and percentages. Pearson correlation examined foot length-stature relationships. Linear regression provided stature equations; multivariate regression added demographic factors. Group differences employed t-tests, ANOVA, and chi-square ($p<0.05$). Standardized measurements minimized bias, conducted forenoon.

RESULTS

Participant Characteristics

The study enrolled 500 participants, equally distributed by gender (250 males, 250 females). The mean age was 33.13 ± 8.29 years (range: 25-55 years), with 82.8% (n = 414)

Figure 1: Stature Measurement Using Anthropometric Rod

Figure 2: Foot Length Measurement Using Spreading Calliper

aged 40 years or younger. Most participants were Hindu (87.8%, n = 439), and 47.2% (n = 236) held graduate or postgraduate degrees.

Demographic Characteristics of Study Participants

Characteristics	Values
Mean Age (± SD)	33.13 ± 8.29 years
Age Range (Min-Max)	25–55 years
Median Age (IQR)	29 (27–37) years
Age ≤40 years	414 (82.80%)
Age >40 years	86 (17.20%)
Gender - Males	250 (50%)
Gender - Females	250 (50%)
Religion - Hindu	439 (87.80%)
Religion - Muslim	61 (12.20%)
Education - High School	193 (38.60%)
Education - Intermediate	71 (14.20%)
Education - Graduate	212 (42.40%)
Education - Postgraduate	24 (4.80%)
Mean Stature (± SD)	160.99 ± 9.81 cm
Stature Range (Min-Max)	139.60–190 cm
Median Stature (IQR)	160.95 (153.18–168.80) cm

Stature: The overall mean stature was 160.99 ± 9.81 cm. Males exhibited a significantly higher mean stature (168.06 ± 7.21 cm) than females (153.92 ± 6.37 cm, $p < 0.0001$, t-test). Participants aged ≤40 years had a greater mean stature (161.44 ± 9.89 cm) compared to those >40 years (158.83 ± 9.18 cm, $p = 0.0246$). **(Table 1)**

Table 1: Foot Length

Foot Length	Right	Left
Mean ± SD	24.21±1.70	24.25±1.70
Range (Min-Max)	19.60-30.40	19.60-30.30
Median (IQR)	24.10 (23-25.50)	24.20 (22.90-25.50)

The mean right foot length was 24.21 ± 1.70 cm (males: 25.37 ± 1.35 cm; females: 23.05 ± 1.12 cm, $p < 0.0001$), and the mean left foot length was 24.25 ± 1.70 cm (males: 25.42 ± 1.33 cm; females: 23.04 ± 1.08 cm, $p < 0.0001$). No significant bilateral differences were observed within genders ($p > 0.05$, paired t-test).

A) Anthropometric Measurements by Gender **(Table 2)**

B) Anthropometric Measurements by Religion **(Table 3)**

C) Anthropometric Measurements by Education **(Table 4)**

Correlation Analysis

Foot length demonstrated a strong positive correlation with stature for both feet (right: $r = 0.85$, left: $r = 0.86$, $p < 0.0001$). Subgroup analyses by age, gender, and religion revealed consistent correlations, with minor variations

Table 2: Stature and Foot Length – Gender Wise

Anthropometry	Stature	Right	Left
Females (Mean ± SD)	153.92±6.37	23.05±1.12	23.04±1.08
Males (Mean ± SD)	168.06±7.21	25.37±1.35	25.42±1.33
P Value	<0.0001	<0.0001	<0.0001

Table 3: Stature and Foot Length – Religion Wise

Anthropometry	Stature	Right	Left
Hindu (Mean ± SD)	161.00±9.82	24.23±1.72	24.27±1.72
Muslim (Mean ± SD)	160.94±9.81	24.03±1.57	24.10±1.59
P Value	0.9622	0.3618	0.4011

Table 4: Stature and Foot Length – Educational Qualification

Anthropometry	Stature	Right	Left
High School (Mean ± SD)	154.79±7.46	23.43±1.42	23.44±1.41
Intermediate (Mean ± SD)	158.84±9.03	23.77±1.66	23.79±1.65
Graduate (Mean ± SD)	166.64±8.36	24.93±1.57	25.02±1.56
Post Graduate (Mean ± SD)	167.39±7.74	25.40±1.63	25.43±1.52
P Value	<0.0001	<0.0001	<0.0001

Table 5: Correlation Coefficients (r) Between Foot Length and Stature

Group	Right Foot Length	Left Foot Length	p-value
Overall	0.85	0.86	<0.0001
Age ≤ 40 years	0.85	0.86	<0.0001
Age > 40 years	0.829	0.848	<0.0001
Males	0.756	0.779	<0.0001
Female	0.6649	0.6332	<0.0001
Hindu	0.86	0.865	<0.0001
Muslim	0.8268	0.834	<0.0001

attributed to demographic differences. **(Table 5)**

Regression Analysis

Linear regression models yielded the following stature estimation equations:

Right Foot Length and Stature (cm) = 4.9408 × Right Foot Length (cm) + 41.388 (R^2 = 0.7225)

Left Foot Length and Stature (cm) = 4.9818 × Left Foot Length (cm) + 40.239 (R^2 = 0.7396)

Multivariate regression, incorporating age, gender, religion, and education, enhanced predictive accuracy:

Stature = 72.912 – 0.098 × Age – 0.638 × Religion + 4.296 × Gender + 1.565 × Education + 3.633 × Right Foot Length (R = 0.898, R^2 = 0.806) **(Table 6)**

Table 6. Model Parameters For Multivariate Stature Assessment Using RFL.

R (Correlation Coefficient)	0.898
R^2 Unadjusted	0.806
R^2 ® squared)	0.804

Stature = 71.003 – 0.089 × Age – 0.509 × Religion + 3.94 × Gender + 1.594 × Education + 3.698 × Left Foot Length (R = 0.899, R^2 = 0.808) **(Table 7)**

Table 7. Model Parameters For Multivariate Stature Assessment Using LFL

R (Correlation Coefficient)	0.899
R^2 Unadjusted	0.808
R^2 (R squared)	0.806

(Coding: Religion: Hindu=1, Muslim=0; Gender: Male=1, Female=0; Education: 1=High School, 2=Intermediate, 3=Graduate, 4=Postgraduate)

DISCUSSION

The average age of the participants in the study was 33.13±8.29 years, with a median age of 29 years and an age range of 25-55 years. The interquartile range (IQR) was 27-37 years, with most volunteers being young males aged 40 years or below (82.80%). The study included an equal distribution of males (50%) and females (50%), with the majority being Hindus (87.80%). All volunteers had at least a high school education, and nearly half (47.20%) were graduates or held higher degrees.

Comparisons with other studies show variation in age distribution. Anamul Haque et al. (2023)[17] studied 200 participants (100 males and 100 females) with a mean age of approximately 21 years. Kavyashree et al. (2018)[18] studied 308 individuals aged 18-20 years, while RS Babu et al. (2013)[19] examined 104 individuals aged 21-35 years from Secunderabad. Kamboj et al. (2018)[20] conducted a study on 320 adult volunteers aged 25-50 years, with a mean age of 38.43 years, slightly higher than in the present study. Similarly, Saharan et al. (2015)[8] examined 500 participants, all above 18 years, highlighting a broad range of age groups across different studies.

The average stature of the volunteers was 160.99±9.81 cm, with a median stature of 160.95 cm. The mean right foot length was 24.21±1.70 cm, with a median of 24.10 cm, while the mean left foot length was 24.25±1.70 cm, with a median of 24.20 cm. Younger adults aged 40 years or below had significantly greater stature than those above 40 years (P=0.0246). No notable difference was observed between right and left foot lengths. Males exhibited significantly higher stature (P<0.0001) and longer right (P<0.0001) and left foot lengths (P<0.0001).

Additionally, individuals with higher educational qualifications, such as graduates and postgraduates, had significantly greater stature and foot length compared to those with only high school or intermediate education (P<0.0001 for all parameters). A similar study by Preeti Agarwal et al. (2018)[21] reported that the mean age of participants was 19.76±1.95 years. The average stature for males and females was 164.90±14.50 cm, with a mean weight of 65.13±12.80 kg.

The left and right foot breadths were 10.1±0.72 cm and 10.30±0.72 cm, respectively, while the left and right foot lengths measured 25.68±1.66 cm and 25.62±1.58 cm, respectively. Another study by Banik et al. (2016)[16] evaluated stature estimation using bilateral hand and foot measurements (length and breadth) through Ordinary Least Squares (OLS) and Multiplication Factor (MF) analysis. The mean stature was found to be 155.51 cm.

The observed deviations between actual and estimated stature were documented as follows: for left hand length, the ordinary least squares (OLS) estimate was 155.17 cm (difference: 0.34 cm), while the multiplication factor (MF) yielded 155.65 cm (difference: −0.14 cm); for left hand breadth, the OLS result was 156.16 cm (difference: −0.66 cm), and MF was 155.77 cm (difference: −0.26 cm); right hand breadth showed an OLS estimate of 155.69 cm (difference: −0.18 cm) and an MF estimate of 155.80 cm (difference: −0.29 cm); left foot length produced 153.98 cm by OLS (difference: 1.53 cm) and 155.67 cm by MF (difference: −0.16 cm); left foot breadth gave estimates of 155.38 cm (difference: 0.13 cm) via OLS and 156.38 cm (difference: −0.87 cm) via MF.

Generally, the MF approach resulted in overestimations, except in the measurement of left foot breadth, whereas regression analysis tended toward slight underestimations, excluding hand breadth. Overall, OLS was determined to yield more accurate stature estimations compared to the MF method. Similarly Geetha et al. (2015)[11], in their study conducted among the Kerala population, observed no significant bilateral differences for any measurement, with the exception of female foot breadth (P<0.001). Additionally, paired sample t-tests demonstrated highly significant differences between males and females across all measured parameters (P<0.001).

In another study, Tanuj Kanchan et al. (2008)[12] examined stature, foot length, and foot breadth in 200 participants (100 males and 100 females). Their findings indicated insignificant bilateral variations for all parameters except foot breadth in males (P<0.01). Sex differences were statistically significant for all measurements (P<0.01).

The discussion section of this study establishes a strong correlation between foot length and stature in an Eastern Uttar Pradesh population, with correlation coefficients (r = 0.85–0.86) that are consistent with other international and regional findings, demonstrating the utility of foot length as a reliable predictor for forensic stature estimation.[5-7] The observed correlations align closely with findings from Assam (r>0.9) and Rajasthan (r=0.756), highlighting regional differences in anthropometric characteristics due to genetic, environmental, & socioeconomic influences.[9-10]

Significant sexual dimorphism was noted, with males exhibiting larger stature and foot lengths than females, consistent with global anthropometric studies, likely reflecting underlying genetic and developmental differences.[13] Furthermore, the lower correlation coefficients observed in females (r = 0.63–0.66) compared to males (r = 0.76–0.78) suggest greater anthropometric variability in females, potentially due to hormonal or morphological factors that require additional investigation.[14]

These gender differences were consistent with prior findings reported in studies such as those by Sah et al.

(2018)[6] and Malik et al. (2015)[5], who emphasized stronger correlations in males and variations between foot dimensions and stature across sexes.

Age-related differences were also significant, with younger adults (≤40 years) demonstrating higher stature than older participants (>40 years), aligning with previous literature documenting stature reductions due to physiological changes such as vertebral compression with advancing age.[15] Additionally, the positive association between education level and stature highlights the socio-economic influences affecting nutritional status and growth patterns, a finding corroborated by existing socio-anthropometric literature.[16]

The use of multivariate regression models incorporating demographic variables (age, gender, religion, and education) markedly enhanced predictive accuracy (R = 0.898–0.899), outperforming simpler linear regression equations (R^2=0.7225–0.7396) and demonstrating greater forensic applicability when multiple demographic factors are known.[17] However, the study acknowledges certain limitations, including convenience sampling and exclusion of subadult populations, which potentially limit broader generalizability. Future research should validate these regression equations across different Indian populations and explore additional anthropometric parameters to refine predictive models further.

Overall, this study substantiates foot length as a robust anthropometric predictor for stature estimation in forensic contexts, underlining the importance of developing localized anthropometric databases to enhance the precision of identification processes in forensic anthropology.

CONCLUSION

This study validates foot length as a reliable predictor of stature for Eastern Uttar Pradesh, with strong correlations (RFL=0.85, LFL=0.86). Younger adults (≤40 years) exhibited significantly higher stature (p=0.0246). Males had significantly greater stature and foot length (p<0.0001). Higher education correlated with increased stature and foot length.

Sexual dimorphism and multivariate models incorporating demographic variables notably improved forensic identification accuracy.These findings advance forensic anthropology by providing tailored tools for stature estimation in cases of fragmented remains. Future studies should expand these models to diverse populations and additional anthropometric traits to further strengthen their forensic utility.

Limitation

This study could have been applied to the dead also. Since identification of the unknown is an integral part of forensic investigations a correlation of foot length and stature estimation could have been done in post mortem bodies.

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Original Research Paper

Correlation Between Blood Group and Suicidal Death Cases Brought to the Mortuary of Civil Hospital, Ahmedabad

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ABSTRACT

Introduction: A popular pseudoscientific belief in Eastern Asia is a person's ABO blood group is predictive of their personality, character and compatibility with others. There are several evidence of association of ABO blood group with various diseases and mental illness. Blood group AB individuals were found to be susceptible to an increased risk of cognitive impairment which was independent of geographic region, age, race, and gender, whereas blood type A is linked with increased incidence of smallpox.[1]

Aims and Objectives: Our goal was to assess the relationship between blood type and suicide death.

Material and Method: A total of 271 cases of suicidal death were selected during the study period. All cases were brought to the mortuary of Civil Hospital, Ahmedabad with an alleged history of suicidal death, as per police papers. We selected those cases with a past history of suicide attempts, psychiatric illness and cases where suicide notes were found at the scene of the offense or from the clothes and belongings of the victim were included in this study. For that, cases of hanging, poisoning, burns, cut-throats, falls from height and railway injury were included. Blood was collected and Blood grouping was done by the conventional slide method using anti-sera.

Result: As per our observation maximum suicidal death were observed in B positive blood group 95 (35.05%) cases followed by O positive 83 (30.63%) cases, A positive 75 (27.68%) cases, and AB positive 14 (5.17%) cases. Out of 271 cases, there are a much smaller number of suicidal death cases in Rh Negative blood groups. Most common method of suicide was hanging. Out of 210 cases of suicidal death due to hanging, 72 (34.29%) cases were blood group O positive, followed by 66 (31.43%) cases that were blood group A positive.

Conclusion: In present study, it was inferred that there is no definite correlation between various blood groups and suicidal death on an individual level. The percentage of blood group distribution in this region is relatively the same as the percentage of blood group distribution in suicide death cases.

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INTRODUCTION

Karl Landsteiner discovered blood group variability in 1901, and his development of the ABO system with its four blood types earned him the Nobel Prize in Medicine in 1930. Human Blood may be divided into four distinct blood group A, B, AB and O depending upon the presence in red cell of two agglutinogens which are designated by the letter A and B.[2] A popular pseudoscientific belief in Eastern Asia is a person's ABO blood group is predictive of their personality, character & compatibility with others. Although researchers wanted to uncover blood group related personality factor prior to 2000, but the results were inconsistent.[3-7] There are several evidence of association of ABO blood group and various diseases.[1,8] There are also reports those specific personality traits such as depression and anxiety with this disease.[9-11] The study

conducted by Sarkar A et al found that most of the suicide victims (63%) were suffering from various chronic illnesses. Out of 377 suicide victims, 89% had history of Psychiatric illness, out of which majority (35%) were suffering from depression, closely followed by Bipolar disorder (28%) and Border Line Personality disorders.[12] In light of that, we carried out this investigation to see whether blood type and suicide death are related.

MATERIAL AND METHODS

A cross-sectional autopsy-based study was conducted in the Forensic Medicine Department, B. J. Medical College, Civil Hospital, Ahmedabad, on cases of suicidal deaths coming for post-mortem examination during the period of 6 months from September 1st, 2024 to February 28th, 2025. A total of 271 cases were selected and studied during this study period. Only the cases comprise alleged suicidal death, as per police papers.

We selected those cases with a past history of suicide attempts, psychiatric illness and cases where suicide notes were found at the scene of the offense or from the clothes and belongings of the victim were included in this study. History from relatives, study of police papers and treatment records confirm suicidal death. For that, cases of hanging, poisoning, burns, cut throats, falls from height and railway injury were included.

Decomposed dead bodies were excluded. For this prospective study, purposive continuous sampling was done. After obtaining consent from next-to-kin, blood was collected by syringe and needle while removing the heart during an autopsy without any anticoagulants. Blood grouping was done by the conventional slide method using anti-sera. Microsoft Excel 2010 was used for the statistical analysis.

Frequencies and proportions were used to summarize the study's qualitative data collection. This study was conducted with the prior approval of the Institutional Ethics Committee of the B. J. Medical College, Ahmedabad.

RESULTS

In present study, as per **Table 1** we observed that very a smaller number of suicidal death cases in Rh Negative blood groups, only one (0.36%) case of AB Negative, 3 (1.11%) cases of O Negative blood group and no case in A Negative and B Negative Blood groups.

Maximum cases of suicidal death were observed in blood group of B positive i.e. 95 (35.05%) cases followed by O positive 83 (30.63%) cases, A positive 75 (27.68%) cases and AB positive 14 (5.17%) cases.

Total 1856 autopsies were conducted during six months of period under study, Out of 271 cases of suicidal death; most common method of suicide was hanging. Out of 210 cases of suicidal death due to hanging, 72 (34.29%) cases were blood group of O Positive followed by 66 (31.43%) cases were blood group A positive. We observed that second most common method of suicidal death was poisoning. Out of 26 cases of suicidal death due to poisoning 16 (61.53%) cases were blood group of B positive followed by 6 (23.07%) cases were blood group of O Positive. There was only one case of Cut throat suicidal death which was belongs to A positive blood group.

We observed that out of 75 cases of suicidal death in A positive blood group, with 66 (88%) cases Hanging was most common method of suicide followed by 3 (4%) cases of Burns and 3 (4%) cases of Poisoning. Out of 95 cases of suicidal death in B positive blood group, with 64 (67.37%) cases of Hanging, it was most common method of suicide followed by 16 (16.84%) cases of Poisoning, 6 (6.31%) cases Burns and 6 (6.31%) cases of drowning.

Out of 14 cases of suicidal death in AB positive blood group, with 11 (78.57%) cases of Hanging, it was most common method of suicide followed by 1 (7.14%) case of Poisoning, 1 (7.14%) case of drowning and 1 (7.14%) case of railway injuries. Out of 83 cases of suicidal death in O positive blood group, with 72 (86.74%) cases of Hanging, it was most common method of suicide followed by 6 (7.22%) cases of Poisoning, 3 (3.61%) cases of Burns and 2 (2.4%) cases of Drowning.

DISCUSSION

There are multiple studies that have been conducted in various parts of the world to examine the relationship between blood type and personality traits, compatibility, and character. Some researchers affirmatively claim that there is a link between the blood type and the prevalence of certain diseases. It is still early to talk about a clear cause-effect relationship, but discoveries made could help to improve health care.[13-15]

David Lester, a prominent suicidologist, conducted significant research on blood groups and suicide.[16] His 2004 study, titled "Blood type, suicide, and homicide," published in Crisis (Blood type, suicide, and homicide), analyzed data from 51 nations and found a negative correlation between the proportion of Type O blood and suicide rates. This means that nations with a higher percentage of Type O blood had lower suicide rates, with a

Table 1: Distribution of Blood Group in People who Died by Suicide (Total 271 Cases).

Blood Group	No. of Male	% of Male	No. of Female	% of Female	Total No.	Total %
A +ve	46	16.97%	29	10.70%	75	27.68%
A -ve	0	0.00%	0	0.00%	0	0.00%
B +ve	**53**	**19.55%**	**42**	**15.49%**	**95**	**35.05%**
B -ve	0	0.00%	0	0.00%	0	0.00%
AB +ve	10	3.69%	4	1.48%	14	5.17%
AB -ve	1	0.36%	0	0.00%	1	0.36%
O +ve	51	18.82%	32	11.81%	83	30.63%
O -ve	3	1.11%	0	0.00%	3	1.11%
Total	**164**	**60.52%**	**107**	**39.48%**	**271**	**100%**

Table 2: Distribution of Blood Group in People who Died of Various Methods of Suicide.

		A +ve	B +ve	AB +ve	AB -ve	O +ve	O -ve	Total	
HANGING	Male	40	37	7	1	42	3	130	217
	Female	26	27	4	0	30	0	87	
POISONING	Male	3	13	1	0	4	0	21	26
	Female	0	3	0	0	2	0	5	
BURNS	Male	1	0	0	0	3	0	4	12
	Female	2	06	0	0	0	0	8	
DROWNING	Male	1	3	1	0	2	0	7	10
	Female	0	3	0	0	0	0	3	
CUT THROAT	Male	1	0	0	0	0	0	1	1
	Female	0	0	0	0	0	0	0	
FALL FROM HEIGHT	Male	0	1	0	0	0	0	1	2
	Female	1	0	0	0	0	0	1	
RAILWAY INJURY	Male	0	2	1	0	0	0	3	3
	Female	0	0	0	0	0	0	0	
TOTAL		75	95	14	1	83	3	271	271

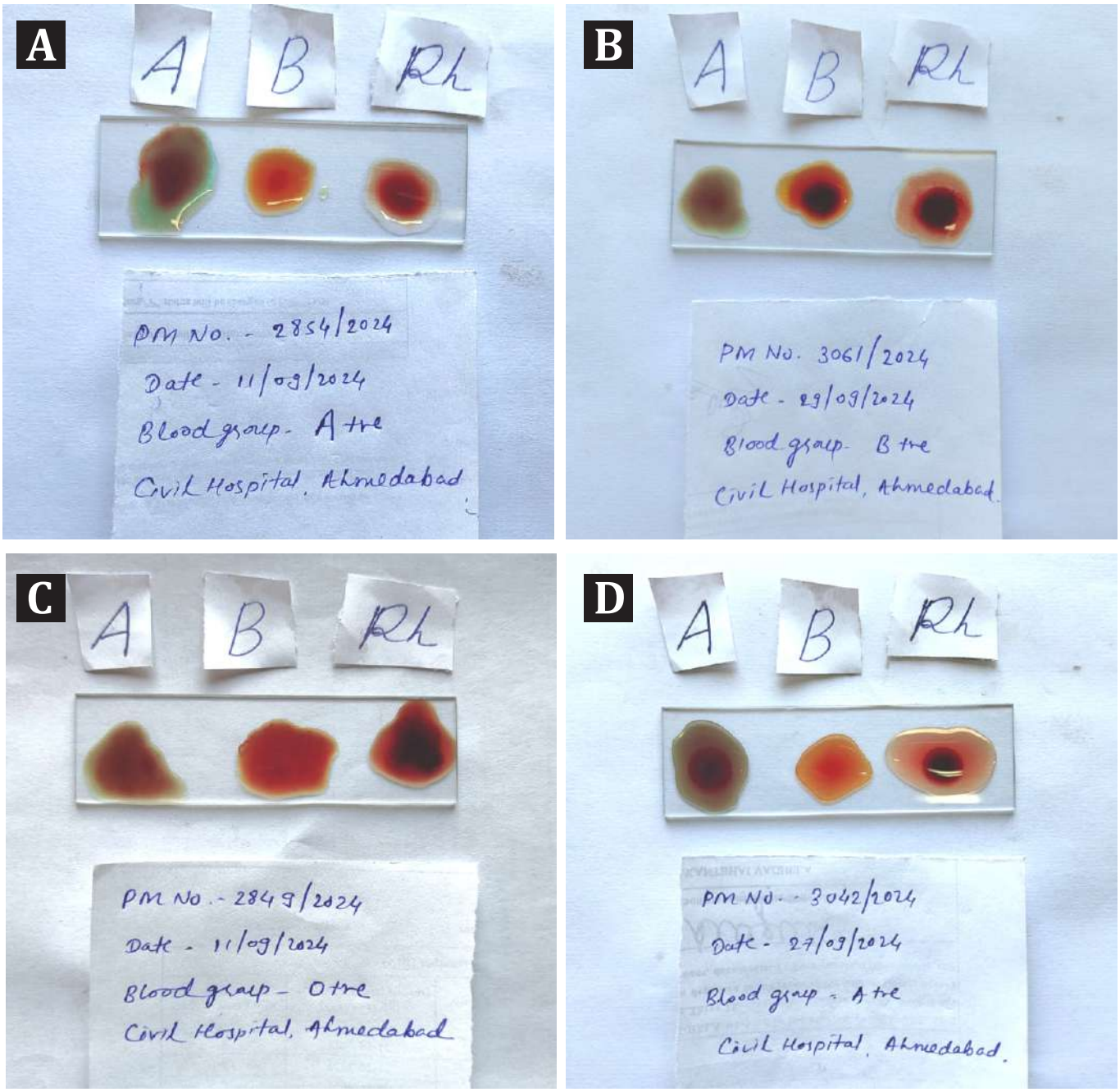
Pearson correlation coefficient of -.67. This finding was consistent with his earlier 1987 study, "National distribution of blood groups, personal violence (suicide and homicide), and national character," which examined 17 industrialized nations and found similar patterns, suggesting that lower Type O proportions and higher Type AB proportions were associated with higher suicide rates.[16]

Suicide is violent death through various methods with explicit and implicit self aggression evidence, in which the deceased had the clear intention of taking its life.[16,17] Individuals of various blood types have different ways to respond to stress. This is because the gene control blood types also control other things like dopamine metabolism, cortisol level and other processes that affect nervous system coordination. The surface of red cell membrane contains a variety of genetically determined antigens. The blood group A and B have H antigen. The terminal sugar N-acetyl galactosamine is present on H antigen on blood group A, while in B group it is galactose. Blood group 'O' individuals have none of above enzymes. The ABO system is arguably the most clinically important of the 29 types of established blood group systems.[18]

A 2017 study titled "Association of psycho-wellness with various blood types in young medical students," published in the International Journal of Research in Medical Sciences (Association of psycho-wellness with various blood types in young medical students) examined 226 medical students to assess psycho-wellbeing including suicidal tendencies, across ABO and Rh blood groups. The study found:

1. Blood group distribution: B (39.38%), O (27.88%), A (27.66%), AB (7.08%)
2. Blood type B was more prone to suicidal tendency, while Type O had the least suicidal tendency.

Figure 1: (a) A Positive Blood (b) B Positive Blood (c) O Positive Blood (d) A Positive Blood



However, these variations were statistically insignificant, leading to the conclusion that there is no significant association between blood type and psycho-wellness, including suicidal tendency.[19]

As per our observation from this study maximum cases of suicidal death were observed in B positive blood group (35.05% cases) followed by O positive (30.63% cases), A positive (27.68% cases), and AB positive (5.17% cases). We have correlated findings of our study with national and likewise regional distribution of blood types in population.

As per G. K. Patidar and Y. Dhiman, national distribution of ABO blood types is A (24.7%), B (35.02%), O (34%) and AB (8%).[20] So, from highest to lowest B>O>A>AB is the sequence. In our observation the distribution of cases of suicide in terms of blood types is A (27.68%), B (35.05%), O (30.63%) and AB (5.71%). So, from highest to lowest B>O>A>AB is the sequence which is like national distribution observed by G. K. Patidar and Y. Dhiman.[20]

As per Patel PA et al, in Ahmedabad city (west) distribution of ABO blood types is A (21.9%), B (39.4%), O (30.8%) and

AB (7.9%); with descending order in the sequence of B>O>A>AB is the sequence.[21] As per Wadhwa MK et al, in Ahmedabad city (East) distribution of ABO blood types is A(23.3%), B(35.5%), O(32.5%) and AB(8.8%); with descending order in the sequence of B>O>A>AB.[22]

Thus, comparing these previous studies from Ahmedabad City, the distribution amongst population of Ahmedabad Metropolitan Area follows the same trends inferred from this study in relation to suicidal tendency amongst decedents with specific blood group. Scripcaru V. et al conducted a similar study in Romania, where data was collected from 677 suicidal deaths during the period between the year 1996 to 2016.

Romania National Distribution of ABO blood types is A (43%), B (16%), O (33%) and AB (8%); with descending order in the sequence of A>O>B>AB. As per the observation of the study, maximum cases of suicidal death were observed in blood group A(39 % cases) followed by O(30% cases), B(19% cases), and AB(12% cases), in correspondence with the sequence of Romanian National Distribution of blood groups.[23]

As mentioned in the observations of present study, in case of death due to suicidal hanging, against the national and regional distribution of blood groups sequence, highest number of deaths occurred in O positive individual (72 cases).

CONCLUSION

While trends existed, they did not reach statistical significance, suggesting individual level factors may not align with population-level correlations. The dataset lacks statistical tests to confirm correlations, and findings may not apply to other populations. Furthermore, suicide is influenced by many factors beyond blood group, such as mental health and social support.

There is no definite correlation between various blood groups and suicidal death in present study. As per our observation from this study maximum cases of suicidal death were observed in B positive blood group (35.05% cases) followed by O positive (30.63% cases), A positive (27.68% cases), and AB positive (5.17% cases). National distribution of ABO blood types is A (24.7%), B (35.02%), O (34%) and AB (8%). So, from highest to lowest B>O>A>AB is the sequence. In Ahmedabad city (west) distribution of ABO blood types is A (21.9%), B (39.4%), O (30.8%) and AB (7.9%); with descending order in the sequence of B > O > A > AB is the sequence.

The percentage of blood group distribution in the population of Ahmedabad Metropolitan Area or Western India is relatively the same as the percentage blood group distribution in suicide death cases. To conclude the study findings, it can be stated that there are no objective elements to be able to ascertain that a certain type of blood group predisposes the individual to perform a suicidal act.

Mental and social factors may predispose to suicidal act at least as much as genetic factors. We suggest that many more studies like this will be done with complete socio-psychological evaluation in various demographic patterns.

Limitation: The interpretation of the results of the study cannot be generalized to the entire population due to limited sample size, interpreted as a constraint on time, and also due to various factors affecting the mental conditions of an individual due to diversity in the Indian population.

Conflict of Interest / Funding: Nill

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Original Research Paper

Doctor's Knowledge and Attitudes Towards Autopsy: A Cross-Sectional Study at A Newly Established Tertiary Care Centre

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ABSTRACT

Introduction: Autopsies play a vital role in forensic and pathological investigations, providing valuable insights into the cause and manner of death. Despite their significance, autopsy rates have declined globally, influenced by various legal, educational, and sociocultural factors. This study evaluates the knowledge and attitudes of medical practitioners toward autopsy practices at a newly established tertiary care centre in India.

Material and Methods: A cross-sectional, questionnaire-based survey was conducted among faculty members, senior residents, postgraduate trainees, and junior residents. A structured 21-item questionnaire assessed participants' autopsy-related knowledge and perceptions. Statistical analyses, including Chi-square and regression analysis, were performed to determine associations between attitudes and demographic variables.

Results: A total of 132 doctors participated in the study. While most respondents acknowledged the relevance of autopsies in medical education and forensic investigations, significant gaps in knowledge and engagement were observed. Higher job titles and greater experience correlated with a declining emphasis on autopsy's academic and research value.

Conclusion: There is an urgent need to integrate standardized autopsy training within medical curricula and address misconceptions among practitioners. Enhancing clinical exposure and institutional advocacy can reinforce the diagnostic and educational significance of autopsies in modern healthcare and forensic medicine.

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INTRODUCTION

The term autopsy originates from the Greek word autopsia, referring to a scientific post-mortem examination conducted to ascertain the cause and manner of death. Autopsies are broadly categorized into two types: medico-legal (forensic) autopsy and pathological (hospital) autopsy. A medico-legal autopsy is performed as part of an official investigation at the request of state authorities in cases involving suspicious or unnatural deaths. Conversely, a pathological autopsy is primarily conducted to establish clinico-pathological correlations and confirm antemortem diagnoses.

The utility of autopsies has been unequivocally demonstrated in various domains, including medical education, quality assurance in clinical practice, medical auditing, and the determination of cause of death. Their role remains indispensable in enhancing medical knowledge and ensuring the accuracy of diagnostic practices.[1-4]

Although the clinical value and relevance of the autopsy in medical education has been well established, the autopsy rate has been falling worldwide in past one decade.[5-7] In India, any registered medical practitioner (RMP) holding an MBBS degree (Bachelor of Medicine and Bachelor of Surgery) is authorized to conduct a medico-legal autopsy. However, due to a limited number of forensic medical experts in the country, the majority of medico-legal autopsies are performed by non-specialist RMPs, often lacking formal training in forensic pathology.

This has led to concerns regarding the quality and accuracy of findings in medico-legal investigations. Recognizing the need for competency in forensic examination, the National

Medical Council has integrated the observation and performance of autopsies into the undergraduate medical curriculum and internship training programs. This initiative aims to enhance medical practitioners' understanding, skills, and professional attitudes toward forensic post-mortem examinations, ensuring more reliable and standardized medico-legal assessments.[8]

A thorough understanding of autopsy procedures among medical practitioners is essential for maintaining the quality and reliability of forensic examinations. However, there is a scarcity of studies assessing autopsy-related knowledge among doctors, particularly registered medical practitioners (RMPs) in India. This study aims to evaluate the level of knowledge and attitudes toward autopsy among doctors working in a newly established tertiary care centre. By identifying gaps in awareness and expertise, the findings may contribute to strengthening forensic education and improving medico-legal practices within the healthcare system.

MATERIALS AND METHOD

This cross-sectional, questionnaire-based survey was conducted in the Department of Forensic Medicine and Toxicology at a newly established tertiary care centre, AIIMS Raibareily, Uttar Pradesh, over a four-month period in 2023. The study population included all faculty members, senior residents, postgraduate trainees, and junior residents of AIIMS, Raebareli, who voluntarily participated and provided informed consent.

Data Collection Procedure

A structured 21-item questionnaire **(Table 1)** was developed to obtain relevant data. The survey was conducted anonymously and in an unlinked manner to ensure confidentiality. Participants were first asked to provide details regarding their department, years of clinical practice, and the number of autopsies they had personally observed or participated in. Further questions assessed their departmental exposure to autopsy procedures.

The remaining items focused on evaluating physicians' perceptions of factors influencing autopsy utilization, measured on a Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). Specific areas of inquiry included:

- The relevance of autopsy in clinical practice and its potential impact on future medical decision-making.
- The necessity of autopsy despite advancements in diagnostic accuracy.
- Concerns regarding litigation stemming from unexpected post-mortem findings and its influence on autopsy requests.
- Opinions on autopsy as a quality assurance tool in medical practice.
- Physicians' comfort level in discussing autopsy with patients' families.
- The role of religious objections in influencing autopsy requests.

The questionnaire incorporated flexible items to capture diverse perspectives on autopsy practices and attitudes.

Statistical Analysis

Data was entered into MS Excel and analyzed using Jamovi v2.3.26.0. Descriptive statistics, including frequency and percentage distributions for categorical variables, were computed. Associations between categorical variables were assessed using the Chi-square test. Additionally, regression analysis was conducted to evaluate the relationship between participants' attitudes toward autopsy and their educational qualifications, job title, and years of experience. A p-value < 0.05 was considered statistically significant.

This methodological approach ensures comprehensive data collection and analysis, contributing valuable insights into medical professionals' knowledge and attitudes toward autopsy in a tertiary care setting.

RESULTS

A total of 132 doctors participated in the study, out of which 69 (52.3%) were male and 63 (47.7%) were female. Age of the participants ranges from 25 years to 45 years with mean of 36.51. 108 (81.8%) participants were married, 21 (15.9%) were single and 3 (2.3%) were divorced. Majority of the participants 79.5 % had a post graduate degree (MD/MS), 13.6% were MBBS doctors and 6.8% had a super-specialty (DM/MCH) degree. 111 participants were working as faculty, 9 as senior residents and 12 as junior residents.

(Table 1) 72 out of 132 participating doctors had a work experience of 5 to 10 years, 30 had work experience less than 5 years, 18 had work experience between 11–15 years, 9 had work experience between 16 – 20 years and 3 had more than 20 years' work experience. **(Table 2)** To study the reflections of the study participants towards autopsies, participants were asked, 'Whether or not I request an autopsy is affected by concern about possible litigation stemming from unexpected findings at autopsy'

Table 1: Sociodemographic and Job Profile Characteristics of Study Population

Characteristics	Number	(%)
Age (Years)	-	-
25-30	17	12.8
31-40	89	67.4
≥ 41	26	19.6
(Mean ± SD)	36.51 ± 4.30	
Gender		
Male	69	52.3
Female	63	47.7
Marital Status		
Single	21	15.9
Married	108	81.8
Divorced	3	2.3
Educational Qualification		
Super-specialty (DM/MCh)	9	6.8
MD/MS	105	79.5
MBBS	18	13.6
Job Profile		
Faculty	111	84.1
Senior Resident	9	6.8
Junior Resident	12	9.1
Experience of Work (Years)		
<5	30	22.7
5-10	72	54.5
11-15	18	13.6
16-20	9	6.8
>20	3	2.3
Department		
Anesthesiology	9	6.8
Anatomy	6	4.5
Community Medicine	9	6.8
Dentistry	6	4.5
Dermatology	6	4.5
Emergency	6	4.5
ENT	6	4.5
Forensic Medicine	6	4.5
General Surgery	9	6.8
Microbiology	9	6.8
Neurosurgery	3	2.7
Obstetrics and Gynecology	9	6.8
Ophthalmology	9	6.8
Orthopedics	3	2.7
Pediatric Surgery	3	2.7
Pathology	12	9.1
Physiology	3	2.7
Pharmacology	6	4.5
Psychiatry	3	2.7
Radiation oncology	3	2.7
Radiodiagnosis	3	2.7
Transfusion medicine	3	2.7

Table 2: Knowledge of Study Participants About Autopsies

Knowledge	Number	(%)
Post Mortem Examination is Done for Legal or Medical Purposes		
Yes	129	97.7
No	3	2.3
Pathological Autopsy is		
With consent of relative	99	75.0
Without consent of relative	21	15.9
don't know	12	9.1
Forensic Autopsy is		
With consent of relative	72	54.5
Without consent of relative	48	36.4
don't know	12	9.1
Objectives of Post Mortem examination*		
To determine cause of death	76	57.5
To determine the manner of death	24	18.1
To determine if medical treatment before death was appropriate	36	27.2
To supply tissue and organ for transplant	6	0.45
For purpose of teaching or medical research	21	15.9
To expose mistakes made by the hospitals and clinicians in the management of the patient	7	0.53
Post Mortem is usually performed by		
Pathologist	96	72.7
Surgeon	30	22.7
Scientist	6	4.5
Number of autopsy cases have observed or participated in as a student, resident or attending physician		
0	12	9.1
<5	48	36.4
5-10	30	22.7
11-20	27	20.5
20	15	11.4

**Multiple response*

12 participants responded strongly agree, 48 responded agree, 45 were neutral or indecisive, 27 responded disagree and none responded strongly disagree.

Also, when asked, 'Many Family members refuse autopsy because of religious objections' 33, 93, 3, 3 and 0 participants responded strongly agree, agree, neutral or indecisive, disagree and strongly disagree respectively. To the question, 'It is not interesting but something I should allocate time for' the response was 6 strongly agree, 57

Table 3: Reflections of Study Participants Towards Autopsies.

Reflections	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Whether or not I request an autopsy is affected by concern about possible litigation stemming from unexpected findings at autopsy	12 (9.1)	48 (36.4)	45 (34.1)	27 (20.5)	0 (0.0)
Many Family members refuse autopsy because of religious objections	33 (25.0)	93 (70.5)	3 (2.3)	3 (2.3)	0 (0.0)
It is not interesting but something I should allocate time for	6 (4.5)	57 (43.2)	42 (31.8)	27 (20.5)	0 (0.0)
It is interesting but not something I have time for	6 (4.5)	42 (31.8)	45 (34.1)	33 (25.0)	6 (4.5)

agree, 42 neutral, 27 disagree and 0 strongly disagree. And in response to the statement, 'It is interesting but not something I have time for' 6 strongly agreed, 42 agreed, 45 were neutral or indecisive, 33 disagreed and 6 strongly disagreed. **(Table 3)**

The participants when asked, 'Autopsies are capable of providing relevant findings that could change my future clinical practice' 45 participants responded strongly agree, 63 responded agree, 15 were neutral or indecisive, 9 responded disagree and none responded strongly disagree. Significant association was observed for this attitude with job title and years of experience.

Similarly, when asked, 'Autopsy is essential for knowledge, research and education goals in department' 69, 42, 18, 3 and 0 participants responded strongly agree, agree, neutral or indecisive, disagree and strongly disagree respectively. Significant association was observed for this attitude with years of experience.

And in response to the statement, 'Currently diagnostic procedures are so accurate that there is little need to perform hospital autopsies' 6 strongly agreed, 18 agreed, 18 were neutral or indecisive, 78 disagreed and 12 strongly disagreed. With these questions we tried to analyse the attitude of study participants towards autopsies. Significant association was observed for this attitude with educational, job title and years of experience. **(Table 4)**

On regression analysis of attitude of study participants towards autopsies with respect to their educational qualification, job title and years of experience, majority disagreed with the statement that autopsy is essential for knowledge, research and education goals in

department and all three variables show a statistically significant negative relationship. This suggests that individuals with higher qualifications, more senior job titles, and more experience are less likely to believe that autopsies are essential for departmental academic and research goals. This could reflect a growing disconnect or evolving views on the role of autopsies in modern medical education and research.

The regression also examines the attitude regarding current diagnostic procedures to be so accurate that there is little need to perform hospital autopsies. Here, all three variables were again statistically significant. Educational showed negative association (more qualified individuals tend to disagree with the statement). Job title and years of experience showed positive associations (those with higher positions or more experience are more likely to agree). **(Table 5)**

DISCUSSION

Autopsies, whether medicolegal or pathological, represent distinct yet interconnected disciplines, each playing a crucial role in medical education and advancing clinical knowledge. Beyond their utility in thanatological sciences-such as determining the mechanisms, timing, and causes of death-autopsies offer valuable insights into the broader psychosocial impacts of morbidity and mortality on individuals and society.

Findings from this study indicate that a significant proportion of participants expressed a strong interest in increased exposure to autopsy procedures, acknowledging their potential to enhance clinical proficiency and diagnostic accuracy. Despite this recognition, there has been a notable and unexplained decline in autopsy frequency and its inclusion in medical curricula. Several factors have contributed to this trend, including a reduction in autopsy rates, constraints on faculty time, and legal uncertainties in specific jurisdictions.[9]

While death is fundamentally a biological event, it holds

Table 4: Association Between Attitude of Study Participants Towards Autopsies with Educational Qualification, Job Title and Years of Experience.

Attitude	Autopsies are capable of providing relevant findings that could change my future clinical practice					Autopsy is essential for knowledge, research and education goals in department					Currently diagnostic procedures are so accurate that there is little need to perform hospital autopsies.				
Variable	SA (n=45)	A (n=63)	N (n=15)	D (n=9)	SD (n=0)	SA (n=69)	A (n=42)	N (n=18)	D (n=3)	SD (n=0)	SA (n=6)	A (n=18)	N (n=18)	D (n=78)	SD (n=12)
Educational Qualification															
Super-speciality (n=9)	6 (66.7)	3 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	6 (66.7)	3 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	9 (100.0)	0 (0.0)
MD/MS (n=105)	30 (28.6)	54 (51.4)	12 (11.4)	9 (8.6)	0 (0.0)	54 (51.4)	30 (28.6)	18 (17.1)	3 (2.9)	0 (0.0)	3 (2.9)	18 (17.1)	18 (17.1)	57 (54.3)	9 (8.6)
MBBS (n=108)	9 (50.0)	6 (33.3)	3 (16.7)	0 (0.0)	0 (0.0)	9 (50.0)	9 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (16.7)	0 (0.0)	0 (0.0)	12 (66.6)	3 (16.7)
p-value	**0.11**					**0.23**					**0.00***				
Job Title															
Faculty (n=111)	39 (35.1)	51 (45.9)	12 (10.8)	9 (8.2)	0 (0.0)	57 (51.4)	33 (29.7)	18 (16.2)	3 (2.7)	0 (0.0)	3 (2.7)	18 (16.2)	18 (16.2)	63 (56.8)	9 (8.1)
Senior Resident (n=9)	0 (0.0)	9 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (66.7)	3 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (66.7)	3 (33.3)
Junior Resident (n=12)	6 (50.0)	3 (25.0)	3 (25.0)	0 (0.0)	0 (0.0)	6 (50.0)	6 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (21.0)	0 (0.0)	0 (0.0)	9 (75.0)	0 (0.0)
	0.01*					**0.45**					**0.00***				
Years of Experience															
Less than 5 years (n=30)	12 (40.0)	9 (30.0)	6 (20.0)	3 (10.0)	0 (0.0)	15 (50.0)	9 (30.0)	3 (10.0)	3 (10.0)	0 (0.0)	6 (20.0)	3 (10.0)	3 (10.0)	18 (60.0)	0 (0.0)
5-10 years (n=72)	27 (37.5)	42 (58.3)	3 (4.2)	0 (0.0)	0 (0.0)	42 (58.3)	18 (25.0)	12 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	12 (16.7)	12 (16.7)	42 (58.3)	6 (8.3)
11-15 years (n=18)	0 (0.0)	12 (66.6)	3 (16.7)	3 (16.7)	0 (0.0)	6 (33.3)	9 (50.0)	3 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	3 (16.7)	3 (16.7)	9 (50.0)	3 (16.7)
16-20 years (n=9)	6 (66.7)	0 (0.0)	0 (0.0)	3 (33.3)	0 (0.0)	6 (66.7)	3 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (66.7)	3 (33.3)
More than 20 years (n=3)	0 (0.0)	0 (0.0)	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (100.0)	0 (0.0)
	0.00*					**0.02***					**0.00***				

**Chi-square with Yates Correction test was applied to find out the difference in responses with respect to educational qualification, job title and years of experience.*

Table 5: Regression Analysis of Attitude of Study Participants Towards Autopsies with Educational Qualification, Job Title and Years of Experience

Variable	Categories					Regression Coefficient; P-value		
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Educational Qualification	Job Title	Years of Experience
Autopsies are capable of providing relevant findings that could change my future clinical practice:	69 (52.27)	42 (31.82)	18 (13.64)	3 (2.27)	0	-0.06; 0.237	0.24; 0.450	0.32; 0.022
Autopsy is essential for knowledge, research and education goals in department	6 (4.55)	18 (13.64)	18 (13.64)	78 (59.09)	12 (9.09)	-0.04; 0.006	-0.01; 0.001	-0.25; 0.002
Currently diagnostic procedures are so accurate that there is little need to perform hospital autopsies.	12 (9.09)	48 (36.36)	45 (34.09)	27 (20.45)	0	-0.07; 0.000	0.18; 0.003	0.23; 0.001

**Chi-square test was applied to find out the difference in responses with respect to educational qualification, job title and years of experience.*

profound emotional and personal significance for grieving families. This study also explored the influence of religious, psychological, and cultural perspectives on the declining utilization of autopsies, identifying them as important determinants shaping autopsy practices. Understanding these factors is essential for reinforcing the role of autopsy in medical training and clinical decision-making, ensuring its continued relevance in modern healthcare.

Previous literature supports these observations. McNamee et al. found that, despite sociocultural apprehensions, medical students largely valued autopsies for their educational merit.[10] A similar investigation by Anders S. in Hamburg, Germany, demonstrated that perceptions of autopsy education are influenced by the stated objectives of the procedure and the attitude of the instructor delivering it.[11] Kassab S. highlighted a perceptual discord between students and educators, where tutors self-identified as 'facilitative-collaborative,' yet were often perceived by students as 'suggestive-assertive,' thereby impeding the intended educational experience.[12]

A parallel discourse in Western contexts has emerged concerning the appropriateness of limited autopsies-balancing familial respect with the investigative utility of comprehensive post-mortem examinations.[13] Van der Tweel J.G. emphasized an often-overlooked dimension of autopsies as mechanisms of institutional quality control.

The concordance between ante-mortem clinical diagnoses and post-mortem findings serves as an indicator of a healthcare facility's diagnostic and therapeutic effectiveness. Similarly, the depth and precision of autopsy reports reflect the academic rigor of forensic pathology training within an institution.[14]

The findings of this study suggest a nuanced perspective on autopsy practices among medical professionals. While senior practitioners and those in leadership roles increasingly rely on modern diagnostic techniques, more academically inclined individuals continue to recognize the confirmatory significance of autopsy in clinical decision-making. Experienced professionals acknowledge the relevance of autopsy in medical practice but may not necessarily consider it indispensable for research or education.

Those occupying higher positions within the healthcare hierarchy tend to place greater trust in advanced diagnostics and exhibit reduced support for autopsy's role in medical education and research. Conversely, individuals with advanced academic qualifications often challenge the notion that autopsies are obsolete, reflecting a deeper engagement with medical sciences and forensic pathology.

Despite various challenges affecting the perceived value of autopsies as diagnostic, educational, and investigative tools, their continued significance remains evident. There is an urgent need to reform and standardize autopsy protocols to ensure comprehensive and high-quality procedural demonstrations while reinforcing their role in structured medical training.

These reforms must be accompanied by targeted interventions aimed at dispelling prevailing misconceptions among medical practitioners regarding the scientific, educational, and clinical importance of autopsy. Establishing a more consistent pedagogical framework will support its integration into modern medical curricula, fostering a renewed appreciation for its

role in advancing diagnostic accuracy and forensic medicine.[15]

CONCLUSION

This study highlights a significant gap in both knowledge and attitudes among medical practitioners regarding autopsy procedures. While many respondents acknowledge the role of autopsies in medical education and forensic investigations, there remains a considerable lack of in-depth understanding of their scientific and procedural aspects. The findings suggest that emotional considerations, time constraints, and institutional policies continue to influence practitioners' willingness to engage with autopsy practices.

Addressing these challenges requires a multifaceted approach, including enhanced educational initiatives, structured clinical exposure, and institutional support to reinforce the importance of autopsy in medical training. Standardizing autopsy protocols and integrating them more effectively into medical curricula can help bridge these gaps, ensuring that autopsies remain a valuable diagnostic and educational tool. Promoting awareness and fostering a positive perception among medical professionals will be critical to maintaining the relevance of autopsies in modern healthcare and forensic medicine.

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Original Research Paper

Assessing Awareness and Attitudes of Postgraduate Residents about Organ Donation and Transplantation Protocols: A Cross-Sectional Study in Chennai, South India

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ABSTRACT

Introduction: Organ transplantation is a vital solution for end-stage organ failure, yet India faces a critical shortage of donor organs. The need for the transplants is higher than the availability of organs and this gap is widening globally. India's organ donation rate falls well short of both the actual demand and the global average. This study aims to evaluate the knowledge, attitudes, and barriers related to organ transplantation among postgraduate residents at tertiary care centres in Chennai, South India.

Materials and Method: A cross-sectional, questionnaire-based study was conducted among 180 postgraduate residents, selected through stratified random sampling. A validated self-administered questionnaire was used to collect data. It asked about demographics, knowledge of regulatory Acts (THOTA), attitudes towards organ donation, perceived barriers, and suggested actions. Descriptive and inferential statistics, including chi-square tests, were used to analyze the data.

Results: The mean age of participants was 26.43 ± 2.12 years. Awareness of THOTA was reported by 68% of participants, with 60% receiving training on organ transplantation. Attitudes were varied, with 42.5% supporting mandatory donation and 50% willing to counsel donor families. Significant barriers included legal challenges (22.5%), cultural beliefs (21.2%), and lack of awareness (20%). Participants suggested educational programs (50%), policy changes (57.14%), and public awareness campaigns (25%) as key measures to address these challenges.

Conclusion: The study identified critical gaps in knowledge, attitudes, and perceived barriers among postgraduate residents, though they were generally supportive of organ donation. It highlighted the need for targeted training programs, policy reforms, and public awareness initiatives. Addressing these challenges can enhance organ donation advocacy and bridge the gap between organ demand and supply, ultimately improving patient outcomes.

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INTRODUCTION

Organ transplantation is a critical medical intervention for patients with end-stage organ failure, offering a potential lifeline and improved quality of life. Kidney, heart, liver, lung, and pancreas are among the vital organs that are routinely used for transplantation, but many other organs draw less public attention such as small bowel, skin, ligaments, bones, and cornea. Successful retrieval of

organs and transplantation are complex processes involving co-ordination of multiple specialists and transplant teams who are expected to be well-versed with the protocols. Despite significant advancements in medical science, the disparity between the demand for and the supply of donor organs remains a pressing global challenge. The WHO estimates that around 172, 397 organ transplants were carried out worldwide in 2023, including transplants from both deceased and living donors.[1] This number, however, caters to only 10-15% of the estimated requirement.

Donating a body or an organ is a very valuable post-mortem altruistic deed. In India, the organ donation rate is estimated at approximately 0.4 per million population, far below global averages and indicating a critical shortage of organs for transplantation.[2] To address this gap, the Indian Government enacted the Transplantation of Human Organs Act (THOA) in 1994. This act was aimed to regulate the removal, storage, and transplantation of human organs and tissues for therapeutic purposes while preventing commercial dealings in human organs.[1] The act was amended in 2011 and was named 'Transplantation of Human Organs and Tissues Act' (THOTA 2011). However, despite the legislative framework, the implementation of organ donation programs faces significant challenges, including limited public awareness, cultural reservations, and infrastructural constraints.[3]

The THOA 1994, was a step forward in recognising concepts such as brain death and was supposed to promote cadaveric organ transplantation in India. This has not happened for many reasons: the inclusion of loopholes either by design or default permitting the continued sale of organs; the availability of enough poor people ready to sell a part of themselves; a social ethos which permits justification of the trade as “good for both – the seller and buyer” and, perhaps most importantly, lack of commitment on the part of Indian society to promote cadaver organ transplant. Nevertheless, there are numerous ethical challenges still to be resolved, particularly about consent, incentives to donors and families, and equitable distribution of donated organs.[4]

Organ transplantation is the most preferred treatment modality for patients with end-stage organ disease. Healthcare professionals, particularly postgraduate medical residents, play a pivotal role in facilitating organ donation processes. They are the critical link in augmenting public awareness about organ donation. Their knowledge and beliefs are crucial for the success of organ donation programs. Their attitudes and practices can largely influence the public opinion.[5] But studies suggest that non-transplant physicians lack knowledge about the organ donation process. It was postulated that knowledge gaps may have their roots in residency and fellowship, given these programs are frequently the final chances for formal medical training.[6]

Research suggests that while many medical students and residents express general awareness about organ donation, misconceptions and gaps in detailed knowledge persist, potentially hindering advocacy efforts.[7] For instance, a study among medical students in Kerala highlighted that despite awareness, many participants lacked adequate understanding of the procedures and legal frameworks surrounding organ donation.[8]

Only a small number of medical students have a clear understanding of the idea of brain death and its diagnostic procedures. This fact was potentiated by a study in Saudi Arabia wherein 4th year medical students demonstrated significant knowledge gaps regarding brain death.[9]

Organ donation programs are yet to gain momentum in India as cultural and religious beliefs are additional barriers to it. A nationwide study assessing the attitudes of the general population towards organ donation revealed that cultural reservations and misinformation were significant obstacles. These societal factors, coupled with inadequate training among healthcare professionals, underscore the need for comprehensive educational programs that address misconceptions and enhance advocacy for organ donation.[10]

Failure to identify potential organ donors, failure to discuss organ donation with families, and a low consent rate after organ donation is discussed contribute to suboptimal deceased donation rates. medical personnel engaged in patient care can facilitate donation, even without directly raising the option of donation with the family, by confidently answering questions about donation and transplantation. This is more likely to occur effectively if medical personnel are more knowledgeable about the medical criteria for organ donation, more aware of the donor conversion process, and more educated about transplantation in general.[11]

Physicians generally have favourable opinions toward organ transplantation but they lack knowledge about basic organ transplantation and procurement topics, such as the criteria for establishing brain death, other medical criteria

for deceased donor organ donation and the laws and regulations governing organ donation.[12] A key component of many public health campaigns, is enhancing awareness of a particular topic. The inherent complexity of organ donation and transplantation concepts may make it challenging to target knowledge gaps in such efforts. The relationship between willingness to donate or register as an organ donor and donation knowledge has been the subject of numerous research.[13]

Even though the recipient gains greatly, the act of donation is still benevolent and generally does not directly benefit the donor. The regulation of organ donation and transplantation has been a hot topic from ethical, medical, and legislative standpoints for the past few decades. Most hospitals do not have defined pathways for identifying and maintaining brain dead donors. They lack trained staff to approach the families for organ donation.[14] In this context, evaluating the knowledge, attitudes, and perceived barriers among postgraduate residents is crucial. Such assessments can inform the development of targeted interventions to improve awareness, address barriers, and ultimately enhance organ donation rates. There is a paucity of studies with aim to evaluate the current awareness and attitudes of postgraduate (PG) resident doctors in South India. This aspect was intended in our study and we also tried to explore existing challenges in our region, and propose actionable solutions to strengthen organ donation practices.

MATERIALS AND METHOD

This cross-sectional, questionnaire-based study was conducted at both government and private hospitals in Chennai, Tamil Nadu after obtaining a formal ethical approval. The study aimed to assess the knowledge level and attitude toward organ donation & transplantation protocols among postgraduate residents. The study also aimed to explore the barriers in practice and communication related to the organ donation process. The study population included postgraduate residents from various specialties in five tertiary care centers in Chennai. Participants were selected using stratified random sampling to ensure representation across specialties and residency years (Year 1, Year 2, Year 3). Inclusion criteria were PG residents with no history of training or experience in any organ donation program and transplantation center. Those who declined or submitted incomplete responses were excluded.

The sample size was calculated based on a 95% confidence level, an expected awareness proportion of 50%, and a 7% margin of error. After adjusting for a 10% non-response rate, the sample size was set at 180 participants. Twenty questions were identified for the subjective assessment of residents to determine their awareness level and attitude toward organ donation. A structured, validated, self-administered questionnaire with 25 questions in total was used for data collection. The tool consisted of sections on demographics (age, gender, specialty, and year of residency), knowledge of organ transplantation (awareness of THOTA, training, and procedural knowledge), attitudes (support for mandatory donation and willingness to counsel families), barriers (perceived challenges), and suggested measures (recommendations to improve organ donation). The questionnaire was pilot-tested on 20 participants for clarity and reliability (Cronbach's alpha = 0.82).

Data collection was conducted over four months (March to June 2023). Participants were recruited via departmental notices and electronic communications. After obtaining written informed consent, the questionnaires were distributed in paper format through a department coordinator in each center to maintain confidentiality. The data materials were collected from the coordinator physically on visits or during postings. Responses were kept anonymous and securely stored.

Data were entered into Microsoft Excel and analyzed using SPSS software (version 26.0). Descriptive statistics (mean, standard deviation, percentages) summarized participant characteristics and questionnaire responses. Inferential statistics, including chi-square tests and t-tests, were employed to identify significant associations. A p-value < 0.05 was considered statistically significant. The study timeline spanned 16 months, from ethical approval in February 2023 to data analysis and manuscript preparation by July 2024.

RESULTS

A. Demographics and Contextual Data

Table 1 highlights the demographic distribution, providing a basis for stratifying further analyses on training, awareness, and attitudes.

B. Knowledge of Organ Donation, its Laws and Protocols

Table 2 demonstrates variations in training and awareness levels across specialties, genders, and residency years, emphasizing gaps in knowledge. The knowledge of organ donation and its procedures did not

Table 1: Participant Demographics and Contextual Data (N = 180)

Aspect	Value / Percentage
Age (Mean ± SD)	26.43 ± 2.12
Gender: Male	56.67%
Gender: Female	43.33%
Specialty: Anaesthesiology	15.56%
Specialty: Radiology	14.44%
Specialty: Internal Medicine	12.22%
Specialty: Surgery	11.67%
Specialty: Pediatrics	10.00%
Specialty: Obstetrics & Gynaecology	8.33%
Specialty: Psychiatry	8.89%
Specialty: Dermatology	9.89%
Year of Residency: Year 1	33.33%
Year of Residency: Year 2	36.67%
Year of Residency: Year 3	30.00%

differ significantly among men and women.

Training Received: Participation was higher among females in Radiology (75%) and Pediatrics (70%) compared to males in other specialties.

Awareness about the organ donation process was highest among Anaesthesiology (83%) followed by Surgery (79%). Awareness about THOTA rules was highest among Radiology (80%) and lowest among Internal Medicine (68%).

C. Attitudes Towards Organ Donation

Table 3 reflects varying attitudes towards organ donation, indicating areas for targeted training and awareness programs.

Mandatory Donation: Support for mandatory organ donation was 42.5%, while 35% opposed it. More than half of the participants (51.7%) were willing to counsel donor families. Comfort levels discussing donation were relatively high (60.0%), though 15.0% were unsure.

The respondents' willingness to live organ donation to a known recipient which included family members, friends, and relatives showed that 33.5% of them had a strong willingness and 46% of them said that they were not sure and would think about donating when a need arose. The rest, about 20.5% asserted their strong unwillingness.

D. Barriers related to Organ Donation process.

1. Physical & psychological factors like health and medical condition, organ compatibility, poor health of the recipient, emotional (grief from the loss of family member), pressure during the consent process, fear and uncertainty about the donation process accounted for 31% of responses. Internal medicine residents were the most respondents choosing this barrier.
2. Education level and social factors: The higher the education, the lower are the disapproval chances. Religious beliefs, family decisions, and social attitudes can act as barriers which made up 23 %.
3. Communication barriers made up almost 30 %. The bar chart **Figure 1** illustrates the distribution of

Table 2: Knowledge of Organ Donation Laws and Protocols (N = 180)

Gender	Specialty	Year of Residency	Training Received (%)	Awareness On Process of Organ Donation (%)	Awareness on Laws-THOTA (%)
Male	Anaesthesiology	Year 1	67.5	83.6	72.5
Female	Radiology	Year 2	75.0	71.3	80.0
Male	Internal Medicine	Year 3	62.5	69.4	68.8
Female	Pediatrics	Year 1	70.0	67.9	75.0
Male	Surgery	Year 2	65.0	79.1	70.0

Table 3: Attitudes Towards Organ Donation

Aspect	Yes (%)	No (%)	Undecided (%)	Unsure (%)
Supports Mandatory Donation	42.5	35.0	22.5	N/A
Willing to Counsel Families	51.7	40.0	N/A	8.3
Believes in Healthcare Role	55.0	37.5	N/A	7.5
Comfortable Discussing Donation	60.0	25.0	N/A	15.0
Willing to Donate if Need (Live Donation)	33.5	20.5	N/A	46
Donor Card Holders Become Real Donors	17	63	N/A	20

Figure 1: Barriers Working Against Organ Donation

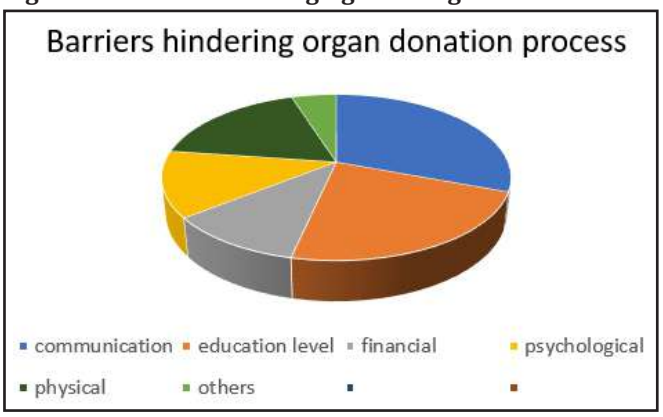
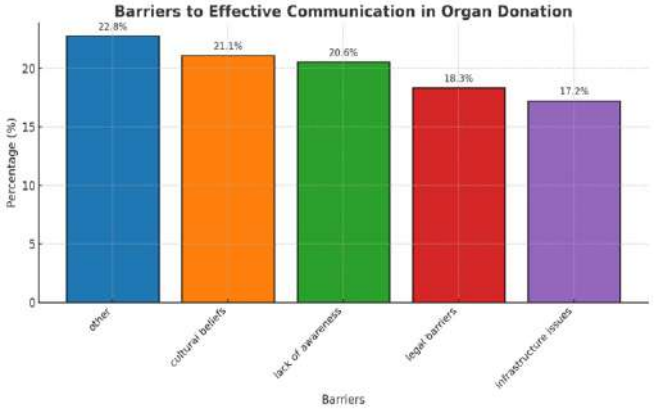


Figure 2: Barriers of Communication in Organ Donation



perceived barriers to effective communication in organ donation among 180 participants.

4. Financial and infrastructure barriers (11%) depend on government funding and the involvement of private parties.

Communication hurdles vary from language barriers (12.5%) to cultural beliefs (21.2%) and lack of awareness (20.6%). Other barriers include infrastructure issues (17.2%), and other barriers like legal (18.3%) & time constraints (7.4%) that might affect the willingness to donate in potential donors. The graph emphasized the relatively even distribution of these barriers, highlighting the need for targeted interventions across all categories.

E. Suggested Measures

Table 4 highlights actionable suggestions from participants to bridge training gaps and address communication barriers, focusing on education, policy, and awareness. Educational Programs: Suggested predominantly by Internal Medicine (50%) and Male Anaesthesiologists (37.5%). Policy Changes: A significant suggestion from Female Anaesthesiologists (57.14%). Public Awareness: Widely recommended across Radiology (25%) and Anaesthesiology (28.57%).

DISCUSSION

A transplantation program's effectiveness depends on the awareness and positive attitudes of medical personnel. Organ transplantation and research rely on donated organs. The use of donated bodies and organs facilitates medical education, and surgical and other post-graduate clinical training. Health care workers have a critical role in facilitating discussion about body and organ donation, and in advocating for their importance in medical care, education, and research.[15] People's decisions on organ donation are influenced by a variety of factors, including their knowledge, opinions, education & social structure, cultural norms, religious beliefs, and myths. Having accurate, current, and nuanced knowledge about body and organ donation programs and procedures is crucial to physicians' ability to advocate for donation effectively and to approach families with sensitivity and confidence.[16]

A. Demographics

The mean age of participants was 26.43 ± 3.12 years, indicating a relatively young cohort. Male participants constituted 56.67%, slightly higher than females (43.33%). Most participants were from Year 2 residency (36.67%), followed by Year 1 (33.33%) and Year 3 (30.00%). The highest representation was from Anaesthesiology (15.56%), followed by Radiology (14.44%).

B. Knowledge of Organ Donation & Laws

The study findings revealed inconsistencies in the

Table 5 Awareness and Training Gap with Suggested Measures

Specialty	Gender	Measure Suggested	Percentage (%)
Anaesthesiology	Female	Policy Changes	57.14
Anaesthesiology	Female	Public Awareness Campaigns	28.57
Anaesthesiology	Male	Educational Programs	37.50
Radiology	Male	Public Awareness Campaigns	25.00
Internal Medicine	Female	Educational Programs	50.00

awareness and training related to organ donation laws, particularly the Transplantation of Human Organs and Tissues Act (THOTA). While a significant proportion of participants in certain specialties, such as Radiology (75%), reported awareness of THOTA, gaps remain in other areas. Similarly, training on organ transplantation is more prevalent among some specialties, such as Pediatrics and Radiology, but lacks consistency across residency years. These disparities highlight the potential for misinformation and inefficiency in communication and decision-making.[17-18] Improving training programs tailored to the specific needs of specialties and residency years is crucial. Regular evaluations of awareness and the impact of training can further ensure that all healthcare professionals are adequately prepared to address organ donation-related scenarios.

C. Attitudes Towards Organ Donation

The attitudes of participants indicate moderate support for mandatory donation (42.5%) and willingness to counsel donor families (50%). However, discomfort in discussing organ donation (15%) and indecision regarding mandatory donation (22.5%) reflect the need for improved confidence and clarity in this area. Almost 63% did not believe that those who possess donor cards will finally become real donors. These findings underscore the role of attitudes in shaping healthcare professionals' willingness to engage with donor families and advocate for organ donation.[19-20] Previous research suggests health workers are less likely to support the donation of their own bodies and/or organs, despite recognizing the public good of donation, and that exposure to gross anatomy teaching may negatively affect support for donation.

Attitudes to body and organ donation were examined in medical students studying anatomy in Australia. Support for self-organ donation was found to be 82.5%, whereas support for self-body donation was lower at 26.5%. Just over 4% of participants said they would not support the election of a family member to donate their organs, and 10% said they would not support donating the body. Exposure to gross anatomy teaching was associated with an increased likelihood of consideration of issues about body and organ donation, whether for self, family, or the public and registration as an organ donor. Thus, gross anatomy courses provide an opportunity to inform about altruistic donation.[21]

Addressing these issues requires initiatives such as role-playing exercises, interactive communication workshops, and policies that promote teamwork and shared goals within healthcare environments. These measures can help cultivate more positive attitudes and greater comfort levels among professionals.[22]

D. Barriers related to Organ Donation process

Legal challenges (22.5%), cultural beliefs (21.2%), and lack of awareness (20.0%) emerged as the most significant barriers to effective communication. Respondents mentioned physical/ emotional (grief from loss), psychological (pressure during the consent process, fear and uncertainty about the donation process), time constraints (window period for obtaining consent), and language as the other barriers (17.4%) might affect the willingness to donate in potential donors. The relatively even distribution of these barriers suggests that systemic, cultural, and informational challenges coexist, creating a multifaceted problem that requires diverse solutions.[23-24]

Qualitative findings of a focus group study in Australia revealed that lack of exposure and knowledge about the organ donation process, religious and cultural beliefs, as well as distrust of the medical system, were barriers to organ donation.[21] Similarly, a study on the effectiveness of an organ donation campaign in Riyadh, found the fear of organ failure after living donation (66.2%), concern about body image distortion after deceased donation (42.5%), the ambiguity surrounding the concept of brain death (35%) as the common barriers.[25] (Shaheen MF)

Simplifying legal frameworks, providing clear guidelines, and conducting cultural sensitivity training can reduce legal and cultural barriers. Public awareness campaigns that demystify organ donation and emphasize its life-saving potential can further address knowledge gaps among both healthcare professionals and the public.[26]

E. Suggested Measures

Participants proposed actionable solutions to overcome these barriers, including educational programs (50%), policy changes (57.14%), and public awareness campaigns that address myths and misconceptions (25%). These suggestions highlight the need for a holistic approach that integrates education, systemic reforms, and community outreach.[27]

Medical advances in transplantation techniques have driven an exponential increase in the demand for transplantable organs. Unfortunately, policy efforts to bolster the organ supply have been less than effective, failing to provide a stopgap for ever-increasing numbers of patients who await organ transplantation.[11]

Educational initiatives should focus on improving healthcare professionals' knowledge and skills related to organ donation, while policy changes can provide institutional support to streamline organ donation procedures. If the legal complications surrounding this unclaimed dead body can be addressed in a timely phased approach, the tedious task of disposing the body can be converted into a precious scientific material for medical education and research. In India, Anatomy Act was enacted in 1948. It is a state Act promoted by legislature and published in the state Government Gazette. The Act provide for supply of unclaimed bodies of deceased person (and for donation before death by a person of his body or any part thereof after his death) to hospital and medical teaching institution for therapeutic purpose or for the purpose of medical education or research including anatomical examination and dissection.[28]

CONCLUSION

The present study identified critical gaps in knowledge, attitudes, and perceived barriers among postgraduate residents in Chennai, though they were generally supportive of organ donation. There was a high level about of awareness various aspects of organ donation, except for the legal aspects (THO Act). However, a high proportion of the participants did not have positive attitudes toward mandatory donation and willingness to donate voluntarily when such an occasion arises. The study highlighted key barriers, such as legal challenges, cultural beliefs, and lack of awareness, and suggested actionable measures to address them. Therefore, educational interventions can help students by providing them with further information about the organ donation process and protocols and allowing them to reflect on their attitudes and opinions.

Awareness of various facets of organ donation and transplantation is of paramount importance in shaping the career path of future specialist doctors and in enabling them to successfully navigate the interface between medical indications and legal implications. Appropriate training of health professionals is recommended to increase organ donation rates. By implementing targeted training programs, policy reforms, and public awareness campaigns, healthcare institutions can play a pivotal role in bridging the gap between organ donors and recipients. These findings provide a comprehensive framework for improving organ donation practices and advancing the life-saving potential of transplantation. Knowledge-enhancing campaigns and other modalities can effectively improve public perception and promote awareness of organ donation.

Limitations of study: Although the study provides valuable insights into various aspects of organ donation process, its limitations should be acknowledged. The data was confined to postgraduate residents in Chennai, potentially limiting its generalizability to other medical professionals and other regions. Additionally, reliance on self-reported data introduces the possibility of bias in assessing knowledge and attitudes. Participants may still choose not to share their honest opinions even after being assured that the survey will remain anonymous. Finally, the relatively even distribution of barriers might obscure nuanced differences that could be better explored through qualitative research. Future studies should consider expanding the geographical scope and incorporating qualitative methodologies.

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Original Research Paper

Analysis of Sexual Dimorphism Using Canine Index : A Study Cast perspective

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ABSTRACT

Introduction: Teeth are most important tool in forensic odontology for identifying both living and deceased individual. With their capacity to withstand any kind of environmental scenario, it makes them a very dependable forensic tool. Among the tooth in the dentition, canine is considered as the tooth which is least susceptible to oral diseases and also can survive any natural calamities due to their labiolingual thickness and firm anchorage in the jaws which makes them withstand all the situations and dependable tool in forensics.

Materials and Method: The study comprised of 80 subjects from South Indian population with 40 males and females in each study group in the age group of 17 – 30 years as canines erupt by this age, show less attrition and fixed intercanine distance. The study subjects were screened properly and after proper oral hygiene, alginate impressions of maxillary and mandibular arches were recorded and study models were fabricated followed by odontometric measurements was carried out. The mesio distal dimension of maxillary and mandibular canine were measured and thereby the inter canine distance of both arches were evaluated.

Results: The mesiodistal dimension of canine in both maxillary and mandibular arches showed that male study group had a higher than the female counterpart.Comparing standard canine indices with males and females shows no statistically significant results except for maxillary left canine index. Standard canine index shows accuracy of maxillary total canine index is 47.5 % and mandibular total canine index is 50% with mandibular canine index having greater accuracy value and making it important in gender determination.

Conclusion: The present study concludes that canine index as an effective tool for gender determination and evaluating mesiodistal dimension of maxillary and mandibular canine is reliable, less expensive and helps in person identification even from mutilated dental remains.

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INTRODUCTION

Forensic odontology is that branch of forensic sciences which uses dental evidence for identification.[1] The dental evidence is characteristic to each individual. Forensic dentistry not only helps in identifying the criminals but also shows interest in identifying the victim and dead, mutilated bodies.[2]

No two mouth are alike as there is difference in most of the

dental features between male and female which is the basis of sexual dimorphism in forensic odontology.[3] Identification of gender is most challenging feature in mass disaster because of disfigurement or mutilation of bodies.[4]

In these condition teeth is considered for identification of gender as they can withstand harsh conditions.[2] As no tooth are identical, they can serve in forensics for sex determination. Hence tooth are an alternative for other parts of the body for human identification. Odontometrics play a vital role in identification of deceased and in gender determination.[2]

Canines are the teeth which show greatest variation in sexual dimorphism and have significant contribution in identification. So canine is for its crediability in this regard is used for odontometric analysis namely tooth dimensions and canine index (CI).[2] The reason why canine shows sexual dimorphism are it is least periodontally affected tooth and shows minimal pathological migrations, last tooth to be extracted, less abrasion from brushing, less occlusal load, and can survive in various situations.[5-7]

As canine shows varied degree of dimorphism especially mandibular canine can be used for odontometric analysis and canine index in the field of forensics.[4] The present study aims to perform sex determination using mesio-distal width of canine teeth and inter-canine distances in South Indian population.

MATERIALS AND METHOD

The South Indian study population comprised of 80 subjects with 40 males and females in each group with age ranging from 17–30 years. The criteria behind selecting these group is that by this canines are erupted, minimal attrition and fixation of inter canine distance at 12 yrs.[1,8-9] The mesiodistal measurements of maxillary and mandibular canine and intercanine distanced of the both the jaws were done using digital vernier calliper. The study was duly approved by Institutional Ethics Committee (IEC/TDCH/158/2021).

Inclusion Criteria

The criteria for inclusion of subjects were presence of fully erupted, normal, and attrition free canine, normal dental arches with normal overjet, overbite (2-3mm), normal molar and canine relationship. [1-2,9-10]

Exclusion Criteria

Subjects with abnormal tooth alignment, including rotation, crowding, and occlusal disharmony or missing anterior teeth, poor oral hygiene, fractured canine fractures, under orthodontic treatment or restored teeth were excluded. Subjects are selected randomly and formal explanation of the study, informed consent was received from them.[1-2,9-10]

Making of Study Models

The intra oral examination for study subjects were done with diagnostic instruments. They were instructed to gargle with mouthwash solution thoroughly for removal of any food debris, etc to avoid any interference in the model fabrication. Followed by this, the impressions were thoroughly washed with disinfectant solution and dental stone models were fabricated which was used for odontometric measurements.

Mesio-distal Crown Width of Canines

The maximum mesio-distal dimension at contact point of canine with the adjacent tooth was measured using pointed ends of the digital calliper placed at this region and the values were noted. **(Figure 1)**

Intercanine Distance

The measurement was done using digital calliper tips placed on the both canine cusp tips and the reading were noted. **(Figure 2)**

Based on formula given by Muller et al[2], the canine index and standard canine index for maxillary and mandibular canines were calculated:

Canine index = Mesio-distal crown width of canine/ Intercanine distance[11-13]

Standard canine index = (mean male CI - SD) + (mean female CI + SD) /2 [11-13]

RESULTS

All the collected data were organized into tables and analyzed statistically using SPSS software and an independent t-test to evaluate gender dimorphism.

Gender Dimorphism in Mesio Distal Dimension of Canine

Comparison of the maxillary and mandibular right and left canine mesio distal (MD) width shows that male group has higher value than female. Independent t test shows that almost all the MD width shows statistically significant value except maxillary left canine. **(Table 1)**

Gender Dimorphism in Standard Canine Indices

Comparing standard canine indices with males and females shows no statistically significant results except for maxillary left canine index. **(Table 2)**

Accuracy of predicting gender using standard canine indices

When comparing the maxillary and mandibular canine indices for gender prediction, it is evident that the mandibular canine index offers a higher accuracy percentage in prediction (50%).While considering quadrant based canine index, mandibular left canine index has higher percentage of accuracy in prediction (50%) than other three quadrant canine index. **(Table 3)**

Table 1: Independent T Test to Compare the MD Dimensions of the Maxillary and Mandibular Canines

	Female (mean ± SD)	Male (mean ± SD)	t value	P value
Maxillary Right Canine	7.09±0.58	7.39±0.59	-2.234	0.028
Maxillary Left Canine	7.01±0.47	7.2±0.62	-1.548	0.126
Mandibular Right Canine	6.14±0.49	6.43±0.4	-2.877	0.005
Mandibular Left Canine	6.01±0.54	6.5±0.52	-4.127	<0.001

Table 2: Independent T Test to Compare the Standard Canine Indices

Standard Canine Indices	Female (mean ± SD)	Male (mean ± SD)	t value	P value
Maxillary Total Canine Index	0.22±0.01	0.22±0.01	1.226	0.224
Maxillary Right Canine Index	0.22±0.02	0.21±0.02	1.097	0.276
Maxillary Left Canine Index	0.21±0.01	0.21±0.02	2.014	0.048
Mandibular Total Canine Index	0.25±0.02	0.25±0.02	0.478	0.634
Mandibular Right Canine Index	0.25±0.02	0.24±0.02	1.359	0.178
Mandibular Left Canine Index	0.24±0.02	0.24±0.02	-0.202	0.84

Table 3 Prediction of Gender using Canine Index and Its Accuracy

Standard Canine Indices	Gender	Female (n=40)	Male (n=40)	Female Accuracy	Male Accuracy	Total Accuracy
Prediction of Maxillary Total Canine Index	Predicted Female	20	22	20/40 (50%)	18/40 (45%)	38/80 (47.5%)
	Predicted Male	20	18			
Prediction of Maxillary Right Canine Index	Predicted Female	19	23	19/40 (47.5%)	17/40 (42.5%)	36/80 (45%)
	Predicted Male	21	17			
Prediction of Maxillary Left Canine Index	Predicted Female	17	22	17/40 (42.5%)	18/40 (45%)	35/80 (43.7%)
	Predicted Male	23	18			
Prediction of Mandibular Total Canine Index	Predicted Female	23	23	23/40 (57.5%)	17/40 (42.5%)	40/80 (50%)
	Predicted Male	17	17			
Prediction of Mandibular Right Canine Index	Predicted Female	19	26	19/40 (47.5%)	14/40 (35%)	33/80 (41.3%)
	Predicted Male	21	14			
Prediction of Mandibular Left Canine Index	Predicted Female	21	21	21/40 (52.5%)	19/40 (47.5%)	40/80 (50%)
	Predicted Male	19	19			

Figure 1: Measurement of Canine Width and Inter Canine Distance by Vernier Caliper

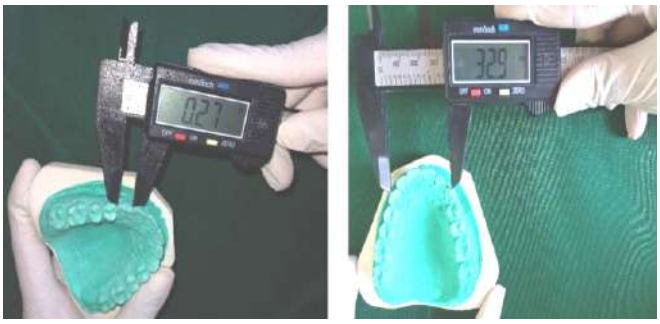


Figure 2: Gender Wise Distribution of Maxillary Canine Index

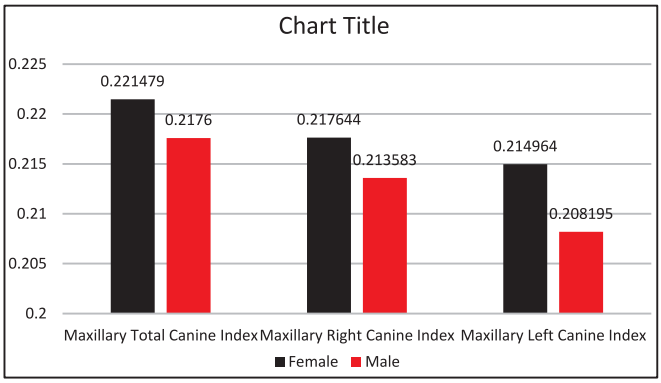
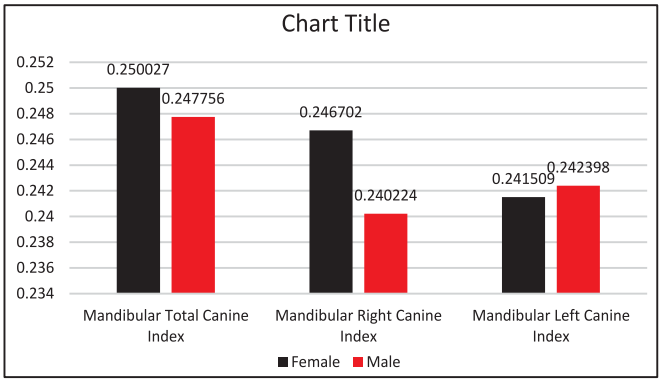


Figure 3: Gender Wise Distribution of Mandibular Canine Index



DISCUSSION

Forensic odontology deals with genuine handling, inspection and assessment of evidences collected from oral cavity and associated structures.[14] In the context of tooth size analysis, sex estimation takes precedence over age determination when sex can be reliably predicted, as it simplifies and enhances the accuracy of the identification process.[15-16]

Out of the permanent tooths, canines provide an information on sexual dimorphism with metric characteristics and also with non metric trait namely observance of minor distal groove in maxillay or mandibular canine. Amongst the maxillary and mandibular canine, the mandibular teeth are easily available since mandible is strong enough to the well preserved and retrieved in a better condition than any bone in the human body.

The Canine Index more specifically Mandibular Canine Index (MCI), a method that is employed in the branch of forensic odontology for sex determination especially in situations when fragmented or damaged skeletal remains are available for investigation.[17] The canine is the most preferred tooth for this system with few key features attributing to this like genetic effect of Y-chromosome in determination of canine tooth size, effect of environmental factors and eating ha bits, variation in canine tooth size influenced by evolutionary changes , steroid hormone influence on tooth size and shape.[18]

Hard tissues of the body serve as a valid tool in forensics as they can withstand any environmental and temperature changes, with tooth being one of the hard tissue in this category which helps in forensic investigation.[14]

With regard to mesio distal dimensions, the mean values of Maxillary right canine in males and females were found to be 7.39±0.59mm and 7.09±0.58mm, respectively , and the similar parameter for maxillary left canine in males and females were 7.2±0.62mm and 7.01±0.47mm, respectively. The similar measurement procedures were implied on mandibular right canine in males and females which showed 6.43±0.4mm and 6.14±0.49mm, respectively, and the similitude for mandibular left canine in males and females showed 6.5±0.52mm and 6.01±0.54mm.

Literature supports that males have higher mean value than females with a statistically significant results.[5,21-23] The results of present study is in accordance with Kaushal et al[5] whose research were on 60 subjects with right canine width in males and females to be 7.229 ± 0.280 mm and 6.690 ± 0.256 mm and similarly for left canine width it is 7.299 ± 0.292 mm and 6.693 ± 0.323 mm respectively.[5,19] Similar studies in accordance with the present study were those carried out by Agarwal et al[20], Nair et al[21], Lew and Keng[22] showed that canine exhibits varied sexual differences with regard to dimensions.

The genetic expression of X and Y chromosome in male is more than in females which is responsible for difference in canine width. The size of the tooth is determined by Y chromosome which decides the dentin thickness and X chromosome decides the enamel thickness. The prolonged amelogenesis time may be the cause behind the sizeable tooth crown in males than in females.[23] Mandibular

canines show varied sexual dimorphism due to changes in functional activity because of evoluation and socialization.[24]

With regard to the mean values of maxillary right canine index in males and females it was found to be 0.21±0.02 and 0.22±0.02 and for maxillary left canine index it showed 0.21±0.02 and 0.21±0.01 and the mean of Maxillary total canine index in males and females were found to be 0.22±0.01 and 0.22±0.01 respectively.

With regard to the mean values of mandibular right canine index in males and females it was found to be 0.24±0.02 and 0.25±0.02 and for mandibular left canine index it was 0.24±0.02 and 0.24±0.02 in males and females. The mean of mandibular total canine index in males and females it was found to be 0.25±0.02 and 0.25±0.02 respectively.

The mean values of maxillary and mandibular canine index of right and left canine in males and females showed significant difference upon performing Independent samples 'T' test (Student's t). The maxillary left canine showed a significant mean difference value between males and females (P Value - 0.048).

In our study gender predictability using Maxillary Total Canine Index was 47.5% and mandibular canine index was 50%. Singh et al[4] reported that the mandibular canine index values seen in females were marginally significant but the accuracy was not determined. Vijayan et al[10] observed that the mean difference in MCI canine index was highly significant in male and female with similar results of both right and left side.[10]

However, Lateef et al[1] found that the mandibular canine index was lower in females in contrast to males (76-80%). Basheer et al[8] had compared casts and intraoral and concluded that female Mandibular canine index was lower than male with the accuracy of 73-76% and SCI score of 0.35.

Our study was in accordance with Jain et al[9], who conducted gender predilection using mandibular canine index which was 65.52%. Yadav et al[15] inferred female Mandibular index was lower than males with the accuracy of 81-83%. Our study was also in accordance with Bakkanavar et al[2] with mean value of both maxillary and mandibular canine index on right and left side had similar values and were statistically significant.

In our study, we found that the mesiodistal width of maxillary and mandibular canine was higher in males than females and there was no significant statistical difference in maxillary and mandibular right and left canine index in males and females but maxillary left canine index showed more sexual dimorphism. In our study, sex prediction rate was about 50% due to certain limitations like variation in the parameters assessed and geographical distribution there by limiting them to be used as a supplemental. So other tissues and parameters like DNA profiling, dimensions of frontal sinus and other features of human origin, from an individual can be considered for forensic investigations in addition to the canine index.[25]

When other non metric traits of tooth along with the parameters considered in the present study, there are higher chance of greater accuracy in sex determination. Similar inferences have been documented by Ghorbanyjavadpour F et al[26] & Abdellah, N et al.[27]

Limitations; The limitations of the study were smaller sample size, application of latest scanning software for measuring the tooth can have certain drawbacks like expertise in using the scanning software's, artefacts and distortion of images caused by reflection of enamel and restorations in the tooth, errors in calibration of the scanners, resolution of images taken, high cost, maintenance of the equipment's, post mortem changes can limit the reconstruction done by scanning software's, noise in digital models, less validated techniques may have legal challenges in court and different geographical locations.

CONCLUSION

The present study shows accuracy of maxillary total canine index is 47.5 % and mandibular total canine index is 50%. The present study concludes that the canine index is one of the tools to be considered in forensic odontology especially the mandibular canine index for sex determination. The forensic odontology in Indian scenario depends on such cost effective and simple approaches in identification.

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Original Research Paper

Prevalence of Atherosclerotic Lesions in the Heart and Major Blood Vessels: an Autopsy - Based Study

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ABSTRACT

Introduction: Atherosclerosis begins early in life with arterial plaque formation leading to severe cardiovascular complications. Autopsy studies provide valuable insights into the disease processes contributing to premature morbidity and mortality and to understand the prevalence which is crucial for combating the rising burden of cardiovascular diseases.

Objective: The study aims to investigate the prevalence, gross, and histopathological characteristics of atherosclerotic lesions (AHA grading) in the heart and major blood vessels of individuals who underwent autopsies at AIIMS Raipur and to analyse its association with demographic and cardiovascular risk factors.

Materials and Method: A cross-sectional study was conducted on 100 autopsy cases between September 2018 - September 2019 considering socio-demographic characteristics, risk factors, and atherosclerotic lesions which were graded according to the American Heart Association (AHA) criteria.

Results: Atherosclerotic lesions were identified in 71% of cases, with a male predominance (73%) in the age group of 51-60 years (63%). Coronary arteries were most frequently affected (11 cases). The lesions showed a significant association with risk factors namely diabetes mellitus (p=0.008), hypercholesterolemia (p=0.010) and hypertension (p=0.001).

Conclusion: This study highlights a high prevalence of atherosclerotic lesions among autopsy cases and emphasizes the importance of recognizing modifiable risk factors.

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INTRODUCTION

Atherosclerosis is a chronic inflammatory disease characterized by the buildup of lipids, cholesterol, and fibrous elements in the arterial walls, leading to the formation of atherosclerotic plaques.[1] This process begins in early childhood and progresses insidiously over decades, often remaining asymptomatic until a significant arterial obstruction occurs.

The disease primarily affects medium and large-sized arteries, with the aorta, coronary, and carotid vessels being the most commonly involved. The Global Burden of Disease study estimates a higher age standardized Cardio Vascular Disease (CVD) death rate in India (272 per 100,000) compared to the global average (235 per 100,000). Risk factors such as age, gender, hypertension, diabetes mellitus, hyperlipidaemia, smoking, and a sedentary lifestyle significantly contribute to the development and progression of atherosclerosis.[2]

Understanding the prevalence and distribution of atherosclerotic lesions in specific populations can shed light on public health challenges associated with cardiovascular diseases. The increasing burden of cardiovascular diseases, particularly in developing countries like India, underscores the critical need for studies that elucidate the prevalence of atherosclerosis.[3]

Autopsy studies provide valuable insights into the disease processes that lead to premature morbidity and mortality.[4] The American Heart Association's Committee

on Grading Lesions of the Council on Arteriosclerosis has devised a method of grading the severity of atherosclerosis in human coronary arteries and aortas which has classified atherosclerotic lesions into 8 grades.[2]

By analysing atherosclerotic lesions in hearts and major blood vessels, this study aims to provide essential data on the prevalence and risk factor associations specific to the local population of Chhattisgarh. The findings could have significant implications for public health strategies, allowing for the development of targeted preventive measures and educational programs aimed at mitigating cardiovascular disease risk.

Hence, the study aims to estimate the prevalence of atherosclerotic lesions in the hearts and major blood vessels of individuals who underwent autopsies at AIIMS Raipur. Additionally, the study determined the association between these lesions and various risk factors.

MATERIALS AND METHOD

A cross-sectional study conducted over one year (September 2018 to September 2019) among 100 cases of both genders and all ages, who were brought to the Institute for medicolegal autopsies. The autopsy examinations took place in the mortuary of the Department of Forensic Medicine and Toxicology, in collaboration with the Department of Pathology. Data were collected from the next of kin or relatives of the deceased, with informed consent obtained prior to participation.

The sample consisted of individuals with varying causes of death, encompassing both natural and unnatural circumstances. Cases with incomplete medical history or insufficient data, decomposed bodies, or gross mutilation, particularly from road traffic accidents, were excluded due to the inability to accurately evaluate atherosclerotic lesions. This study employed a systematic approach to data collection, including obtaining informed consent, gathering detailed clinical history, and conducting comprehensive autopsies.

To identify potential risk factors for atherosclerosis, comprehensive interviews were conducted with the next of kin or relatives of the deceased individuals. A structured questionnaire captured demographic details, medical history, lifestyle factors, and family history of cardiovascular diseases. The heart and major blood vessels were meticulously examined both macroscopically and microscopically, with specimens processed and stained for histological analysis.

This information was meticulously analysed to investigate the association between these factors and the presence and severity of atherosclerotic lesions observed during autopsies. The American Heart Association (AHA) grading system was used to classify atherosclerotic lesions identified during the histological examination.[5] Socio-demographic data and findings from gross and microscopic examinations were recorded in a case proforma and presented in tabular format. Descriptive statistics, including percentages, means, proportions, and ratios, were used to explain the results. Inferential statistics, such as chi-square tests, were applied, with statistical significance set at $p < 0.05$.

RESULTS

Demographic Characteristics of Study Population

A total of 100 autopsy cases were included in this study, comprising 73 males and 27 females. The age of participants ranged from 11 to 80 years, with a mean age of 40 years and most of the cases were in the fourth decade followed by the third decade. **(Table 1)**

Cause of Death

The analysis of the cause of death reveals a predominance of males, particularly in cases related to head injury (84%), myocardial infarction and coronary artery disease (88%), and shock due to road traffic accidents (87%), indicating a significant gender disparity. Poisoning, however, was evenly distributed between males and females (50% each). Natural causes, excluding cardiovascular diseases, showed a slight male majority (56%). **(Table 1)**

Risk Factors

Cardiovascular risk factors such as diabetes mellitus and hypertension were present in both males and females equally (15 individuals each), but hypercholesterolemia was primarily seen in males (83%). Lifestyle risk factors such as smoking/tobacco intake and alcohol consumption were overwhelmingly prevalent in males (95% and 98%, respectively). A sedentary lifestyle and mixed diet were also more common among males.

Past History

Notably, only 3% of patients had a previous history of cardiovascular disease, all of whom were male. Family history of cardiovascular disease and deaths within the family due to cardiovascular conditions were equally distributed between genders (2 each). Regarding treatment, more males sought treatment than females (13 vs. 9), though adherence to regular treatment was low overall, with only 3 patients maintaining regularity.

Table 1: Distribution of Age and Cause of Death Among the Study Population

Variable	Male	Female	Total
11-20	6	6	12
21-30	13	6	19
31-40	17	4	21
41-50	16	2	18
51-60	14	5	19
61-70	6	4	10
71-80	1	0	1
Total	73	27	100
Cause of Death			
Head Injury	16 (84%)	3 (16%)	19
Poisoning	9 (50%)	9 (50%)	18
Natural Causes (Excluding CVD)	10 (56%)	8 (44%)	18
MI & CAD	14 (88%)	2 (12%)	16
Shock due to RTA	13 (87%)	2 (13%)	15
Asphyxia	6 (86%)	1 (14%)	7
Electrocution	2 (100%)	0	2
Snake Bite	1 (50%)	1 (50%)	2
Others	2 (67%)	1 (33%)	3

Age & Sex Distribution of Atherosclerotic Lesions

The prevalence of atherosclerotic lesions increased with age, with higher percentages observed in individuals aged 51-60 years (35%) and 61-70 years (18%). Among the younger age groups (11-30 years), atherosclerotic lesions were relatively rare, affecting only 4-6% of individuals. In contrast, from 41 years onward, there was a sharp rise in prevalence, peaking at 35% in the 51-60 years age group. Males consistently outnumbered females in terms of lesion prevalence.

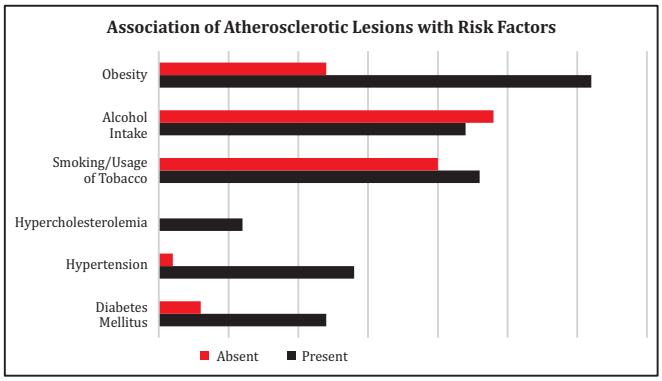
Case Distribution with Atherosclerotic Lesions at a Single Site

Among cases with atherosclerosis affecting only one arterial site, the coronary arteries were the most involved, particularly in males. In the 31-40 age group, 33% of cases had atherosclerosis in the coronary arteries. This pattern was also observed in older age groups, with a gradual increase in prevalence of lesions in the arch of the aorta and common carotid arteries. **(Figure 2 & Figure 3)**

Case Distribution with Atherosclerotic Lesions at Multiple Sites

Atherosclerosis involving multiple arterial sites was seen predominantly in older individuals, especially those aged 51-60 years. In this group, 45% had lesions affecting two or more arteries, with some cases showing involvement of all four major arteries. The most frequent combination of affected arteries was observed in the 51-60 and 61-70 age groups, reflecting the progressive nature of atherosclerosis with age.

Figure 1: Association of Atherosclerotic Lesions with Risk Factors



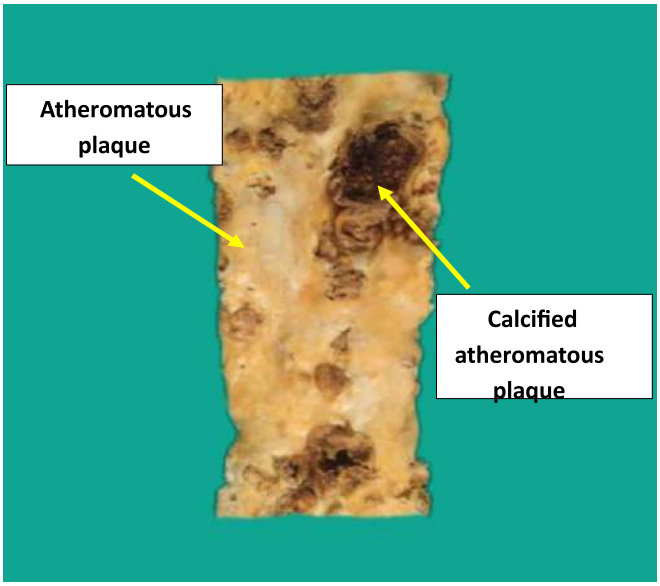
Site of Distribution of Atherosclerotic Lesions

Out of 100 cases, 51 showed no arterial involvement, while 49 cases had varying degrees of atherosclerotic involvement. Notably, 14 cases had atherosclerosis affecting only one artery, while 6 cases exhibited lesions in up to seven arteries, indicating widespread vascular involvement in some individuals.

Atherosclerotic lesions were most frequently observed in the coronary arteries, particularly the left circumflex (LCX) and left anterior descending (LAD) arteries. Among the older age groups, the arch of the aorta and bifurcation of the abdominal aorta were also common sites of atherosclerosis. The most extensive involvement was

Figure 2: Left Common Carotid Artery with Atheromatous Plaque (Gross)

Figure 3: Arch of Aorta with Areas of Atheromatous Plaque and Calcified (Gross)



noted in individuals aged 51-60 years, accounting for 43% of all lesions. **(Figure 4)**

Distribution of Atherosclerotic Lesions by Age and Artery

The study analyzed the presence of atherosclerotic lesions in different arteries, including coronary arteries (LCX, LAD, RCA), common carotid arteries, the arch of the aorta, and the bifurcation of the abdominal aorta. The most common age group affected by atherosclerosis was 51-60 years, with 43% of total cases showing lesions, followed by the 61-70 age group (23%). This indicates that atherosclerosis prevalence increases significantly with age. Among the specific arteries, lesions were more frequently observed in coronary arteries, particularly in the Left Anterior Descending (LAD) artery, which had a higher prevalence across age groups, especially from 51-70 years. **(Figure 4)**

Pattern of Involvement in Coronary Arteries

Triple vessel disease was the most common pattern observed, affecting 15 males and 3 females, predominantly in the 51-60 age group. This suggests a high prevalence of multi-vessel atherosclerosis in older adults. Single and double vessel involvement were less common but still observed, primarily in individuals over the age of 40.

AHA Grading of Atherosclerotic Lesions

The AHA grading system demonstrated that atherosclerosis severity increased with age. Most lesions classified as AHA VI (complicated plaques) were found in individuals aged 51-60 years (43%). Younger age groups, particularly those below 40 years, mainly exhibited earlier-stage lesions (AHA I and II), indicating that atherosclerosis tends to progress with advancing age.

Significant Atheromatous Lesions

Significant atheromatous lesions were predominantly found in older age groups, with the highest prevalence (40%) in the 51-60 years age group. Males were more frequently affected, comprising 79% of the cases. The prevalence of significant lesions declined slightly in the 61-70 and 71-80-years age groups but remained substantial. Calcification, a marker of advanced atherosclerosis, was observed in 57% of cases, with the highest prevalence in individuals aged 61-70 years (37%). Males showed a higher tendency for calcification compared to females,

Figure 4: Left Anterior Descending Coronary Artery with Calcified Atheromatous Plaque (Gross)

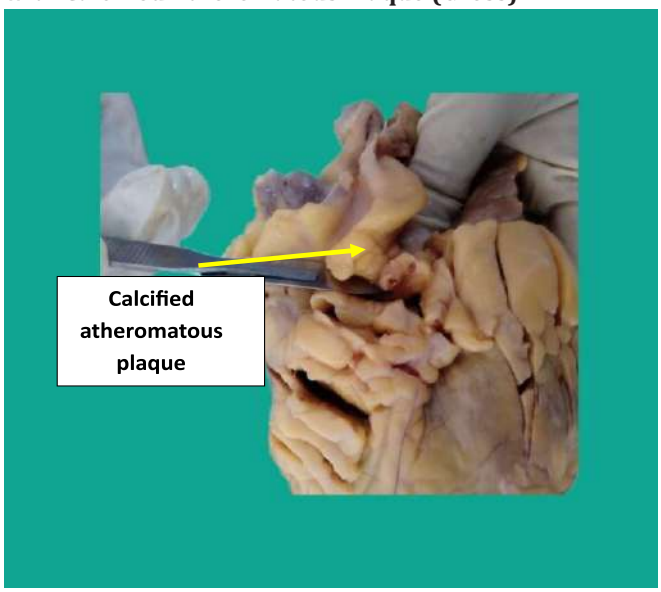


Table 2: Association between Atherosclerotic Lesions and Risk Factors

Risk Factors		Total No. of Cases	Cases with Atherosclerotic Lesions	
			n	p-value
Diabetes Mellitus	Yes	15	12	0.008*
	No	80	33	
	Not known	5	4	
	Total	100	49	
Hypertension	Yes	15	14	0.000*
	No	80	31	
	Not known	5	4	
	Total	100	49	
Hypercholesterolemia	Yes	6	6	0.010*
	No	89	39	
	Not known	5	4	
	Total	100	49	
Smoking/Usage of Tobacco	Yes	43	23	0.028*
	No	52	21	
	Not known	5	5	
	Total	100	49	
Alcohol Intake	Yes	46	22	0.062
	No	49	22	
	Not known	5	5	
	Total	100	49	
Diet	Vegetarian	15	8	0.715
	Mixed	85	41	
	Total	100	49	
Physical Activity	Sedentary	65	31	0.721
	Moderate	35	18	
	Total	100	49	
Obesity	Yes	43	31	0.000*
	No	57	18	
	Total	100	49	

particularly in the 51-60 and 61-70-years age groups. Of the cases with atherosclerosis, 47% showed secondary changes, primarily calcification. There were no cases of haemorrhage or thrombosis associated with the lesions.

AHA Grading of Atherosclerotic Lesions According to Site

The distribution of atherosclerotic lesions across various coronary and major arteries revealed a significant burden of advanced disease. The Left Circumflex, Left Anterior Descending, and Right Coronary arteries exhibited a high prevalence of severe (Grade VII) lesions, indicating substantial atherosclerosis in these crucial vessels. **(Figure 5)** The Arch of Aorta and Abdominal Aorta also showed marked atherosclerotic involvement, particularly with Grade VII lesions. **(Figure 6 & Figure 7)** While the Common Carotid arteries **(Figure 8)** displayed a moderate degree of atherosclerosis, with a mix of less severe and advanced lesions, the overall picture highlights the widespread nature of the disease across multiple vascular sites, emphasizing the importance of early detection and intervention.

AHA Grading of Atherosclerotic Lesions According to Age & Sex

The study revealed a clear age-related progression of atherosclerosis, with the most severe lesions (Grade VII) predominantly found in individuals aged 50 years and older. Notably, males exhibited a higher prevalence of atherosclerosis across all age groups, suggesting a greater susceptibility to this condition. The findings underscore the importance of early identification and intervention to mitigate the risks associated with advanced atherosclerosis.

Atherosclerotic Lesions and Risk Factors

A strong association between atherosclerosis and

Figure 5: Photomicrograph of Left Anterior Descending Artery Showing a Well-Defined Core with the Luminal Surface Covered by Normal Intima, AHA Grade IV (H&E, 10x)

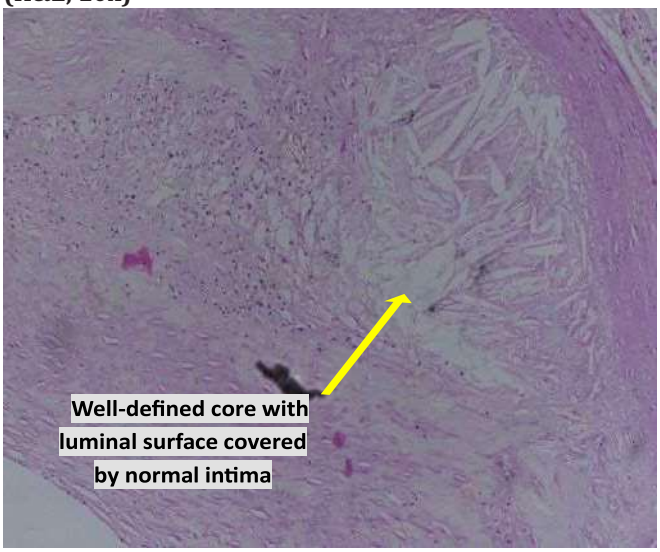


Figure 6: Photomicrograph of the Arch of Aorta Showing a Lipid Core with a Fibrous Cap, AHA Grade V (H&E, 4x)

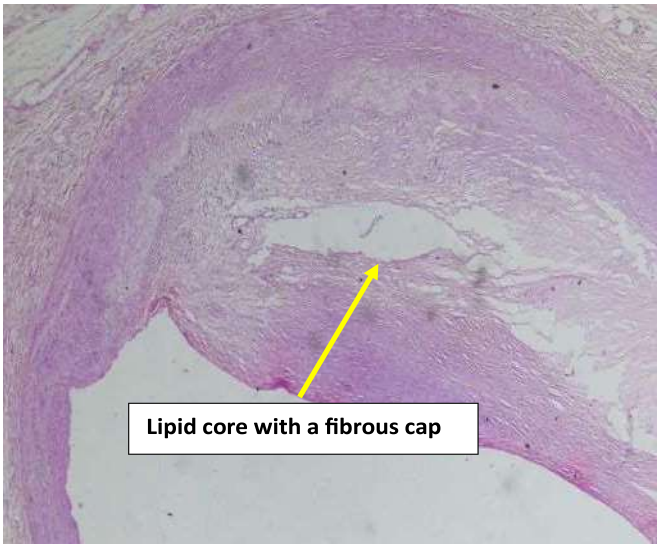


Figure 7: Photomicrograph of Abdominal Aorta Showing Prominent Calcification Along with Atherosclerotic Changes, AHA Grade VII (H&E, 2x)

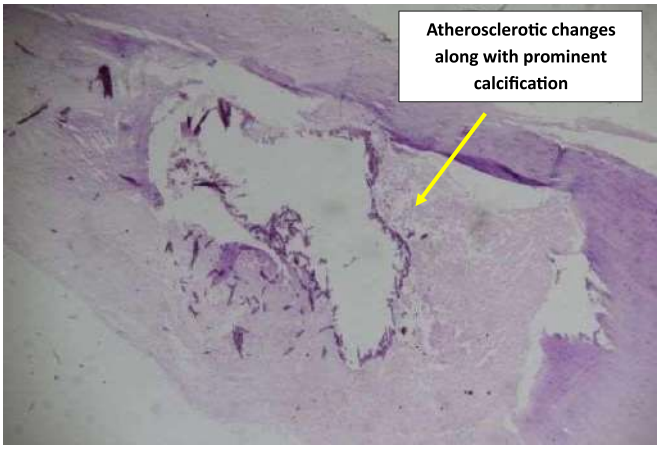
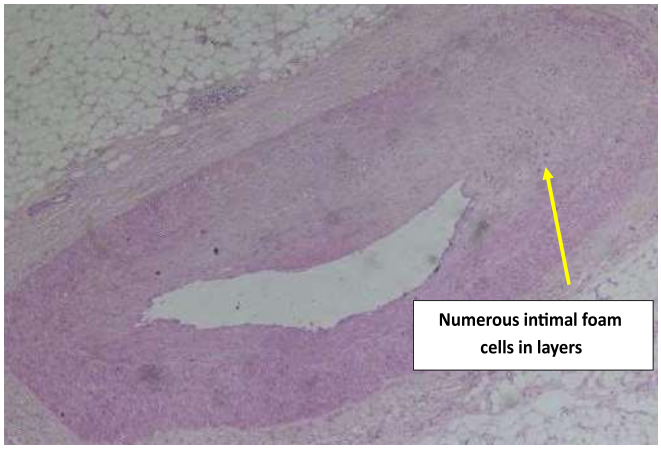


Figure 8: Photomicrograph of Right Common Carotid Artery Showing Numerous Intimal Foam Cells in Layers as Fatty Streaks, AHA Grade II (H&E, 4x)



traditional cardiovascular risk factors was observed. **(Table 2)** Diabetes mellitus (p=0.008), hypertension (p=0.00), hypercholesterolemia (p=0.010), and smoking/tobacco use (p=0.028) were significantly associated with the presence of atherosclerotic lesions. Alcohol intake and dietary habits did not show statistically significant associations, although mixed diet and sedentary lifestyle were prevalent among affected individuals. Obesity emerged as a significant risk factor (p=0.000), particularly in males. **(Figure 1)**

Cardiovascular Risk Factors Associated with Atherosclerosis

The study found significant associations between cardiovascular deaths and risk factors like diabetes, hypertension, hypercholesterolemia, and obesity. The prevalence of these risk factors was notably higher among those who died due to cardiovascular diseases compared to those who died of other causes ($p < 0.05$). Males were more likely to be affected by cardiovascular conditions, constituting 88% of deaths due to cardiovascular disease.

Comparison Between Gross and Microscopic Examination

There were notable discrepancies between gross and microscopic findings. For instance, microscopic examination revealed a higher incidence of lesions in the arch of the aorta (26%) compared to gross findings (11%), with a statistically significant p-value ($p = 0.006$). This indicates that microscopic examination is more sensitive in detecting atherosclerotic changes, especially in vessels like the common carotid arteries and abdominal aorta, where gross examination may underestimate the extent of disease.

Site-Specific Analysis

The most affected site was the bifurcation of the abdominal aorta, indicating that regions of turbulent blood flow or bifurcation points are more susceptible to atherosclerosis. Lesions were also frequently observed in the Left Circumflex Artery (LCX), Left Anterior Descending (LAD), and Right Coronary Artery (RCA), aligning with findings from other autopsy studies showing the coronary arteries are major sites of atherosclerotic burden.

Cardiovascular Risk Factors in Deaths Due to Cardiovascular Diseases

Deaths attributed to cardiovascular diseases were significantly associated with diabetes (p=0.001), hypertension (p=0.001), and obesity (p=0.046). Most of the deceased were male (88%), and many had a history of smoking, a sedentary lifestyle, and a non-vegetarian diet, indicating the role of these factors in fatal cardiovascular events.

Gross and Microscopic Examination of Atherosclerotic Lesions

Gross examination revealed significant atherosclerotic involvement in major arteries, particularly in the left circumflex artery (LCX) and left anterior descending artery (LAD). Histopathological examination (HPE) further confirmed these findings, showing a higher prevalence of lesions in the right common carotid artery (RCCA), left common carotid artery (LCCA), and bifurcation of the abdominal aorta (ABD A). Statistically significant differences between gross and microscopic findings were observed in the aorta (p=0.006), RCCA (p=0.011), LCCA (p=0.031), and ABD A (p=0.016).

DISCUSSION

Atherosclerosis has become an alarming health concern in India, contributing significantly to both morbidity and mortality rates.[6] This chronic inflammatory condition affects multiple arteries, with its distribution varying based on the anatomy and shear stress at specific sites. Arteries at branch points or where vessel diameters change are especially prone to atherosclerotic lesions. The aorta is often the first to be affected, with lesions appearing as early as the first decade of life.[7] Over time, atherosclerosis spreads to the coronary and carotid arteries, with coronary artery involvement typically beginning in the second or third decade of life.[8]

Although atherosclerotic changes start early, their clinical complications emerge much later. Once these lesions begin forming, the progression of atherosclerosis cannot be reversed, though it can be slowed with appropriate interventions. The multifactorial nature of atherosclerosis means that numerous factors, including lifestyle, genetics, and environmental exposures, contribute to the development and progression of this disease.[8-9]

Cardiovascular diseases, particularly ischemic heart disease, are among the most serious outcomes of advanced atherosclerosis. India has seen a significant rise in cases of ischemic heart disease, making it a major public health concern. The disease tends to progress more rapidly in India, with earlier onset and higher fatality rates than in many other countries.[10]

One of the primary challenges in studying the development of atherosclerosis is the lack of reliable methods for observing the disease in living individuals. As a result, autopsy-based studies remain the most accurate means of understanding the pathology and progression of atherosclerosis. In the current study, both gross and microscopic examinations were performed, following similar methodologies as in studies by Modelli MES et al.,[11] Saldana JR et al.,[12] and Singh P et al.[13] This approach ensured a detailed analysis of the atherosclerotic lesions in the coronary arteries, carotids, and aorta.

The study sample consisted of 73 male and 27 female cadavers, reflecting the higher involvement of males in medicolegal autopsies, a pattern observed in similar studies by Babu M et al.[14] and Dhruva GA et al.[15] The sex distribution in this study aligns with both national and international findings, with a male predominance likely due to increased exposure to risk factors such as smoking, physical inactivity, and dietary habits among men. Age-wise, the cases ranged from 11 to 80 years, like other studies conducted in India and abroad.[13,16]

The study revealed that the left anterior descending (LAD) artery had the highest incidence of atherosclerotic lesions, in line with findings from both Indian and international studies.[16] The LAD is particularly vulnerable due to its role as the primary blood supplier to a significant portion of the heart and the hemodynamic stress it experiences. Among the cases studied, 37% showed involvement of all three coronary arteries, a finding consistent with other research. Triple vessel involvement was common in studies by Dhruva GA et al.,[15] Beelwal D et al.,[17-18] and Agravat AH et al.,[19] further emphasizing the widespread and severe nature of coronary atherosclerosis. In a study by Sharma M et al, in 21% of cases no vessel was involved while 29%

cases showed involvement of a single coronary vessel and 24% showed double vessel involvement.[20] In another study by Suri AK et al., single, double and triple vessels coronary involvement was noted in 51%, 49% and 49% respectively.[21]

Histopathological grading of atherosclerotic lesions, based on the American Heart Association (AHA) classification, showed that AHA grade VII was the most prevalent across all three coronary arteries in this study. However, other studies have reported different grades as the most common. For example, Dhruva GA et al.[15] found AHA grade IV to be the most frequent, while Garg M et al.[16] and Sharma P et al.[22] reported AHA grades III and V as the most common. Another study by Suri AK et al. AHA grade I to III was more common in Right Coronary artery while AHA grades IV to VI were more common in both Left Coronary and Left Anterior Descending arteries.[21] AHA grades I and II were common in Right Coronary artery while grades III to VI were common in Left Circumflex artery in a study by D'Souza H et al.[23]

In the carotid arteries, AHA grade II was the most frequent lesion, consistent with findings from Saldana RJ et al.[12] In the abdominal aorta, AHA grade VII was the most common, a result that aligns with earlier studies. The bifurcation of the abdominal aorta was the site most affected by atherosclerosis, a finding that mirrors those of Babu M et al.[14] and Kalyani R et al.[24]

Overall, significant atherosclerotic lesions were observed in 59% of the cases in this study, while calcified lesions were found in 33%. These results are like those of Dhruva GA et al.,[15] who reported a prevalence of significant atheromas in 69% of cases. However, some studies, such as those by Agale SV et al.,[25] noted a lower prevalence of calcified lesions.

Among the cases of sudden cardiac death, a significant association was found between coronary artery disease (CAD) and risk factors such as diabetes, hypertension, and obesity. This association has been noted in other studies as well, including those by Arzamendi D et al.[26] and Venkatesh K et al.,[27] reinforcing the need for effective management of these risk factors to reduce the burden of atherosclerosis.

The accuracy of histopathological examination in detecting atherosclerotic lesions was highlighted in the current study, where microscopic analysis revealed a higher incidence of lesions than gross examination. This underscores the importance of detailed histological assessment in understanding the extent of atherosclerosis.

Strengths: This autopsy-based study offers several strengths, including direct observation of atherosclerotic lesions, comprehensive histopathological analysis, and a focus on a specific population. By examining atherosclerotic lesions across multiple arterial sites, the study provides insights into the systemic nature of the disease and its associations with various cardiovascular risk factors. These findings contribute to a deeper understanding of atherosclerosis and inform the development of targeted preventive measures and health policies.

Limitations: The small sample size and single-centre design may limit the generalizability of findings. The cross-sectional nature restricts the ability to infer causality or disease progression. Reliance on autopsy data may introduce bias, and the absence of comprehensive risk factor data limits understanding of the factors influencing atherosclerotic lesions.

Conclusion: This study emphasizes the significant burden of atherosclerosis in India, with high prevalence rates, early onset, and triple vessel involvement being common findings. It also highlights the critical role of risk factors such as diabetes, hypertension, and obesity in the progression of the disease. Given the limitations of current diagnostic methods in living populations, autopsy-based studies remain essential for understanding the pathology of atherosclerosis and guiding preventive strategies. Future research should aim to further explore specific demographic variations and longitudinal studies to assess the progression of atherosclerotic disease and the effectiveness of implemented preventive strategies in the community.

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Original Research Paper

Pubertal Onset in Girls from Urban and Rural Settings of North-West Punjab: A Medicolegal Perspective

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ABSTRACT

Introduction: The process of female puberty is a unique process with sequential development of secondary sexual characteristics. This study aimed to examine the medicolegal importance of the onset of puberty in girls of urban and rural regions.

Materials and Method: It was a cross-sectional questionnaire-based study done in 7 to 15-year-old school girls (n= 200; 100 urban, 100 rural) over 18 months in the north-west region of Punjab. Secondary sexual characteristics were evaluated according to Marshal and Tanner's (1962) recommendations for pre-defined age groups (7-9 years, 9 -11 years, 11-13 years, and 13-15 years, with each group consisting of 25 girls).

Results: The mean age of Tanner stage 1 of breast development among urban and rural girls was 8.16 years and 7.67 years, respectively (P value 0.002). The mean age of Tanner stage 3 among urban and rural girls was 11.34 years and 12.93 years, respectively (P value <0.001). There was no statistically significant difference between stages 2 and 4. For pubic hair growth, statistical significance was noticed in Tanner stage 2 only (P value <0.001, mean age of onset among urban and rural girls being 11.82 years and 12.96 years, respectively). Similarly, the mean age of stage 2 of axillary hair growth was statistically meaningful (P value 0.006) (urban girls- 14.11 years and rural girls -13.66 years). The mean age of menarche in urban girls (among 42 girls of 100) was 12.79 years, and the mean age of menarche in rural girls (among 19 girls of 100) was 12 years (significant p value of <0.001).

Conclusion: The onset of puberty and development of secondary sexual characteristics can help in assessing age of the child which has an important medico-legal importance.

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INTRODUCTION

A female child gets transformed into an adult woman by a complicated process. In the majority of adolescent girls, growth acceleration is the first sign of puberty, which is followed by the formation of breast buds known as thelarche. Pubic hair emergence i.e., pubarche, is the next phenomenon before the final step of the start of menstruation (menarche). The entire process can be completed over a span of 1.5 to 6 years with an average of 4.5 years.[1]

The formation of the hypothalamic–pituitary portal venous system before birth by 19–20 weeks of gestation is accompanied by germ cell and follicular development; the latter being stimulated by a rise in the gonadotropins and ovarian sex steroids.[2] This hypothalamic activity is usually suppressed till puberty, and this 'juvenile pause' is seen in

all the higher primates including apes and humans.[3] Stimulation by GH, oestrogen, and adrenal steroids helps in achieving about 50% of peak bone mass by the age of 17–19, apart from gaining height and growth.[4] In girls, the peak velocity in bone mineral accretion happens about 9–12 months after peak height velocity is reached, usually around the time of menarche.[5]

Marshall and Tanner in 1969 developed a staging system, which is most commonly used to look for the visible changes of puberty in the form of sequential development of secondary sex charact-eristics.[6] Normal monthly menstrual cycle starts after the maturation of the HPO axis in the later stages of puberty.[7] It has been seen that genetic factors play a pivotal role in causing around half of the phenotypic variance in the onset of puberty and menarche in females in developed nations.[8]

The estimation of the age of an individual plays an essential role in the Medico-legal field. It is particularly important in cases involving validity or nullity of marriage, kidnapping, rape, questions of criminal responsibility, judicial punishment and eligibility for employment. Accurate age determination helps in appropriately categorizing individuals as minors or adults, for further application of specific legal provisions. The onset of puberty and development of secondary sexual characteristics can also help assess the age of the child for this purpose.[9]

In cases where documentation or birth records are unavailable, these features, after a careful assessment, can serve as a significant physiological indicator and provide supplementary evidence in age estimation. Along with other usual methods of ascertaining age like examination of ossification of bones and teeth, determination of age from secondary sexual characteristics (puberty) in addition will provide a more accurate estimation of age and hence will be helpful for the investigating and law enforcement agencies in applying the relevant sections of law to meet the ends of justice.

AIMS AND OBJECTIVES

1) The study aimed to estimate the Age of onset of puberty in female subjects.
2) The primary objective was to assess age-specific differences in the onset of puberty in all subjects.
3) The secondary objective was to assess and evaluate the difference in the onset of puberty in girls of the urban and rural regions of northwestern Punjab, India.

MATERIALS AND METHOD

It was a cross-sectional study that was conducted in school girls aged 7 to 15 years old over a period of 18 months in the north-west region of Punjab. The study protocol was approved by the thesis and ethics committee of the regional health university and the District Education Officer for visiting Primary and Elementary schools for the study. 4 schools were enrolled in the study (2 in urban areas and 2 in rural areas).

Informed consent in writing was obtained from participants and their parents on a proforma. Those unwilling for the study were excluded. Also, girls having any history of chronic disorder or on medication that might affect growth and puberty were subject to exclusion. The definition of healthy status was based on history, health records available with the school authorities, and physical examination. A total of 200 girls were included in the study, 100 from urban and rural regions each. Consenting participants were divided into four age groups seven to nine, nine to eleven, eleven to thirteen, and thirteen to fifteen; each age group containing 25 subjects.

A questionnaire consisting of demographic details, height-weight record, secondary sexual characteristics, status of menarche, and its onset was filled out for each participant as per proforma. The calculation of Body mass index (BMI) was done by dividing the weight in kilograms by the square of the height in meters. The age of the participants was measured by reducing their date of birth from the day of data collection and was mentioned in years and months. Marshal and Tanner's (1962) recommendation was used to assess the secondary sexual characteristics, including breast development (B1-5) and pubic hair (P1-5).

The Statistical analysis Data thus collected were reported as mean ± SD and 95% CI for variables. To assess the onset of menarche, the status quo technique was utilized, which is based on the proportion of girls who achieved menarche at each age. Data on Puberty was registered as stage transitions, indicating whether or not a certain stage had been attained. To determine the probability of breast (B1-5), pubic hair (P1-5) stages, and menarche, logistic regression was utilized. Microsoft Office Excel 2007 was used to plot these probabilities against age, height, weight and BMI.

These curves showed the probability of girls with a specific age, height, weight, and BMI reaching menarche or stages of breast development. P-values were considered statistically significant if it were calculated to be less than

0.05.

RESULTS

The present study was undertaken by the Department of Forensic Medicine and Toxicology at a tertiary care centre in North India over a period of 18 months. A sample of 200 girls (100 from the Government Urban and another 100 girls from the Rural School) were studied. Each group of 100 girls was divided into four age groups: 7-9 years (25 girls), 9 -11 years (25 girls), 11-13 years (25 girls), and 13-15 years (25 girls), from both urban and rural regions, respectively. After taking consent from the subjects and their mothers, a question-based proforma was given to the girls. The observations of the study have been depicted in the following figures and tables.

In the urban girls' group, no girl had the onset of menstruation or menarche in the age group 7-9 years or 9 to 11 years. Whereas, in the age group 11 -13 years, 17 (68%) girls out of 25 had history of menarche, while among 8 (32%) girls, no such history was present. In the age group 13 to 15 years, all 25 (100%) subjects had

Figure 1: Frequency and Distribution of Cases in Each Stage of Breast Development in Urban Girls.

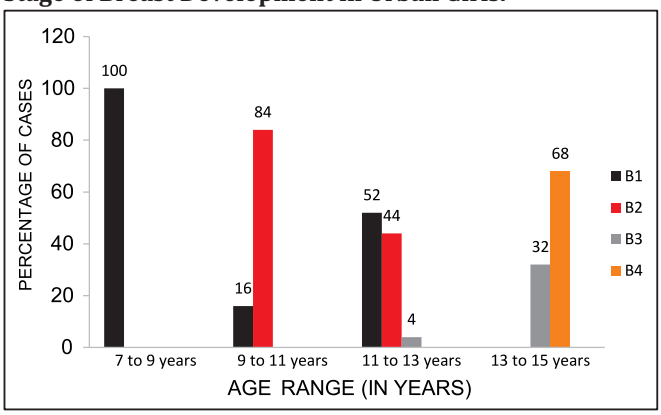

Figure 2: Frequency and Distribution of Cases in Each Stage of Breast Development in Rural Girls.

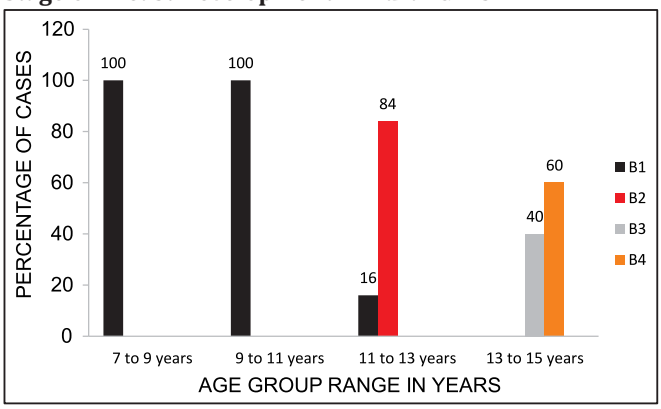

Figure 3: Frequency and Distribution of Subjects in Each Stage of Pubic Hair Growth in Urban Girls.

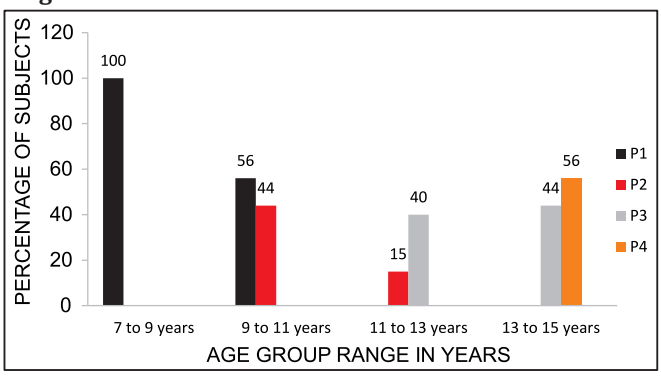

Figure 4: Frequency and Distribution of Subjects in Each Stage of Pubic Hair Growth of Rural Girls.

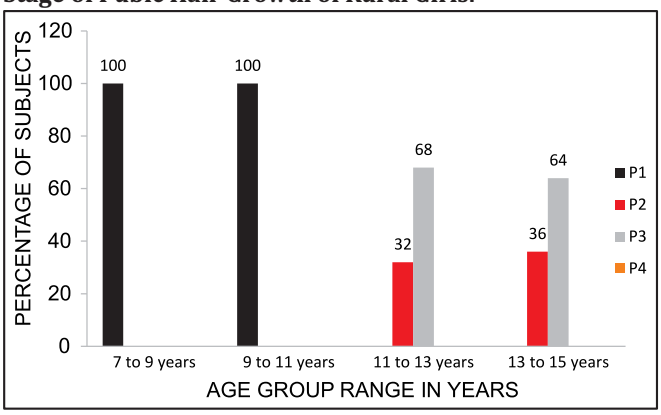

Figure 5: Frequency and Distribution of Subjects in Each Stage of Axillary Hair Growth in Urban Girls.

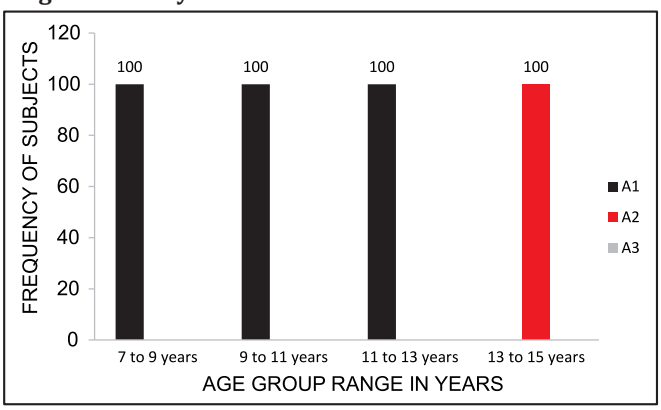

Figure 6: Frequency and Distribution of Subjects in Each Stage of Axillary Hair Growth in Rural Girls.

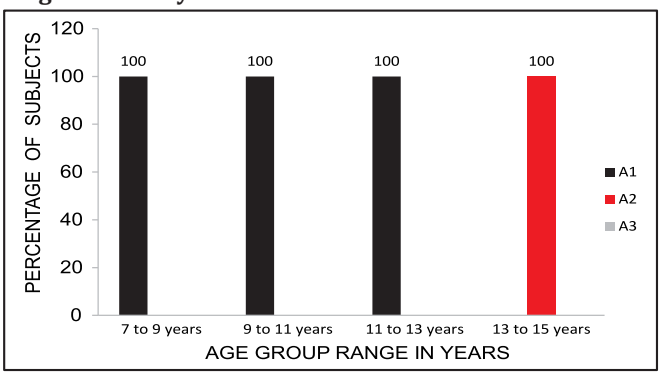

Table 1: Mean Age of Appearance of Different Secondary Sexual Characters (in Urban and Rural Girls)

Secondary Sexual Characteristics	Staging	Age in Mean (Years)		SE of Difference	P value
		Rural	Urban		
Breast	1	7.67 ± 0.42	8.16 ± 0.60	0.147	0.002*
	2	10.46 ± 0.92	10.00 ± 0.65	0.477	0.337NS
	3	12.93 ± 0.75	11.34 ± 1.14	0.242	<0.001**
	4	13.51 ± 0.53	13.19 ± 0.76	0.230	0.171NS
Axillary Hair	1	10.09 ± 2.01	10.42 ± 1.92	0.321	0.307NS
	2	13.66 ± 0.50	14.11 ± 0.58	0.154	0.006*
Pubic Hair	1	9.40 ± 1.75	8.99 ± 1.27	0.323	0.207NS
	2	12.96 ± 0.77	11.82 ± 1.06	0.260	<0.001**
	3	13.50 ± 0.55	13.39 ± 0.72	0.213	0.619NS
	4	-	14.26 ± 0.60	-	-
Menstrual History	0	10.36 ± 2.16	9.78 ± 1.71	0.341	0.091NS
	1	13.64 ± 0.57	13.50 ± 0.91	0.226	0.541NS
Age of Menarche		12 ± 0.33	12.79 ± 0.64	0.341	<0.001**

* *Statistically Significant* ** *Highly Significant* *NS- Not significant*

history of menarche.

In the rural group, no girl had the onset of menstruation or menarche in the age groups 7-9 years, 9 to 11 years, and 11-13 years. Whereas, in the age group 13 -15 years, 19(76%) out of 25 girls had history of menarche, while among 6(24%), no such history was present.

The minimum age at which history of menstrual cycle was present was 11.67 years among urban girls and 13.11 years among rural girls. The maximum age at which the history of start of first cycle of menstruation was 15.36 years among urban girls and 14.67 years among rural girls.

The mean BMI (Body Mass Index) was obtained as 14.67 kg/m2 in urban girls and 13.62 kg/m2 in rural girls for the age group 7 to 9 years. The mean BMI (Body Mass Index) was 18.71 kg/m2 in urban girls and 17.09 kg/m2 in rural girls in the age group 9 to 11 years. In the age group 11 to13 years, mean BMI (Body Mass Index) was 18.03 kg/m2 in urban girls and 16.19 kg/m2 in rural girls. In age group 13 to 15 years mean BMI (Body Mass Index) was 21.42 kg/m2 in urban girls and 17.32 kg/m2 in rural girls. This shows that body mass index of urban girls was more that of rural girls in all age groups.

DISCUSSION

Available literature and research have traditionally emphasized more on females than males as far as human sexual maturity is concerned. This focus is understandable as occurrence of menarche as a distinct event has sudden and more significant social implications. It is in contrast with the pubertal changes happening in males, which are more gradual. Adolescence, as defined by the World Health Organization (WHO), is the period from 10 to 19 years of age, during which transition from childhood to adulthood takes place in the form of the development of secondary sexual characteristics with further progression to a sexually and reproductively mature individual.[10]

The pattern of transition from childhood to womanhood follows a structured sequence that is influenced by a wide array of external and internal factors. The first secondary sexual milestone to develop is Thelarche, i.e., the development of the breast. In the current study, the mean age of Tanner stage 1, 2, 3 and 4 of breast development among urban girls is 8.16 ± 0.60 years, 10.00 ± 0.65 years, 11.34 ± 1.14 years, 13.19 ± 0.76 years and among rural girls 7.67 ± 0.42 years, 10.46 ± 0.92 years, 12.93 ± 0.75 years, 13.51 ± 0.53 years, respectively. Tanner stage 2 of breast development represents the onset of puberty.

The age of all the stages of development of breast in our study is less among urban girls and the same comparable result are there for the rural subjects as well; quiet lower than the results from the study conducted in year 1969 by Marshal and Tanner et-al in United Kingdom in which reported age of breast development were 11.5, 12.5, 13.1 and 15.3 years for stages B2, B3, B4, B5 respectively.[11] The present study is also comparable to the study conducted in 2009 by Sahoo et al, where the mean age of breast development for urban girls was 10.36 and for rural girls was 10.86 years in Dharwad, Karnataka, and 10.22 and 10.61 years, respectively in Khurda, Orissa.[12]

Regarding the next noteworthy development of pubic hair, the study conducted in year 1996 by Malleswari et al in

Tirupati, Andhra Pradesh found that the urban girls attained pubic hair stages P2 to P5 at mean ages of 11.60, 14.09, 14.61, and 16.45 years, respectively, while rural girls reached these stages at 11.64, 13.36, 14.90, and 16.38 years which is comparable to present study.[13]

In the present study, the age of axillary hair growth is less compared to the study conducted in the year 1996 by Malleswari et al, where growth of axillary hair occurred for the urban group at the mean age of 14.89 years and for the rural group at 14.40 years. However, another study conducted in the year 2009 by Sahoo et al found the mean age of growth of axillary hair for urban and rural areas to be 12.25 and 12.9 years, respectively,[12] which was in fact lesser as compared to our study. These differences in the age of axillary hair growth could be attributed to different geographical, temperate climate, and dietary habits.

In our study, the mean age of menarche among urban girls and rural girls is 12.79 ± 0.64 years and 12 ± 0.33 years, respectively; which is comparably lesser than the results obtained in the esteemed study conducted by Marshall and Tanner (1969), where they have categorically mentioned the age of menarche as 13.47 years.[11] In the present study the age of menarche is also similar to other studies like Rokade et al[14] (12.62 years), Semiz S. et al[15] (12.41 years), Sahoo et al[12] (12.14 and 13.1 years respectively for urban and rural regions of Dharwad and 12.5 and 12.43 respectively for urban and rural regions of Khurda), Tabassum et al[16] (12.37 years for rural girls and 12.51 years for urban girls).

The study conducted by Al Agha et al had an age of menarche 11.5 years, which is less than that of the present study.[17] Singh D et al[18] studied 312 Punjabi adolescent school girls from the middle socioeconomic group and found that menarche was present in 100% females by 13 years. A study conducted by Kaur et al[19] among girls of Patiala, Punjab which also has regional similarity with the present study, reported age of menarche as 13 years, similarly another study conducted by Prakash et al[20] had age of menarche 13.18 years in girls of plain region and 14.21 years in hilly area girls which is numerically more that of our study. These differences could be attributed to different demographics, ethnicity, and diet.

The pattern of physical growth which is important parameter of sexual maturation is same in the present study with the study of Talwar et al[21] but the physical growth (body mass index) in the present study is more than the study done by Talwar et al on account of healthy dietary habits in this region of Punjab which is known as the food bowl of India.

In Forensic medicine, different methods have been developed and employed for age estimation of adolescents and young individuals, such as tooth development, anthropometry, ossification of bones, and skeletal maturation, either alone or in combination.[22] However, age estimation by the secondary sexual characteristics occurring during puberty in adolescent girls is less well studied, especially in the study region. This comparative analysis among the rural and urban girls will give new insights and direction to conduct randomized controlled studies in the future pertaining to medico-legal age estimation.

Limitations: of this study, which the authors would like to point out, is single-centre and regional study; we wish to collaborate with more centres to pursue more significant data for age estimation. More studies on a bigger multicentric scale involving different regions can help in providing generalizability to the data in a real-world scenario. Secondly, information bias cannot be excluded fully, as data regarding secondary sexual characteristics and menarche were obtained from questionnaires. Thirdly, this study does not differentiate by the socio-economic status of the subjects, and this aspect also needs to be included in future studies.

CONCLUSION

The pattern of sexual development in girls of either urban or rural origin is influenced by various external and internal factors. The onset of puberty and development of secondary sexual characteristics could help assess the age of the child, which has an important medico-legal importance. This study underscores the importance of creating more awareness among Forensic Medicine specialists in assessing the puberty changes in correlation with various socio-demographic determinants and medico-legal aspects.

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Original Research Paper

Epidemiology and Pattern of Homicidal Head Injuries – A Trauma Centre and Mortuary based study

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ABSTRACT

Introduction: Homicidal head injury being one of the commonreason of Medico legal deaths, Thus,it is worth to observe the different types of head injuries and skull fractures in varied cases of assault and to analyze the specific causes of these fractures in instances of homicidal deaths.

Aims: To determine the fatality rate, pattern of skull fracture, nature ofincidence, type of force and epidemiological profile ofvictims ofhomicidalheadinjuryin prayagrajregion.

Materials and Method: This study comprised of 150 assault cases presenting to the Trauma center and Mortuary of S.R.N. Hospital associated with Moti Lal Nehru Medical College, Prayagraj for a period of 1 year, from 01/04/2023 to 31/03/2024.

Results: The most common age group affected was 31-40 years. Males constituted 76.66% cases and females, 23.33 % cases. Male to female ratio was 3.3:1. Most of the victims belonged to rural areas(76%). Educationally, most victims were illiterates(39.33%) and married(78.66%) while the most common occupation was labourer(34%). Hard and blunt weapons(62.66%) were used commonly with laceration of scalp(64%). The most commonly affected was frontal bone while the most commonly observed type of fracture was linear fracture.

Conclusion: Despite homicidal head injury being one of the most severe reasons of Medicolegal deaths, there is a vast lack of literature in the understanding of its pattern and social demographic aspects. The findings of this study takes us one step closer towards bridging that lack of information especially in the region of eastern Uttar Pradesh, where deaths due to head injury of homicidal intent are often encountered.

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INTRODUCTION

The core of the life is about discovering pleasure, sharing joy, growing gracefully, and living with Dignity. Yet, throughout history, the ongoing issue of Violence has consistently hindered these goals.[1] Any dispute can escalate to violence. Drug addiction, domestic violence, terrorism and other crime threatens safety and community peace. Poverty, inequality, and lack of opportunity among people can lead to criminal behavior.[2] The head is crucial because even trivial injuries there can be deadly, much more than injuries to other parts of the body. Attackers often aim for areas where causing harm is easy and fatal. Head is a major target because it holds vital organs and even a single ill aimed injury can cause serious damage.[3]

The sequel of assault depends on several factors: the weapon used, the site of injury, the type of injury, the presence of skull fracture and number of hits. Intracranial hemorrhage if present, its site and type is also crucial for deciding what happens next in such cases. Our study might help the law enforcing authorities and policy makers to make further well informed decisions on handling these

sorts of crime.

MATERIAL AND METHOD

The present study is a cross-sectional observational study of descriptive nature. Ethical clearance was obtained from Institutional Ethics Committee, MLN Medical college and Associate Hospitals, Prayagraj (Ethics Committee Registration No. ECR/922/inst/UP/RR-22 Issued under New Drugs &Clinical Trials Rules,2019).

As per the Inclusion/Exclusion criteria , all the patients and/or attendant of patient with clear homicidal head injury were interviewed in Trauma Centre of Swaroop Rani Nehru Hospital and Mortuary of Swaroop Rani Nehru Hospital from 1st April 2023 to 31st March 2024. The data was entered in a pre-structured questionnaire.

Exclusion Criteria

1. All alleged suicidal and possibly accidental head injury cases including cases of road and rail traffic accidents.
2. Cases with mutilation of head or significant loss of head tissues.
3. Cases who refuse to consent for the study.
4. Cases who have no radiological head imaging despite head trauma.

RESULTS

The outcome of the overall observation and the results of 150 medicolegal cases of homicidal Head Injury have been presented systemically. Most commonest age group affected were 31-40 years with 40% Followed by 21.33% cases that belonged to 21-30 years age group. The least affected age group was 0-10 years with only 1% of total cases**(Figure 1)**. Male were the maximum number of cases 76% of the total 150 homicide head injuries, while women Constituted rest 35 cases (23.33%). Male to female ratio was found to be 3.3:1 **(Figure 2)**.

Rural areas had the highest number of victims, with 114(76%) individuals affected. In comparison, urban areas recorded 36(24%) victims **(Figure 3)**. Majority of the homicidal head injury victims were illiterate (39.33%) and married (78 %). Most victims (34%) of homicidal head injury belonged to the laborer group. Hard and blunt weapons were the most common type of weapon (62 %) used for inflicting injuries. Sharp edged and heavy weapon in 23 cases (15.33 %). Multiple weapon were used in 15 cases (10 %).

The firearm and sharp edged with pointed weapon constitute 6 cases (04.00 %) and 1 case (0.60 %) respectively. Weapons were not reported in 2.66% cases.

Figure 1: Distribution of Victims of Homicidal Head Injury on the Basis of their Age Group (n =150)

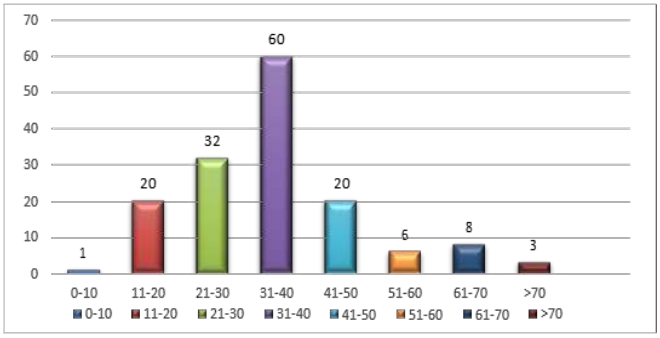


Figure 2: Distribution of Victims of Homicidal Head Injury on the Basis of their Sex (n=150)

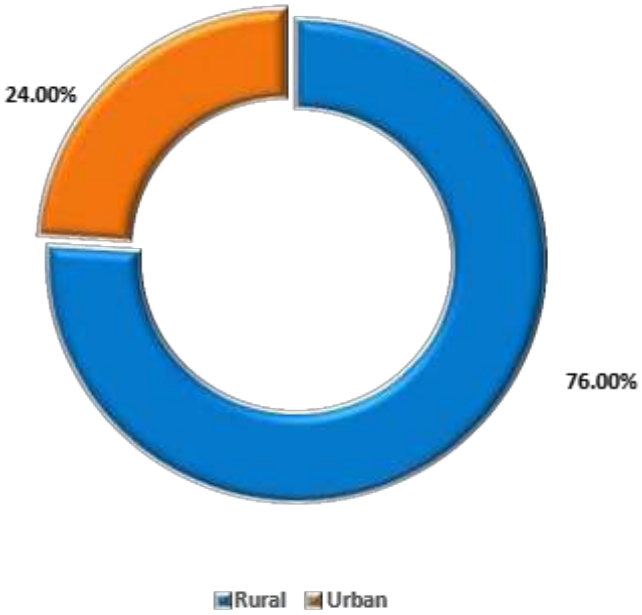
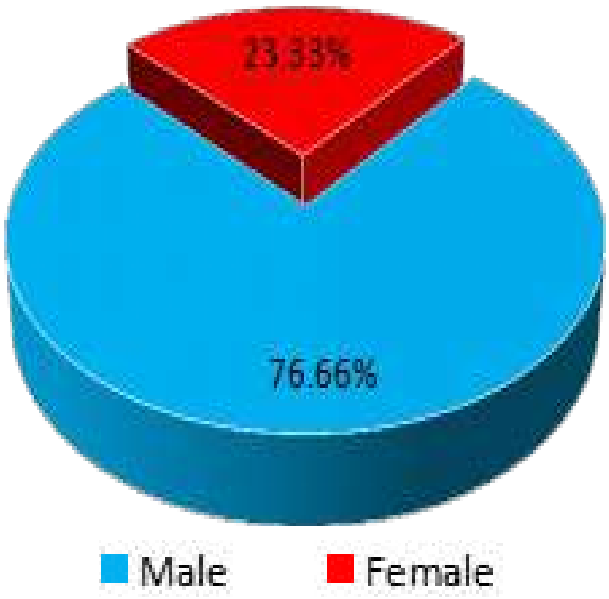


Figure 3: Distribution of Victims of Homicidal Head Injury on the Basis of their Residential Status (n=150)



On examination of homicidal head injuries cases, 64% (96 out of 150 cases) were laceration. Abraded contusions were seen in 36 (24%) cases, both Fracture of Skull and intracranial hemorrhages' were seen in 25(16.66%) cases.

Abrasion and concussion injury were noted in 4 (2.6%), and 3 (2%) cases respectively. In 0.6 % (1 case) case stab injury were seen. Incised wound on scalp were seen in 6(4.0%) cases. No chop injury was seen. Linear or fissure fractures were seen in 12 cases (8.0%), followed by depressed fractures in 8 cases (5.3%). Comminuted fractures were seen in only 2 cases (1.33%). Basilar fracture was found 1 case (0.66%). No sutural fracture was seen. Frontal bone fracture was seen in 7 cases (4.66%) which was the maximum, followed by temporal bone fracture in 5 cases (3.33%).

Parietal bone fractures were seen in 4 cases 8.00% (2.66%). Occipital bone fracture with 2 cases (1.33%). Combination of frontoparietal and fronto-parieto-temporal in 2 cases(1.33%), 1 case (0.66%) respectively with other combination. In only one case (0.66%) perisylvian fracture is seen.

DISCUSSION

In this study, a total of 150 cases of homicidal head injury were analyzed who were brought to Trauma Centre and Mortuary of Swaroop Rani Nehru hospital, Prayagraj for treatment and postmortem examination respectively spanning from 1st April 2023 to 31st march, 2024. This study primarily focused on exploring the epidemiological and medico legal dimensions of these incidents. In this study most common age group among the victims of homicidal head injury was found to be 31-40 years (40 %).

Similar findings to present study were observed by Henderson et al.,[1] A.K.Gupta et al.,[2] Rajeev Kumar[3] Rekhi et al.,[4] and Wahlsten et al.[5] Contrasts of our study were observed by Mohanty et al.[6] where most of thevictims were belongs to 21- 30 years and by Prajapati et al.[7] where majority of victims were being between 21 and 40 years old. Pokorny A[8] showed that almost half of the victims were between 20 to 34 years old. Majority of the victims were males; Similar findings were observed by A.K.Gupta et al.,[2] Mohanty et al.,[6] Prajapati et al.,[7] Pokorny A[8] and Zimring et al.[9] was mainly affected in Homicidal Head Injury, with 114 victims (76 %) who are in comparison with findings of Das Gupta et al.,[10] Rajeev Kumar[2] and Nabachandra.[11]

In the present study, it was observed that the majority of victims, 39.33 % of cases, were categorized as illiterate in terms of their educational status. This was followed by individuals with education levels ranging from primary schooling (27.33%) to up to matriculation (18.66%), graduate (11.33%), postgraduate (1.33 %), and unknown (2%). This is in comparison with the finding of another study done in New Delhi by Kulshrestha et al.[12] and Oberoi et al.[13] In which it was found that the preponderance of homicide victims were noted to be illiterate, accounting for 39% of total cases in each Investigation.

This study found that total 118 cases (78.66%) of homicide victims weremarried followed 24 cases (16%) unmarried. This finding is also consistent with Punia et al.[14] comprising 76.38 % cases and with Dhaval J Patel,[15] comprising 70 % of married person.Most common occupation of the victims were labourer (34 %) followed by farmer (16 %). Which is consistent with the finding of a study done in Patiala by Oberoi et al.[13] and Shah et al.,[16] done in Peshawar Pakistan which also found that the labourer to be most frequently affected.

In 62% cases hard and blunt weapons was most common method of homicide in our present study. Our finding is consistent with study of Henderson et al.,[1] Zimring et al.[9] Punia R.K. et al.,[14] and Suraj Sundaragiri et al.[17] Laceration (64 %) was commonest scalp injury followed by abraded contusion (24 %). Fracture of the skull and intracranial haemorrhages was seen in 25cases (16.66%). Incised wound on scalp was seen in 6 cases (4%). Firearminjury was also seen in 6 cases (4%). No study is consistent with our study.Linear fracture is the most common type of skull fracture followed by depressedfracture.

This study is consistent with the study of Yogendar Malik et al,[18] and Mathiharan K. and Patnaik AK.[19] In our study maximum fracture is associated with the frontal bone followed bytemporal bone. Base of skull fracture was seen in 1 case. This study isconsistent with study of Sunil Naik and Rupesh Naik,[20] and Chattopadhaye S et al.[21]

CONCLUSION

Unemployment, marital disputes, and family problems, especially of people aged 30-40 should be addressed effectively and should be deal as an important social problem by the concerned. Social awareness and strict laws against violence, specially using weapons for rectification of disputes, should be incorporated to condemn and restrict such incidences among societies.

Awareness policies against drugs and alcohol addiction should be spread with co-commitment of law enforcement of laws. Considering psychiatric evaluation and support for

offenders seems essential. Improve coordination between police, forensic experts, and the judiciary to better solve crimes may serve as deterrent against suchincidents.

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Table 1: Distribution of Victims of Homicidal Head Injury According Toeducational Status (n=150)

Educational Status	Numbers	Percentage
Illiterate	59	39.33%
Primarilyeducated	41	27.33%
Uptomatriculation	28	18.66%
Graduate	17	11.33%
Post graduate	02	01.33%
Unknown	03	02.00%
Total	**100**	**100 %**

Table 2: Distributions of Victims of Homicidal Head Injury According Tomaritalstatus (n =150)

Marital	Numbers	Percentage
Married	118	78.66%
Unmarried	24	16.00%
Divorced	03	02.00%
Widow	02	01.30%
Notknown	03	02.00%
Total	**150**	**100 %**

Table 3: Distributions of Victims of Homicidal Head Injury on the Basis of Their Occupational Status (n =150)

Occupation	Numbers	Percentage
Service/ Job	02	01.30%
Selfemployed / Business	21	14.00%
Farmer	24	16.00%
Laborer	51	34.00%
Housewife/ Homemaker	22	14.66%
Student	15	10.00%
Underlegal Custody	00	00.00%
Unemployed	12	08.00%
Unknown	03	02.00%
Total	**150**	**100 %**

Table 4: Distributions of Victims of Homicidal Head Injury According to Types of Weapon Used (N =150)

Types of Injury	Numbers of Cases	Percentage
Hardandblunt	94	62.66%
Sharpedged	07	04.66%
Sharp Edged Andheavy	23	15.33%
Sharp Edgedandpointed	01	00.60%
Firearm	06	04.00%
Multiple	15	10.00%
Unknown	04	02.66%
Total	**150**	**100 %**

Table 5: Distribution of Nature of Injury Observed With Homicidal Head Injury (N =150)

Injury	Numbers	Percentage
Only Abrasion	04	02.66%
Abraded Contusion	36	24.00%
Laceration Of Scalp	96	64.00%
Fracture/dislocation Of Skull	25	16.66%
Avulsion Of Scalp	01	00.60%
Incised Wound On Scalp	06	04.00%
Stab Wound	01	00.60%
Chop Wound	00	00.00%
Firearm Injury	06	04.00%
Intracranial Haemorrhages	25	16.66%
Concussioninjury	03	02.00%
Lacerationofbrain	01	00.60%

Table 6: Type of Skull Fracture in Homicidal Head Injury Victims (n=150)

Type of Skull Fracture	Numbers	Percentage
Linear Fracture	12	08.00%
Depressed Fracture	08	05.30%
Comminuted Fracture	02	01.33%
Partial Depressed Fracture	02	01.33%
Sutural Fracture	00	00.00 %
Basilar Fracture	01	00.60%

Table 7: Distribution of Fracture of Skull in Homicidal Head Injury (n=150)

Location of Skull Fracture	Numbers	Percentage
Frontal bone	07	04.66%
Parietal bone	04	02.66%
Temporal bone	05	03.33%
Occipital bone	02	01.33%
Frontal+Parietal	02	01.33%
Parietal+Occipital	01	00.66%
Temporal+Parietal	01	00.66%
Perisylvian	01	00.66%
Frontal+Temporal+Perietal	01	00.66%
Baseofthe Skull	01	00.66%
Total	**25**	**16.66 %**

Table 7: Distribution of Fracture of Skull in Homicidal Head Injury (n=150)

Location of Skull Fracture	Numbers	Percentage
Frontal bone	07	04.66%
Parietal bone	04	02.66%
Temporal bone	05	03.33%
Occipital bone	02	01.33%
Frontal+Parietal	02	01.33%
Parietal+Occipital	01	00.66%
Temporal+Parietal	01	00.66%
Perisylvian	01	00.66%
Frontal+Temporal+Perietal	01	00.66%
Baseofthe Skull	01	00.66%
Total	**25**	**16.66 %**

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Original Research Paper

Estimation of Stature from Head Breadth in Medical Students of Kumaon region of Uttarakhand: An Anthropometric Study

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ABSTRACT

Introduction: Identification of a person, dead or alive, is of most importance in forensic practice, especially when decomposed, fragmented and mutilated human remains are received for postmortem examination. Stature happens to be an important parameter in medico-legal examinations. Human development and growth are affected by ethnic, racial, environmental and nutritional factors and therefore affect the stature of an individual. Studies conducted in the past have shown the relationship between stature and every part of the human skeleton and this relationship helps in calculating stature from mutilated and dismembered body parts.

Objective: The present study focuses on estimation of stature from head breadth and finding the correlation and regression formula between them among the medical students.

Materials and Method: The present cross-sectional study was carried out for a period of 3 months from March 2025 to May 2025 in the Department of Forensic Medicine and Toxicology, Soban Singh Jeena Government Institute of Medical Sciences and Research, Almora, Uttarakhand on total of 200 (100 male and 100 female) medical students in the age group of 17 to 30 years.

Result: The current study showed low positive correlation between stature and breadth of head with correlation coefficient ® 0.106 in males and (r) 0.017 in females which is statistically not significant.

Conclusion: The present study showed that accurate estimation of stature from head breadth is not possible as there was low positive correlation between stature and head breadth.

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INTRODUCTION

Identification of a person, dead or alive, is of most importance in forensic practice, especially when highly decomposed, fragmented and mutilated human remains are received in mass disasters like earthquakes, air crashes, landslides, tsunamis, mass fires and road traffic accidents.[1] One of the important parameters for the identification of an individual is estimation of stature.[2] Human development and growth is affected by ethnic, racial, environmental and nutritional factors and therefore affect the stature of an individual.[3]

Many studies in the past have been conducted by different anthropologists to determine a relationship between the stature and different body parts.[4] As there is a strong effect of genetic and environmental factors on the height of the individual, uniformity of the study population is vital in formulating the regression equations.[5] Stature refers to natural height of an individual in standing position. It shows variation at different times of the day. It is less in the afternoon and evening due to reduced elasticity of the inter-vertebral disc and longitudinal vertebral muscles.

It peaks between 21 and 25 years and then for every 25 years, it is decreased by approximately 2.5cm due to some slouching posture consequent upon reduced tone of muscles and thinning of intervertebral disc. Stature is proportionally linked to dimensions of facial, head, vertebral column, trunk and extremities. However, no

single formula can accurately estimate the stature of different body parts due to variations across race, age, ethnicity and sex.[1] The present study focuses on the stature estimation from head breadth and to find the correlation and regression formula between them in the medical students.

MATERIALS AND METHOD

The present cross-sectional study was carried out for a period of 3 months from March 2025 to May 2025 in the Department of Forensic Medicine and Toxicology, Soban Singh Jeena Government Institute of Medical Sciences and Research, Almora on a total of 400 medical students, out of which 200 (100 male and 100 female) belonged to kumaon division of Uttarakhand. The students included were in the age group of 17 to 30 years, who were brought up in the state of Uttarakhand (Kumaon region).

Students with a history of head injury, congenital physical deformity or any developmental or metabolic disorders, students from other states and from Garhwal region were excluded from the study. After obtaining written informed consent from the students, the height of an individual was measured using a stadiometer as the distance between vertex and standing platform with the subject standing barefooted, erect on an even floor, on Frankfurt's plane. The measurements were taken from 09.30am to 11.30am by a single person, repeated thrice and the mean was taken to eliminate any diurnal and inter-observer variations.

The head breadth, the distance between the most lateral points of the parietal bones, was measured using a spreading caliper from behind in the anatomical position, the head being in the Frankfurt plane. The data was collected in pre-structured pro forma, and statistically analyzed. The mean and standard deviation were obtained. The correlation coefficient and regression equation were formulated to estimate the stature by using a software statistical package for social science (SPSS).

RESULTS The study consisted of 200 individuals, which included 100 females and males respectively . The most frequent age reported was 21 years (21 %), followed by 22 years (20%) in males and 19 years (23 %), followed by 21 years (20%) in females **(Table 1)**. The average age for males was 21.53 + 1.98 years, from minimum age of 18 years to maximum 28 years and the mean age for females was 20.60 + 1.70 years, ranging from 17 years to 25 years as shown in **Table 2**.

The breadth of head in males averaged 14.17 + 0.74 cm, ranging from 12.5 cm to 16.70 cm and the mean head breadth in females was 13.84 + 1.25 cm, ranging from 3.05 cm to 15.40 cm. Males had a mean stature of 168.07 cm, ranging from 152 cm to 184 cm and females had a mean stature of 154.85 + 5.58 cm, ranging from 144 cm to 171 cm as seen in **Table 2**. The current study showed a low positive correlation between stature and breadth of head in males with a correlation coefficient (r) of 0.106, which did not attain statistical significance at 0.05 level with a p value of 0.29 as illustrated in **Table 3**.

The male regression equation was formulated as : Stature (cm) = 157.82 + 0.79 x breadth of head (cm) The current study showed that in females, breadth of head and stature displayed a weak positive association, with a correlation coefficient of 0.017, which did not attain statistical significance at 0.05 level with a p value of 0.86 as illustrated in **Table 3.**

The female regression equation was formulated as: Stature (cm) = 153.80 + 0.7 x breadth of head (cm).

Discussion In the current study, males exhibited larger head breadth measurements than females. Similar findings were observed in studies conducted by Kokatanur et al[1] with mean head breadth of 14.04 ± 0.765 cm and 12.17 ± 0.783 cm in females, Kumar et al[3] with mean head breadth of 15.15 ± 0.72 cm in males and 14.72 ± 0.74 cm in females, Prasad et al[6] with mean head breadth of 13.48 ± 0.79 cm in males and 12.81 ± 0.67 cm in females, Wankhede et al[7] with mean head breadth of 14.64 ± 0.63 cm in males and 14.16 ± 0.66 cm in females, Marko et al[8] with mean head breadth of 13.7 ± 0.08 cm in males and 12.7 ± 0.07 cm in females, Parmod et al[9] with mean head breadth of 13.094 ± 1.154 cm in males and 12.109 ± 0.777

Table 1: Age wise Frequency of Males and Females

Age (Years)	Male		Female	
	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)
17	0	0	2	2
18	6	6	6	6
19	10	10	23	23
20	14	14	18	18
21	21	21	20	20
22	20	20	19	19
23	12	12	8	8
24	12	12	1	1
25	3	3	3	3
27	1	1	0	0
28	1	1	0	0
TOTAL	**100**	**100**	**100**	**100**

Table 2: Statistical Summary of Age, Skull Breadth and Stature

Variable		Minimum (cm)	Maximum (cm)	Mean ± SD
Age (years)	Male	18	28	21.53±1.98
	Female	17	25	20.60±1.70
Skull Breadth	Male	12.50	16.70	14.17±0.74
	Female	3.05	15.40	13.84±1.25
Stature	Male	152	184	168.07±5.61
	Female	144	171	154.85±5.58

Table 3: Regression Equation for Stature from Head Breadth in Both Sexes.

	Correlation Coefficient (r)	P value (2 Tailed)	Regression Equation	SEE
Male	0.106	0.29	Stature= 157.82+0.79 x head breadth	5.612
Female	0.017	0.86	Stature= 153.80+0.7 x head breadth	5.616

cm in females, Khan MA et al[10] with mean head breadth of 15.172 ± 0.63 cm and 14.4 ± 0.98 cm in females, Reddy et al[11] with mean head breadth of 14.64 ± 1.177 cm in males and 13.406 ± 1.204 cm in females, Agnihotri et al[12] with mean head breadth of 15.45 ± 0.76 cm in males and 14.48 ± 0.81 cm in females.

This is because the male's cranium is bigger than that of the female. An exception to the above findings was seen in the study done by Sagar et al[13] in the Jatavs of Delhi, where there was no appreciable difference in the measurements of both sexes: 13.9 ± 0.07 cm in males and 13.44 ± 0.06 cm in females. Males were observed to have greater mean stature as compared to females. Similar results were reported in studies conducted by Kokatanur et al[1] (173.71 ± 6.259 cm in males and 158.75 ± 6.578 cm in females), Kumar et al[3] (155.34 ± 5.88 cm in females and 167.2 ± 6.2 cm in males), Prasad et al[6] (172.22 ± 6.88 cm in males and 157.43 ± 5.32 cm in females).

Wankhede et al[7] (171.67 ± 6.5 cm in males and 156.44 ± 5.32 cm in females), Marko et al[8] (156 ± 0.5 cm in females and 172 ± 0.44 cm in males), Patil et al[2] (158.08 ± 6.05 cm in females and 170.45 ± 5.83 cm in males), Singh R[14] (167.2 ± 7.8 cm in males and 158.0 ± 5 cm in females), Pandey et al[15] (170.42 ± 5.78 cm in males and 159.01 ± 7.261 cm in females), Keche et al[16] (171.21 ± 6.23 cm in males and 159.43 ± 5.87 cm in females), Parmod et al[9] (163.25 ± 6.84 cm in males and 154.12 ± 5.45 cm in females), Khan MA et al[10] (172 ± 11.37 cm in males and 160 ± 16.34cm in females), Chahal P et al[17] (171.66 ± 7.11 cm in males and 157.89 ± 5.01 cm in females), Agnihotri et al[12] (173.3 ± 7.2 cm in males and 155.24 ± 5.11 cm in females). This is most probably due to influence of the Y chromosome on stature

Figure 1: Shows Scatter Plot Showing Relationship between Stature and Head Breadth in Males.

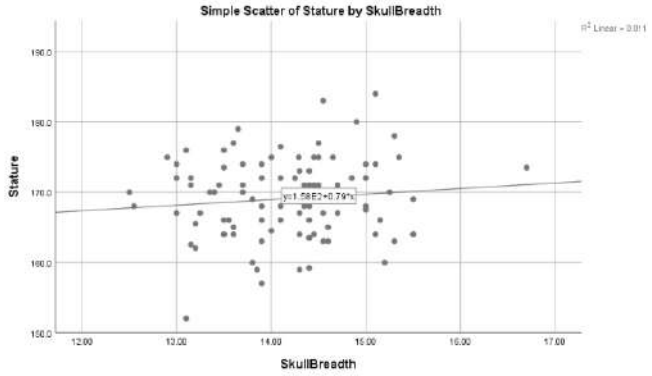
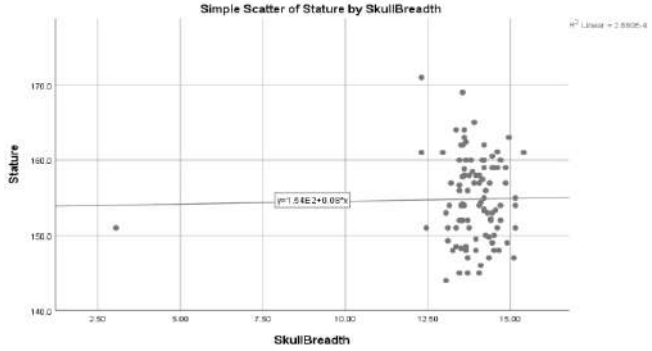


Figure 2: Shows Scatter Plot Showing Relationship Between Stature and Head Breadth in Females.



and delayed onset of puberty in males compared to females, latter achieving it about 2 years earlier, resulting in the availability of more time for growth. Findings in the study done by Sagar et al[13] (152.53 ± 0.56 cm in males and 152.44 ± 0.39 cm in females), showed no appreciable difference.

The study found that head breadth is not a reliable predictor of stature in both females and males, given the weak and statistically insignificant correlation between

the two variables at a significance level of 0.05 (p value 0.29 and 0.86) as illustrated in **Table 3**. This can be due to the fact that the growth of the skull is influenced by genetic makeup.

Similar findings were noted in studies conducted by Kokatanur et al[1] [male (r) 0.144 and female (r) 0.155], Kumar et al[3] [male (r) 0.178 and female (r) 0.256], Prasad et al[6] [male (r) 0.054 and female (r) 0.160], Wankhede et al[7] [male (r) 0.053 and female (r) 0.262], Marko et al[8] [male (r) 0.183 and female (r) 0.338], Patil et al[2] [male (r) 0.367 and female (r) 0.255], Singh R[4] [male (r) 0.21 and female (r) 0.31], which is in contrast to study conducted by Reddy et al[11] which showed positive correlation between breadth of head and stature [male (r) 0.612 and female (r) 0.606] and Nemade et al[18] [male (r) 0.536 and female ® 0.578].

The correlation coefficients in females and males was 0.017 and 0.106 respectively, head breadth does not show a significant association with stature, rendering it a poor predictor. The correlation coefficients and regression equations vary from one place to another as stature depends upon various demographic variables. Hence, regression equations for stature estimation are tailored to specific populations and may not applicable to others.

CONCLUSION

The present study found that head breadth is not a reliable predictor for accurate stature estimation as there was low positive correlation between stature and head breadth.

LIMITATIONS

1. Intra-rater reliability while taking the stature and head breadth.
2. Instrument reliability used for measurement.

CONFLICTS OF INTERESTS / FUNDING: None

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Original Research Paper

A Validation of the Post Mortem Computed Tomography Technique to Predict the Stature using Sternum and Clavicle Measurements in the Northern Indian Population

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ABSTRACT

Introduction: The estimation of stature from the skeletal remains is a challenging aspect to any forensic anthropologist/pathologist. The exact stature from the particular bone is difficult to be measured, however, a specific stature range could be given based on anthropometric measurements. The post mortem computed tomography (PMCT) can be considered as an artificial intelligence tool which gives an exact measurement of the bone to be studies. Hence, the present study assessed the correlation between the stature and various PMCT based sternum measurements and clavicle length (both sides) in order to develop population–specific regression equations in a contemporary Northern Indian population.

Materials and Method: A total of 500 samples (333 males and 167 females) were randomly collected based on inclusion and exclusion criteria. Four linear anthropometric measurements of the sternum and clavicle measurements from either side were measured using the 3D volume rendered technique by an electronic cursor in PMCT. Each anthropometric measurement showed a significant difference between males and females (p-value <0.05). Regression analysis was applied to match the taken measurements against stature.

Results: The accuracy to predict stature ranged from 4.42 to 5.22cm for males and from 4.17 to 5.56cm for females, respectively. Total sternal length were better predictors of stature in both sex. The correlation coefficient between stature and the clavicle length on both sides remained same among males and females.

Conclusion: The author concluded the study by developing a better predictive model to estimate stature from sternum and clavicle in the contemporary Northern Indian population using the PMCT measurement technique.

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Keywords: Forensic Anthropology; North Indian Population; Sternal Measurements; Clavicle; Regression Analysis; Post Mortem Computed Tomography.

INTRODUCTION

The estimation of stature from the skeletal remains is a challenging aspect to any forensic anthropologist/ pathologist because the estimated stature guides the investigating authorities. Two methods could be practiced to estimate the stature-the anatomical method and the mathematical method. The anatomical method is the one where the available bones are assembled anatomically and measuring the length of individual bones and estimating the stature.

Even though it is considered as an reliable method to estimate stature both forensically and archeologically, the availability of all the bones of that particular individual is an inevitable factor one needs to ensure which is difficult in majority scenario. In such scenario the mathematical method is used where predictive models are calculated using statistical regression analysis technique. Since the anthropometric measurements are biologically related, a

specific stature range could be commented based on anthropometric measurements obtained from individual bones retrieved.[1] But, the application of the derived formulae from measurements of a particular population to a different population is still unclear. This mandates the researchers to explore population-specific and sex-specific formulae for the human bones. Several researchers adhered to different methodologies like measuring tapes, spreading vernier calipers to measure the lengths of the bones.

With the advent of artificial intelligence in the recent past, the researchers worldwide had considered using post mortem computed tomography (PMCT) to measure the lengths of the bone.[2-7] The author intends to access the credibility of the PMCT bone length measuring technique and compare the results with the existing literatures who had utilized the vernier caliper measuring technique. Hence, the present study assessed the correlation between the stature and various PMCT based measurements of long bones namely; sternum and clavicle (both sides) in order to develop population–specific regression equations in a contemporary Northern Indian population.

MATERIALS AND METHOD

Sample Collection

This retrospective cross-sectional study was performed at the Department of Forensic Medicine and Toxicology, All India Institute of Medical Sciences [AIIMS], New Delhi after approval by the institute ethics committee (IEC 577/02.11.2018, RP-29/2018). Data were collected from 500 subjects of known age and sex who underwent PMCT and subsequent forensic autopsy at the department between 2021 and 2022 belonging to North Indian population.

The study population consisted of 333 male deceased (mean age 40.03 +14.57; range, 21–82 years) and 167 females deceased (mean age, 41.1 +15.43 years; range, 21–78 years). The estimated postmortem interval of the subjects was <48hours for the studied subjects. The study population belonged to Northern India that includes the following states: Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Uttar Pradesh, Bihar and Uttarakhand.

The deceased succumbed to death following road traffic accidents, falls from height, gunshots, electrocution, railway accidents, poisoning, hanging, strangulation, sudden death cases, etc. All the bones altering the stature fuses by 21 years, hence the deceased who were more than and equal to 21years of age were included in the study.

The study participants who had sustained a fracture of any bones of the body modifying the stature, had any deformity of spine altering the stature, any notable gross congenital sternal deformities or with non-fused sternal end was excluded from the study. A temporary identification consisting of details like serial number, postmortem no, age, sex, and locality was created in a data collection proforma before collecting the data and the same was updated in the Microsoft Excel 2016 spreadsheet.

Anthropometric measurements

PMCT examination was performed using a 16-slice MSCT spiral scanner (Scanning parameters: 120kV; 70mA; 16 x 1 mm collimation) Cannon America Medical Systems, Inc Aquilion Lightning TSX-035A CT data acquisition. The raw data processing was done at 1mm slice thickness. Vitrea software v.6.9.1 was used for evaluation of the data. The images were viewed using Multiplanar Reconstruction and Volume Rendering technique [MPR-VRT].

The following five variables were measured from the reconstructed images as shown in **Figure. 1(a)**: Stature [STAT], **Figure 1[b]**. Manubrium Length [ML], and Manubrium Width [MW], Sternal Body Length [SBL], Total Sternal Length [TSL], Right Clavicle Length [RCL], Left Clavicle Length [LCL]. All the variables were measured using the PMCT electronic cursor available in the software. The collected data were entered directly into a data collection proforma initially followed which was updated in Microsoft Excel 2016 Spreadsheet.

Stature (STAT)

The most distal part of the vertex till the distal-most part of the calcaneum is measured as stature **(Figure 1 A)**. [3]

Clavicle Length (CL)

- Left Clavicular Length (LCL): Superior margin of left sternal facet to anterior point of left acromial end **(Figure 1 B)**.
- Right Clavicular Length (RCL): Superior margin of right sternal facet to anterior point of right acromial end **(Figure 1 B)**.

Manubrium Length (ML)

It is measured as the distance straight distance from the center of the suprasternal notch to the center of the manubrium-sternal junction **(Figure 1 C)**.

Manubrium Width (MW)

It is measured as the distance between the midpoints of the

facet for the first costal cartilage on each side **(Figure 1 C)**.

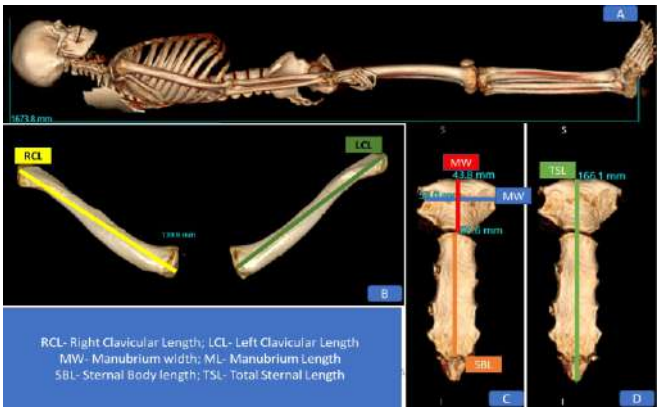
Sternal Body Length (SBL)

It is measured from the manubrium–sternal junction to the sternum–xiphoidal junction of the sternum in the mid-sagittal plane **(Figure 1 C)**.

Total Sternal Length (TSL)

It is measured as the sum of the lengths of the manubrium, the sternum body and the xiphoid process **(Figure 1 D)**.

Figure 1:



RESULTS

Descriptive Statistics

The data of 500 subjects were considered for analysis in the study during the period 2021-2022. A total of 333 [66.6%] were males and 167 [33.4%] were females. The randomly collected 500 subjects were further classified based on age and sex. The descriptive statistics for the general population, males and females are presented in **Table 1**. Age in years was the independent variable and the remaining were outcome variables, measured in cm.

The mean age of the female population was greater than the mean age of the male population participating in the study. It was concluded that the males had a mean sternal length and width of more than 5cm while the females' mean values were less than 5cm. In the case of mean clavicle length, the mean length for females was less than 14cm while males had a mean length of more than 14cm. The average TSL of the males was 17.86+ 2.04 cm which is higher than the females' average TSL which was 14.89 + 2.12 cm.

Intra-observer Error and Inter-Observer Error

The test-retest method was used to assess the intra-observer reliability. Accordingly, the measurement was taken twice by the same observer at different periods preferably after 7 days post-first measurement and the mean value of the two was considered for analysis. On comparing the average obtained by the first observer with measurements taken by the second independent observer for 100 cases the Inter-observer reliability was measured.

The mean value calculated by the second observer was considered for the reliability analysis. The Intra Class correlation coefficient method was used to assess the observers' reliability. The consistency for various sternal measurements ranged between 76% and 85% (good reliability) while the agreement for clavicular and stature measurements was more than 97% (excellent reliability) between the observers. 8

Regression Analysis

Table 2 shows the predicted regression equations to estimate stature from various lengths of sternum and clavicle for the combined population and respective sex. All measurements presented statistically significant correlation coefficients with stature ($p<0.05$). The accuracy of stature prediction ranged from 4.42 to 5.22 cm for males and 4.17 to 5.26 cm for females when the dimensions of a single variable stature were used to calculate the stature.

The total sternal length (TSL) gave the most accurate measurement out of all the sternal measurement studies and the sex-wise comparison of clavicular lengths showed, that the left-sided measurements were more accurate than the right-sided measurements. The manubrium width showed better correlation than the manubrium length among the combined population and sex-wise as well. The accuracy of stature prediction was more for the females compared to males for the multiple regression analysis **(Table 3)**. The range of accuracy for stature prediction using multiple regression equations was from 3.87 to 3.89.

Validation of Regression Equations

The stature calculated for all the 500 subjects using the derived formulae was labelled estimated stature (Es). The stature measured using the PMCT measuring technique is observed stature (Os). The Intraclass correlation reliability statistical method was performed to validate the derived linear regression equations and a consistency of 75-90% using linear regression analysis and consistency range was 88-93% using multiple regression was obtained between Es and Os among the combined population. While among males and females, the range of consistency was 67-84% and 63-86% respectively using linear regression analysis. **(Table 2 & 3)**

Table 1: Descriptive Data in Relation to Different Study Characteristics-Combined and Sex-Wise.

Sex/ Parameters	Combined		Male		Female	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Age	40.38(14.86)	21-82	40.03 (14.57)	21-82	41.1(15.43)	21-78
STAT	159.95(8.31)	133.2-180.9	163.6 (6.41)	143.8-180.9	152.6(6.57)	133.2-172.8
ML	4.91(0.76)	2.17-7.86	5.16 (0.72)	3.27-7.86	4.52(0.7)	2.7-6.67
MW	5.27(0.69)	2.77-7.07	5.5 (0.69)	2.77-7.07	4.87(0.56)	3.11-6.58
SBL	9.05(1.53)	5.16-13.95	9.66(1.39)	5.65-13.95	7.95 (1.16)	5.16-11.67
TSL	16.87 (2.49)	10.49-23.75	17.86 (2.04)	10.54-23.75	14.89 (2.12)	10.49-20.76
RCL	14.04 (1.13)	11.11-17.33	14.51 (0.91)	11.53-17.33	13.1(0.82)	11.11-16.63
LCL	14.19 (1.14)	11.08-17.25	14.67(0.90)	12.15-17.25	13.22(0.94)	11.08-16.76

** Age in years, all measurements are in cms.*

Table 2: Linear regression equations for estimation of stature from various sternum and clavicle measurements among combined population (P<0.001), males (P<0.001) and females (P<0.001). SEE: Standard error estimate, R: Correlation Coefficient, ICC: Intra Class correlation; CI: Confidence Interval.

Equation	SEE	R^2	R	95% CI	ICC
Combined (n=500)					
125.53 + 6.96 * (ML)	6.33	0.42	0.65	6.24 - 7.68	0.75
118.35 +7.86 * (MW)	6.12	0.46	0.68	7.11 – 8.61	0.77
123.38 + 4.03* (SBL)	5.55	0.55	0.75	3.71 - 4.35	0.83
113.26 + 2.77 * (TSL)	4.63	0.69	0.83	2.61 – 2.93	0.90
83 + 5.48 * (RCL)	5.54	0.56	0.75	5.05 – 5.91	0.83
82.32 + 5.47 * (LCL)	5.48	0.56	0.76	5.04 – 5.89	0.84
Male (n=333)					
136.83 + 5.2 * (ML)	5.22	0.34	0.58	4.42 – 5.98	0.67
132.67 +5.63* (MW)	5.09	0.37	0.61	4.84 – 6.42	0.70
135.9 + 2.88* (SBL)	5.03	0.39	0.63	2.49 – 3.27	0.72
122.88 + 2.28 * (TSL)	4.42	0.53	0.73	2.05 – 2.52	0.84
103.17 + 4.17 * (RCL)	5.17	0.35	0.59	3.56 – 4.79	0.70
101.2 + 4.26 * (LCL)	5.14	0.36	0.60	3.64 – 4.87	0.70
Female (n=167)					
130.4 + 4.91* (ML)	5.56	0.28	0.54	3.8 – 6.22	0.65
121.17 +6.45* (MW)	5.53	0.3	0.54	4.91 – 7.99	0.63
127.99 + 3.09* (SBL)	4.97	0.43	0.66	3.1 – 4.38	0.71
116.82 + 2.4 * (TSL)	4.17	0.60	0.77	2.1 – 2.70	0.86
95.82 + 4.33 * (RCL)	5.26	0.36	0.60	2.71 – 4.88	0.70
96.29 + 4.26 * (LCL)	5.23	0.37	0.59	3.4 - 5.11	0.70

Table 3: Multiple regression equations for estimation of stature from various sternal and clavicle measurements among combined population, males and females on both left and right side. SEE: Standard error estimate, R: Correlation Coefficient, ICC: Intra Class correlation.

Sex	R	R^2	SEE	MRE Equation	ICC
Combined (n=500)	0.87	0.76	4.11	104.68 + 1.77(ML) +2.10 (MW)+ 1.25(SBL) + 1.43 (TSL)	0.93
Male (n=333)	0.80	0.64	3.87	113.90 + 2.03(ML) +2.17 (MW)+ 1.07(SBL) + 0.95 (TSL)	0.88
Female (n=167)	0.81	0.66	3.89	107.77 + 1.01(ML) +1.42 (MW)+ 1.25(SBL) + 1.57 (TSL)	0.89

Table 4: Comparison of the Correlation Coefficients Between Stature and Sternum Measurements from available Literature.

Place (NS)	Year	Method	MW	ML	SBL	TSL
South India (35) 16	2009	VC	-	-	-	0.638
Chandigarh (252) 18	2011	VC	-	0.191	0.255	0.318
Portugal (40) 19	2012	VC	-	-	-	0.329
China (288) 17	2015	PC	-	0.459	0.541	-
Puducherry (210) 20	2020	VC	-	0.534	0.540	0.611
Thailand (219) 21	2022	VC	0.531	0.425	0.666	-
Present study (500)	2022	PC	0.65	0.68	0.75	0.83

NS: No of subjects; VC: Vernier Caliper; PC: PMCT – Cursor

Table 5: Sex Wise Comparison of the Correlation Coefficients Between Stature and Clavicle Measurements from available Literature.

Place (NS)	Year	Method	Male		Female	
			RCL	LCL	RCL	LCL
Gujarat (200) 23	2014	VC (D)	0.735	0.736	0.585	0.627
Tamil Nadu (200) 24	2017	VC (D)	0.498	0.450	0.663	0.592
Japan (131+118 = 249) 25	2017	PC	0.665	0.755	0.769	0.816
Nigeria (1000) 26	2019	VC (L)				
18-24			0.474	0.521	0.098	0.358
25-31			0.522	0.554	0.434	0.446
>31			0.773	0.778	0.605	0.499
Maharashtra (50 M) 27		VC	0.403	0.389	-	-
Himachal Pradesh 28	2021	VC	0.878	0.881	0.538	0.541
Present study (500)	2022	PC	0.59	0.60	0.60	0.59

NS: No of subjects; VC: Vernier Caliper; PC: PMCT – Cursor

DISCUSSION

The authors in their previous studies explored the feasibility of the PMCT measurement technique using scapula which is a flat irregular bone and foramen magnum which is a part of the flat bone skull.[3,9] According to the authors, the results were promising to estimate the stature using the PMCT measuring technique from scapula and foramen magnum. Among the existing literature several researchers had utilized this technique to measure the lengths of sternum, lower limb long bones, pelvis and sacrum and developed a predictive model for their respective populations.[10-14]

A study by Grabherr S et al reiterated the fact that PMCT images are highly reproducible, so repeated measurements could be taken.[15] This PMCT measurement technique doesn't require the procedures like dissection of the attached tissues and processing the skeleton to obtain the measurements owing to its real-time operation of object mass.[3]

This enables the researchers to take the bone measurements owing to the preservation of anatomy. Adhering to the following measurement procedures like involving independent observers to collect measurement and analysing the reliability between them; taking the measurements at different interval of time and utilising the average measurement of observations for statistical analysis would give a better predictive model by reducing the chances of the error as performed in the present study.

The present study was performed utilizing the 3D volume rendered technique (VRT) and an electronic cursor that is available in the PMCT to measure the long bones i.e., sternum and clavicle. The authors were able to get only one study published globally exploring the stature estimation from the sternum and clavicle respectively using the 3D VRT technique admixed multiple caliper-based measurements after performing a thorough literature review.[17]

The notable findings of this study are as follows: Two independent observers performed the measurement of the various bone lengths from sternum and clavicle at different intervals of time. The intraclass correlation method was performed to look for the agreement between the results. Despite the probabilities of difference in

measurements, there was an acceptable to excellent reliability between the observers' measurements. The total sternal length (TSL) measured from the sternum of the northern Indian population was most promising to predict the stature compared to other obtained measurements which was in congruent with the studies utilizing either measurement techniques.[17-21]

The mean width of the manubrium (MW) was greater than the mean length of the manubrium (ML) among both sexes. This could be considered as one of the few studies to explore and comment the variations in the MW and ML. The sterno-clavicular joint is radiologically well interpreted facilitating the measurement at PMCT; in comparison to autopsy which requires dissection of the soft tissues which could be time consuming to exactly find the sterno-clavicular joint to take the MW measurement. This might be a reason for the researchers preferring to study ML than the MW. However, the comparative results of ML and MW in the present study were in line with Jeamamornrat V et al, who explored the Thai population.[21]

A significant positive correlation was observed between the stature and various sternum and clavicle measurements on both sides among the combined and sex-wise population ($P<0.05$). The authors compared the results of the present study to the recent studies that included population of North China, Portugal, Thailand and various parts of India (South, Central & North). Amongst the compared studies, only two including the present study utilized the PMCT cursor technique while the others used Vernier Caliper (VC) to measure the bones.

The comparison of correlation coefficients observed in various studies with the present study is summarized in table 4 & 5 respectively. The benefit of the present study is that a total of four measurements were obtained from the sternum in addition to bilateral clavicular measurements and furthermore, multiple regression predictive model was obtained for individual bones.

The results gave an insight into the sex prediction where a TSL of 15cm was the reference length for sex determination from the sternum of studied population. It could be interpreted that if a TSL is greater than 15cm, then there exists a probability that it could be a male sternum and likewise if a TSL is lesser than 15cm then, the chance that it could belong to a female sternum exist. Similarly, the reference length was 14cm for the clavicle in the similar manner discussed above.

Firstly, the analysis was performed for a pooled population denoting the Northern India population in-total and secondly for the males followed by the females as well. The standard error of the estimate (SEE) of the pooled population ranged between 4.63 to 6.33 which is very less when compared to the study done in Thai population (6.64-8.64).[21] The TSL predictive model of the pooled population of our study had the least SEE (4.63) which is the least among the existing literatures.[16-18,20]

The derived predictive model of the pooled population was validated in the study population using the intraclass correlation method. The results of the validation showed a good and excellent reliability (75% - 90%). The accuracy of prediction of stature using the derived predictive model is less than 5.22cm and 5.56cm among males and females respectively. The minimum and maximum confidence interval range noted was 2.05 – 2.52 and 4.84 – 6.42 for males respectively similarly 2.1–2.70 and 4.91–7.99 for females. The correlation coefficient of the pooled population is greater than the sex-wise population considering the variation in the skeletal maturation physiology among the sex.

The derived pooled population predictive model has its implications in scenario where the sex of the bone is not known. In such a scenario, the stature of the bone could be concluded using the formula. Sing et al had concluded that the multiple regression equations are more useful than the linear regression equation with a greater accuracy rate.[17] The present study reiterates the findings of Singh J et al[17] **(Table 3)**.

An extensive study by Brough et al. compared clavicular measurements obtained using PMCT and the direct osteometric method. No significant difference in lengths was observed obtained by either technique.[22] The present study followed the 3D VRT reconstruction of the clavicles except for the utilization of HU reference which was followed by S Torimitsu et al.

This could be a probable reason that the study performed on the Japan population had better correlation in comparison to the Northern Indian population (present study).[22] The present study was compared with the results of the studies performed using vernier caliper technique **(Table 5)**.[23-28] The author concludes that there was not much difference in the correlation values of the predictive model for clavicle obtained in the present study and other studies done in various parts of India and Nigeria.

CONCLUSION

To the best of our knowledge, this is the pioneer study to

derive a predictive model for stature estimation using long bones i.e., sternum and clavicle measurements using the PMCT technique in the Indian population. It is evident from the study that PMCT cursor technique is a reliable tool to obtain bone measurements for anthropological purposes. The present study validated the derived predictive model of the sternum and clavicle for pooled population, males and females on both sides.

The derived predictive model could medicolegally fulfill the purpose of estimating the stature range considering the comparatively lesser standard error of the estimate. However, more region, race, and ethnic groups-based studies analyzing the correlation between stature and sternum, clavicle measurements are warranted in order to compile a list predictive model that would help in cases of Disaster victim identification, dismembered remains etc.

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Original Research Paper

Introduction of Analytic Rubrics for Assessing Short Answer Questions in Forensic Medicine & Toxicology for Phase III Part-1 Medical Students

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ABSTRACT

Introduction: In the field of medical education, the most crucial component for educational excellence is assessment of learning outcomes amongst students. Short Answer Questions (SAQs) are precious for evaluating comprehension, reasoning, and the application of medical principles in legal contexts. The objectives of the study were to design and implement analytic rubrics for assessing SAQs in Forensic Medicine.

Materials and Method: The study was conducted on Phase III Part-1 MBBS students (n=75) after being approved by the Institutional Ethics Committee. The analytic rubrics for assessing SAQs were prepared and validated by subject experts from different institutes. The students were assessed in the taught competency by SAQ based tests. These answer sheets were evaluated by traditional method. Thereafter, the department faculty was sensitized to rubric-based assessments and the answer sheets were re-evaluated using the analytic rubrics method. A scores obtained by the two assessment methods were compared and feedback of the students was obtained using feedback questionnaires. One-to-one interviews were conducted for obtaining faculty's feedback.

Result: There was a significant increase in the scores by rubric assessment method ($p<0.001$). The faculty & students' feedback indicated a strong preference for rubrics and appreciated the clarity and effectiveness of this method.

Conclusion: implementing analytic rubrics in Forensic Medicine assessments has improved objectivity and transparency, fostered better educational outcomes and enhanced student understanding of assessment criteria.

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INTRODUCTION

Assessing learning outcomes is a pertinent parameter of educational excellence. The assessment methods, particularly in medical education needs to be robust, subjective and free from biases. This holds true for Forensic Medicine assessment as well. The development of analytic rubrics is an effective tool to assess Short Answer Questions (SAQs) using predefined criteria and different levels of performance. This method provides a clear and structured framework for evaluating student responses with greater consistency, transparency, and objectivity.[1]

The Rubric's method of assessment not only guides educators in their assessments but it also clarifies student's expectations, ensuring that they understand what is required to succeed.[2] This clear communication between students and teachers regarding assessment criteria provides a supportive and constructive learning environment for the students.

In health professions education, rubrics have been documented to be a powerful tool for the assessment process. This method ensures fair and consistent grading by reducing the potential for bias and subjectivity in the evaluation of student's work. It evaluates student's performance in a structured and objective manner across a variety of assessment formats, including SAQs.[3-4]

Rubric assessment ensures that evaluations are aligned with learning objectives and desired outcomes. It is also useful in providing the specific and constructive feedback

by the assessors as it uses clear criteria.[5] This feedback is essential for promoting the student academic growth, as it enables them to understand their strength and weakness. Moreover, It encourages self-regulation among students and promote a sense of ownership during learning thus, motivating them to engage more deeply with the study material.

All these advantages make rubrics assessment more consistent, reliable and valid. Rubrics help students understand how to improve and refine their responses. Additionally, analytic rubrics have been shown to foster metacognitive awareness, as students gain a better understanding of the expectations and standards for their work, and can track their progress over time.[6] One of the advantages of the analytic rubrics is its capacity to involve and engage students in the assessment process. If involved in developing rubrics with evaluators, the students gain a clearer sense of ownership over the criteria used to assess their work, better understanding of the learning objectives and make them more confident and better learner.[7]

The novelty of the study is that the Rubric method of assessment has not been used in the subject of Forensic Medicine. More so, SAQs that form an important component of theory assessment have not been evaluated using structured method. Hence this study was planned to introduce Analytic Rubric method of assessment for evaluation of SAQ questions in the subject of Forensic Medicine & Toxicology and to assess its effectiveness using feedback questionnaire.

MATERIALS AND METHODS

This study was conducted on Phase- -III Part 1 MBBS students in the Department of Forensic Medicine & toxicology after approval from the Institutional Scientific Research and Ethics Committee. Students who filled the feedback questionnaire were included in the study (n=75). At the beginning of the study, the analytic rubrics for assessing SAQs were prepared.

These rubric models were then validated by MEU members and experienced subject experts (five faculty members from the department as well as from other institutions, each with a minimum of five years of teaching experience). For validation of the rubrics for each SAQ, the criteria and levels used are given in **Table 1**.[8]

The students were assessed in the taught competency by SAQ based tests (four questions of 2.5 marks each) with prior information. Initially the SAQs were assessed using traditional assessment methods. Thereafter, the department faculty were sensitized regarding the development of rubrics for assessing the short answer questions and were asked to re-evaluate the answer sheets using the analytic rubric model for these SAQs. The evaluated answer sheets and rubrics model for SAQs were shown to the students and their feedback was obtained.

Feedback questionnaire for students were made and validated by experts. The questionnaire consisted of 10 items, each using a 5-point Likert scale. At the end of the study, the feedback questionnaire was administered to the students, and their responses were recorded. Students were asked to complete the survey during class time and in the presence of the tutors. They were asked not to record their names, to preserve anonymity. The satisfaction index (SI) of each item was calculated using the following formula.[9]

$$\frac{[(n1*1) + (n2*2) + (n4*4) + (n5*5)] *20}{(n1 + n2 + n4 + n5)}$$

Here n is the total number of students gaining the score mentioned in the subscript for that particular item.

Feedback from faculty was obtained by one-to-one interview using standardized open-ended questions.

RESULTS

All the students of MBBS Phase III Part 1 were enrolled in the study. However, only 75 students filled the feedback questionnaire and their data was used for analysis. The scores obtained by traditional and rubric assessment methods are given in **Table 2**. A statistically significant difference between scores at 95% CI (p-value <0.001) was obtained by the two assessment methods.

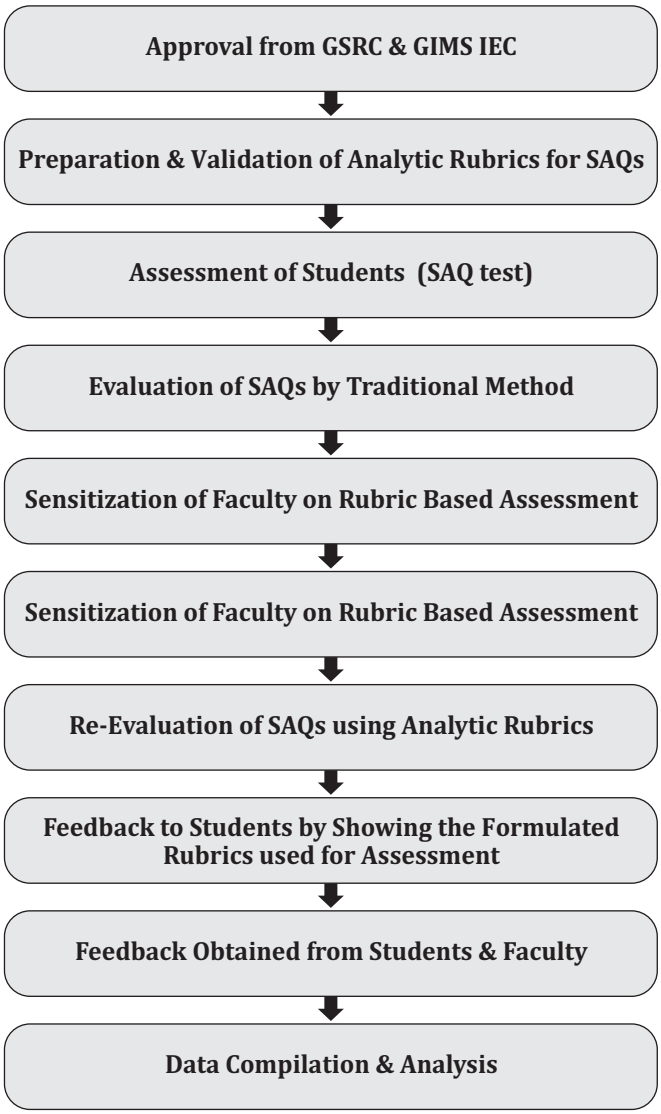
The scores were compared using Wilcoxon Signed Rank test Feedback regarding Rubrics The questionnaire used for obtaining students' feedback and their responses is given in **Table 3**. Scores are presented as absolute number of responses to each statement and as percent (mentioned within bracket). Here 1= Strongly disagree, 2=Disagree, 3=Neutral, 4 =Agree, 5= Strongly agree, SI- satisfaction index. This feedback survey reveals a positive reception of the rubric's method of assessment among students.

A majority of participants agree that rubrics provide a clear understanding of assignment and exam expectations, with 78.7% indicating agreement. Similarly, the criteria in the rubrics are perceived as fair and objective by 80% of respondents, with 62.7% agreeing and 17.3% strongly agreeing. Respondents also feel that rubrics clarify how

Table 1: The Criteria and Levels used For Validation of the Assessment Rubrics.

S. No.	Criteria	Levels			
		A. Excellent (4-5)	B. Good (3-4)	C. Fair (2-3)	D. Poor (<1)
1.	Knowledge of Forensic Medicine Concepts Extremely important Very important Important Less important Not Important.	Demonstrates an exceptional understanding of key concepts in forensic medicine, including terminology, principles, and methodologies. Provides accurate and comprehensive explanations.	Demonstrates a good understanding of key concepts in forensic medicine, with minor inaccuracies or omissions. Provides mostly accurate explanations.	Demonstrates a basic understanding of key concepts in forensic medicine but lacks depth or clarity. May contain significant inaccuracies or omissions.	Demonstrates little to no understanding of key concepts in forensic medicine. Contains numerous inaccuracies or omissions.
2.	Application of Concepts to the Scenario Extremely important Very important Important Less important Not Important.	Applies forensic medicine concepts effectively to the given scenario, demonstrating insight and critical thinking. Offers well-reasoned analyses and interpretations.	Applies forensic medicine concepts to the scenario adequately, with some lapses in insight or critical thinking. Offers mostly coherent analyses and interpretations.	Applies forensic medicine concepts to the scenario superficially, with limited insight or critical thinking. Offers vague or simplistic analyses and interpretations.	Fails to apply forensic medicine concepts to the scenario effectively. Lacks insight and critical thinking. Offers incomplete or irrelevant analyses and interpretations.
3.	Clarity and Organization of Response Extremely important Very important Important Less important Not Important.	Presents ideas clearly, logically, and coherently. Organizes response effectively, with a clear introduction, body, and conclusion. Transitions smoothly between ideas.	Presents ideas with clarity but may lack consistency or coherence in the organization. May have minor issues with transitions between ideas.	Presents ideas with some clarity but lacks consistency or coherence in organization. May have significant issues with transitions between ideas.	Presents ideas unclearly or illogically. Organizes response ineffectively, lacking a clear structure or coherence. Transitions between ideas are absent or confusing.
4.	Use of Evidence and Examples Extremely important Very important Important Less important Not Important.	Supports arguments with relevant evidence and examples from forensic medicine literature or case studies. Integrates evidence seamlessly into the response.	Supports arguments with mostly relevant evidence and examples from forensic medicine literature or case studies. Integrates evidence adequately into the response.	Provides limited or inconsistent support for arguments with evidence and examples. May not integrate evidence effectively into the response.	Fails to provide relevant evidence or examples to support arguments effectively.
	Language and Mechanics Extremely important Very important Important Less important Not Important	Demonstrates exemplary language use, including precision, clarity, and sophistication. Contains few to no errors in grammar, punctuation, or spelling.	Demonstrates good language use, with occasional lapses in precision or sophistication. Contains minor errors in grammar, punctuation, or spelling.	Demonstrates basic language use, with notable lapses in precision or sophistication. Contains significant errors in grammar, punctuation, or spelling.	Demonstrates poor language use, with frequent lapses in precision or sophistication. Contains numerous errors in grammar, punctuation, or spelling.

Flowchart of Methodology is given below:



their work will be graded, as 85.2% either agree or strongly agree with this statement. As per the feedback, most of the participants felt that rubrics may improve they write their answers to short answer questions. Feedback provided through rubrics is considered helpful and constructive by 78.6% of respondents. While a majority (60%) agree that rubrics reduce grading subjectivity, 32% feel that this is not the case. Rubrics are also seen as useful for identifying specific areas needing improvement by 79.7% of respondents. Approximately 79% participants expressed the need of Rubrics for assessment in other subjects. A majority of respondents (81%) endorsed the clarity and ease of understanding of the rubric language. Finally, a preference for rubrics over other assessment methods is expressed by 67.5% of participants, indicating a strong overall favorability towards this assessment approach.

The satisfaction index was calculated for each item of the feedback questionnaire using the formula given above. Over a range of 1–100, the satisfaction index for all the items was above 80%. The maximum satisfaction index of 87 was for the items 3 & 5 which stated that the Rubrics helped them in understanding the grading method and provided them with constructive feedback respectively. The students were satisfied in all aspects by this method of assessment.

The faculty were interviewed using standardized open-ended questions. The faculty views on assessment using rubrics were very promising. They felt that this type of assessment should be used for questions of other formats also. They felt that using Rubrics based assessment is more transparent, unbiased, objective and less time consuming".

They were able to give feedback in a structured way after this assessment method and found students to be more satisfied with this marking system. Some of the in verbatim comments by the faculty include "I was very much contented by my assessment using Rubrics"; "I find it less time consuming"; "This method is as useful for a novice teacher as it is for an experienced teacher". Similar to students, the faculty were also satisfied by this assessment method and recommended using it further.

DISCUSSION

In the study, the analytical rubrics for assessment of Short Answer Questions (SAQ) were used during formative examinations in the department of Forensic Medicine and Toxicology and feedback of the students and faculty was obtained. The purpose of the study was to create an objective, unbiased and structured assessment instrument that assesses students' ability to comprehend, analyse and apply the concepts.

Feedback from faculty and students was extremely positive, with high levels of satisfaction noted with various aspects of the rubric assessment method. Students appreciated the clarity and fairness of the rubrics (84% SI), which helped them understand how their work was being graded and identify specific areas for improvement. The feedback provided through the rubrics was perceived as constructive and helpful in improving the quality of student work (87% SI). Faculty also recognized the benefits of using the rubrics, particularly in terms of reducing subjectivity and providing clearer, more useful feedback to students.

In this study, the feedback survey reveals a positive

Table 2: Scores Obtained by the Students in the Test Containing 04 SAQs of 2.5 Marks each.

	Scores Obtained by Traditional Assessment Method (MM- 10)	Scores Obtained by Rubric's Method of Assessment (MM- 10)
Maximum	5.5	6
Minimum	0	1
Mean ± SD	3.44 ± 1.04	4.11± 1.12
Median	3.75	4.25
Interquartile Range	3-4	3.5-5
Mean + SD of Difference in Paired Scores	0.67 +1.42 (0.31-1.03)	
P-value	<0.001	

Table 3: Responses-Absolute Number (n) and Percent (%) to each Item of the Feedback Questionnaire, and Satisfaction Index.

S. No	Items	1	2	3	4	5	SI
1.	The rubrics method of assessment provides a clear understanding of what is expected in assignments and exams.	1(1.3%)	0%	15(20%)	45(60%)	14(18.7%)	84
2.	The criteria outlined in the rubrics were fair and objective.	0	1(1.3%)	14(18.7%)	47(62.7%)	13(17.3%)	84
3.	I was able to understand how my work was graded.	0	0	11(14.9%)	40(54.1%)	23(31.1%)	87
4.	I will be able to attempt SAQs in a better way.	0	1(1.4%)	16(21.6%)	37(50%)	20 (27%)	86
5.	I find the feedback provided through rubrics to be helpful and constructive.	0	0	16 (21.3%)	37 (49.3%)	22 (29.3%)	87
6.	I feel that rubrics reduce the subjectivity in grading.	0	6 (8%)	24(32%)	29(38.7%)	16 (21.3%)	82
7.	The rubrics help me identify specific areas where I need improvement.	0	0	15(20.3%)	43 (58.1%)	16 (21.6%)	85
8.	I feel the Rubrics should be used for assessment in other subjects also.	0	1(1.3%)	16 (21.3%)	43 (57.3%)	15 (21.3%)	84
9.	The language used in the rubrics was clear and understandable.	0	0	17 (22.7%)	44 (58.7%)	14 (18.7%)	85
10.	I prefer the rubrics method of assessment over other methods of assessment.	0	0	24(32.4%)	36 (48.6%)	14 (18.9%)	86

reception of the rubric's method of assessment among students. A majority of participants agree that rubrics provide a clear understanding of assignment and exam expectations, with 78.7% indicating agreement. These results are similar to the study by Andrade and Du (2005) which concluded that rubric-guided assessment improved student work quality and fostered greater engagement and self-regulation among learners.[1]

In this study, the majority of students perceived the criteria in the rubrics as fair and objective. Respondents also felt that rubrics make give more clarity about grading of their assignments. Similar to this study, Brookhart (2013) also emphasized that assessment rubrics enhance instructional clarity and facilitate more meaningful feedback, thereby empowering students to take ownership of their learning journey.[2]

A majority agree that rubrics reduce grading subjectivity, this finding corroborates to the conclusion of many other studies that emphasize the importance of rubrics in promoting clarity, consistency, and fairness in assessment practices within medical education.[3-4,10]

The feedback results also suggest that assessment rubrics may help in identifying specific areas that need improvement. In higher school setting, assessment rubrics have shown to be helpful in identifying areas of improvement, however none of medical literature have mentioned this aspect of rubrics assessment.[5]

Students (78.6%) in this study considered feedback as a pertinent aspect of rubric based assessment, thus improving their performance. Similar to this, Panadero and Jonsson (2013) emphasized the role of rubrics in providing actionable feedback that facilitates self-

regulation and promotes continuous improvement in student performance.[6]

A majority of respondents (81%) felt that the rubric language was clear and easy to understand. The pioneers in rubrics-based assessment emphasized the importance of clarity and easy comprehension of the language by the students, while formulating the criteria of rubrics.[11-12]

The strength of the study is that this method has been introduced for assessing SAQs in Forensic medicine for the first time. The study is limited by small sample in terms of students as well as questions assessed.

Despite the positive results, the implementation of analytical rubrics is not without challenges. The formulation of rubrics and its validation is tedious and time consuming. Motivating faculty to use this assessment tool is another challenge. Future research could include more number of assessments through this method and exploring the long-term impact of rubric-based assessments on student learning and outcomes, as well as their applicability to other disciplines within medical education.

CONCLUSION

In conclusion, the comparison between traditional assessment methods and the rubric-based approach revealed a statistically significant improvement in scores following the introduction of the rubric method, with a p-value less than 0.001. Despite this, the correlation between scores remained weak and statistically insignificant.

Feedback from participants was overwhelmingly positive, with a majority appreciating the clarity and effectiveness of the rubric-based assessment in enhancing the quality of their work and addressing specific subject areas. Overall, while the rubric method led to significant improvements in scores and was well-received, the weak correlation suggests that other factors may also influence performance outcomes.

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Original Research Paper

Nail as A Biomarker for Age Estimation in Chandigarh and Haryana Region

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ABSTRACT

Introduction: This study explores the potential of utilizing nail composition as a reliable biomarker for age estimation in the Haryana and Chandigarh regions of India in this study total of 360 fingernail samples were collected from various aged individuals between 1.5 and 60 years and categorized into six age groups for comprehensive analysis. Each sample underwent a standardized cleaning protocol followed by advanced analytical procedures, including Attenuated Total Reflectance Fourier-Transform Infrared Spectroscopy (ATR-FTIR) and multivariate statistical analysis using Principal Component Analysis (PCA). The results demonstrated significant correlations between specific spectral features of nail keratin and age groups. External validation and blind testing further supported the robustness of the methodology, yielding 100% accuracy in age classification. These findings suggest that fingernails can serve as effective biological markers for age estimation, offering practical applications in forensic science and anthropological research. This study contributes to a deeper understanding of nail biochemistry and its implications for demographic profiling.

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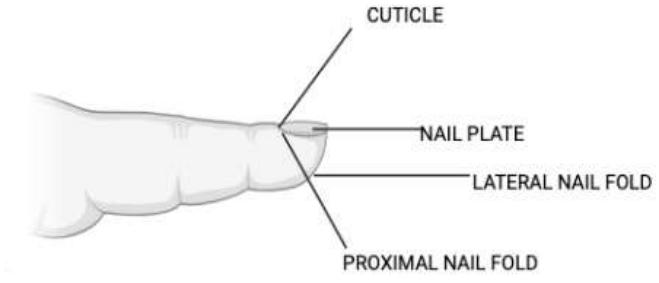
INTRODUCTION

The relationship between biological markers and age estimation has become a focal point of interest in both forensic and anthropological research, especially regarding regional variations[1] The unique environmental, dietary, and lifestyle factors inherent to these areas are likely to influence the physical and chemical properties of nails, rendering them significant indicators of chronological age.[2-3]

By utilizing these advanced analytical techniques to analyse nail samples from various age groups, this research seeks to establish meaningful correlations between nail and their characterisations by various parameters.[4] It has been know that Nails, primarily are composed of hard keratin, representing a unique biological material that can yield significant forensic insights. The structure of nails includes the nail plate, nail bed, and matrix, each contributing to their overall function and resilience. Recent studies have shown that nails not only reflect an individual's health and environmental exposure but also encapsulate aspects of their biological age through the incorporation of trace elements and metabolites during growth[5] **(Figure 1)**.

Figure 1: Showing Human Nail Parts



Understanding the biochemical composition of nails is crucial in forensic science, particularly in age estimation, as variations in nail morphology and chemical makeup can provide valuable clues about an individual's life history.[6] Traditionally, the analysis of nails found at crime scenes involved invasive methods like DNA extraction followed by DNA fingerprinting leading to the damage or deration of the evidence.[7]

However, with advancements in forensic technology, there is increasing interest in non-invasive techniques that preserve the integrity of the evidence while still providing detailed and accurate information. One such technique is Attenuated Total Reflectance Fourier-Transform Infrared (ATR-FTIR) spectroscopy, a powerful, non-destructive method for identifying and analysing materials at the molecular level without direct contact with the sample.

As we know that the nail as an evidence plays a crucial role in forensic science, particularly in cases involving assault, homicide, or sexual violence. Fingernails and toenails can serve as valuable trace evidence in forensic investigations. As a result, enhancing non-invasive techniques for analysing these samples can be extremely beneficial. During physical altercations, victims often scratch or claw at their attacker in an attempt to defend themselves, which can leave behind material from the perpetrator on the victim's nails.

This material, along with the nails themselves, can provide crucial evidence for linking a suspect to the crime. By improving and refining non-invasive analysis techniques, forensic experts can more easily and quickly extract important information from nails without compromising the integrity of the evidence.[8]

These material can be collected and analysed to identify the attacker or to confirm the presence of a suspect. Additionally, nails may contain other biological evidence, such as semen or saliva, which can further provide crucial information in sexual assault cases.[9-11] The objective of this research paper is to explore the application of ATR-FTIR as a non-invasive technique for the identification of nails at crime scenes.

This paper will discuss the principles of ATR-FTIR, its forensic relevance, and how it can be used to identify and analyse substances present on nails, including biological residues, trace chemicals, and forensic markers. The paper will also address the potential advantages of ATR-FTIR over traditional methods, including its non-destructive nature, rapid results, and ability to provide detailed molecular information from a sample without the need for sample preparation or alteration.

This study aims to investigate the potential of nail composition as a reliable biomarker for age demographics in the Haryana and Chandigarh regions.[12]

The Role of Keratin in Nail Structure

Keratin is a fibrous structural protein found in the nails, hair, and skin, playing a critical role in providing strength and protection. The structure of keratin encountered from nails, when analysed using ATR-FTIR (Attenuated Total Reflectance Fourier-Transform Infrared Spectroscopy)[25-26], reveals the molecular composition and organization of this fibrous protein. Keratin in nails is primarily composed of long chains of amino acids, which form an α-helix structure, contributing to its rigidity and durability.

This helical structure is stabilized by hydrogen bonds between the amino acid backbone. In addition to the alpha-helices, keratin has a high proportion of cysteine residues, which contain sulphur atoms that form disulphide bonds. These disulphide cross-links between the protein chains further enhance keratin's strength and resilience. Through ATR-FTIR analysis, characteristic absorption peaks corresponding to amide I and amide II bands are observed, which are associated with the peptide bonds in the protein's backbone.

The sulphur-containing cysteine residues can also be detected, offering insights into the cross-linking and the overall structural integrity of the keratin in the nail. ATR-FTIR thus provides a detailed, non-invasive way to study the intricate molecular structure of keratin in nails, revealing its composition and the degree of cross-linking, which plays a crucial role in the nail's mechanical properties and resilience.

Thus, Keratin's unique composition enhances the rigidity and resilience of nail plates, which are essential for protecting the distal phalanx and improving tactile sensation.[14-15]

Keratin is notably characterized by a high content of sulphur-rich amino acids, particularly cystine. Cystine contains thiol groups that can form disulphide bonds with adjacent cystine residues, contributing to the overall stability and strength of the keratin structure. Understanding these biochemical properties is critical for forensic applications, as they can aid in the interpretation of evidence and enhance the accuracy of criminal investigations.[16]

Additionally, trace elements such as zinc, copper, and selenium are vital for maintaining nail health, as they support keratin synthesis and contribute to the structural integrity of the nails. Deficiencies or imbalances in these trace elements can lead to changes in nail morphology, potentially indicating systemic issues that may serve as biomarkers for age estimation.

Therefore, understanding the intricate relationship between keratin and trace elements not only deepens our knowledge of nail biology but also has significant implications for forensic science, particularly in demographic studies.

The type of keratin present in nails is alpha-keratin, recognized as the strongest among proteins, providing structural integrity and support for gripping and manipulating objects. Furthermore, alpha-keratin contributes to the formation of alpha-helical polypeptides. [17-19]

Techniques used for Fingernail Analysis

Research on fingernail clippings focuses on the analysis of trace elements, both organic and inorganic, which can provide insights into environmental exposure, geographical factors, and dietary patterns. Various instrumental techniques have been utilized for fingernail analysis, including:

Atomic Absorption Spectroscopy (AAS): Keratin, being a fibrous protein found in human hair, nails, and skin, plays a significant role in forensic science, particularly in the analysis of trace evidence and the determination of exposure to various substances.[20] AAS works by measuring the absorption of light (usually in the ultraviolet or visible spectrum) by atoms in a sample. In forensic science, AAS is typically used to detect heavy metals or other elements that may be present in keratin-containing tissues, such as hair or nails.

For example, hair samples are often examined for elements like lead, mercury, or arsenic, which can be indicative of poisoning, environmental exposure, or illicit drug use. Since keratin in hair and nails retains elements absorbed by the body over time, it can provide a record of long-term exposure to toxic substances.[21-23]

Neutron Activation Analysis (NAA): NAA plays an essential role in forensic investigations by allowing for the detailed examination of keratin-containing tissues for trace elements. Its non-destructive nature and high sensitivity make it a powerful tool in identifying long-term exposure to toxic substances, drugs, or environmental contaminants, thus providing critical evidence in criminal cases. Whether used to detect poisons, metals, or other elements, NAA aids forensic scientists in linking suspects or victims to specific locations, events, or causes of death, making it an invaluable technique in modern forensic science.[24]

Inductively coupled plasma mass spectrometry (ICP-MS): ICP-MS plays a crucial role in forensic science by providing a highly sensitive and precise method for analysing keratin tissues such as hair and nails for trace elements. Its ability to detect a wide range of toxic metals, drugs, and environmental contaminants at very low concentrations makes it invaluable for uncovering historical exposure to harmful substances, aiding in the investigation of poisoning, environmental exposure, and even criminal activities. By offering detailed elemental profiles, ICP-MS helps forensic scientists link suspects to specific exposures or toxic events, thereby advancing justice in forensic toxicology.[25]

Laser-Induced Breakdown Spectroscopy (LIBS): Laser-Induced Breakdown Spectroscopy (LIBS) has emerged as a powerful tool for the rapid, non-destructive analysis of keratin-rich human tissues like hair and nails in forensic investigations. Its ability to detect and quantify trace elements such as heavy metals, toxins, and drugs at high spatial resolution makes it a valuable technique for uncovering past exposure to harmful substances.

The real-time analysis and minimal sample preparation requirements of LIBS make it particularly well-suited for forensic applications, where time and precision are critical. By providing elemental profiles of keratin samples, LIBS contributes to forensic investigations involving poisoning, environmental exposure, or drug abuse, helping to establish connections between suspects and victims, and offering critical evidence in criminal cases.[26]

Nuclear Magnetic Resonance (NMR): Nuclear Magnetic Resonance (NMR) spectroscopy is a valuable tool for forensic science, especially in the analysis of keratin-rich tissues such as hair and nails. It provides detailed chemical profiles that can identify a wide range of substances, including toxins, drugs, and heavy metals, which may be relevant in cases of poisoning, drug abuse, or environmental exposure.

Additionally, NMR allows for non-destructive, highly sensitive, and comprehensive analysis, making it an essential technique in modern forensic toxicology. Through NMR, forensic scientists can obtain critical

information that helps establish the cause of death, confirm criminal activity, or shed light on the circumstances surrounding a case.[27]

Raman Spectroscopy: Raman spectroscopy is a powerful and versatile technique for examining human keratin-rich tissues, such as hair, nails, and skin, in forensic science. Its ability to provide detailed molecular and structural information makes it invaluable in detecting and identifying drugs, toxins, and other substances that may be incorporated into keratin over time. With advantages such as non-destructive analysis, minimal sample preparation, and high sensitivity, Raman spectroscopy is a critical tool for forensic toxicology, helping to uncover the presence of illicit substances, determine the history of exposure, and aid in criminal investigations.[33]

Thus, all the above techniques Techniques play crucial roles in forensic investigations, particularly in the examination of keratin-rich tissues such as hair, nails, and skin. As, together, these techniques enable forensic scientists to gather critical evidence from biological samples, trace toxic or drug-related exposures, and contribute to solving criminal cases involving poisoning, overdose, and long-term substance abuse, making them indispensable tools in modern forensic science.[29]

MATERIAL AND METHODS

Study Design

The study is designed as a cross-sectional observational study aimed at exploring the potential of human nails as reliable biomarkers for estimating chronological age. The study was conducted in the Chandigarh and Haryana regions, involving a representative sample of 36 healthy individuals by taking all the 10 nails from each individual thus the sample size come out to be 360. The individuals aged between 1 year to 60 years. Participants were selected through stratified random sampling to ensure a balanced distribution across various age groups and both sexes. Fingernail samples were collected under standardized conditions, and relevant demographic and lifestyle data was also recorded through structured questionnaires.

The nail samples were analysed for physical characteristics such as thickness and morphology using calipers and biochemical properties were analysed through techniques such as Fourier-transform infrared (FTIR) spectroscopy. These biochemical properties helped in analysing the keratin content through these nail clippings. The relationship between nail parameters and chronological age is being statistically analysed using correlation and regression models. The study aims to develop a predictive model for age estimation based on nail as a biomarkers, while also examining regional and sex-based variations. Ethical clearance was not required as no invasive sample was taken like blood , semen , saliva etc . The consent was only obtained by utilising the questionnaire and informed consent was secured from all volunteers , ensuring confidentiality and adherence to ethical standards throughout the research.

Exclusion and Inclusion Criteria: During this study only, healthy individuals were included. The healthy status of participants was confirmed through structural questioner designed to screen for underlying medical conditions or lifestyle factors that could influence the nail biology. The age included was only 1 years to 60 years. Individuals above 60 years were not included as after 60 years the biochemical metabolites start reducing down thus effecting the study.

During this study, only healthy individuals were included. The age range of the participants was limited to 1 to 60 years. Individuals above 60 years of age were excluded from the study, as it is well-documented that biochemical metabolites and physiological processes begin to decline significantly after this age. Including older participants could have introduced variability and confounding factors, thereby affecting the accuracy and reliability of the study's findings related to age estimation using nail biomarkers.

Sample Collection

A total of 360 fingernail samples were collected using a clipping method, with 10 samples obtained from each donor. The size of each nail clipping was approximately 1 mm. Samples were collected from 36 individuals over a period of six months, encompassing ages ranging from 1.5 years to 60 years. Prior to collection, written consent was obtained from each participant; for those under 18 years of age, consent was secured from their parents. The collected samples were stored in zip-lock pouches at room temperature. Each volunteer's nail clipping was assigned a unique identification code for tracking purposes.

Sample Preparation

Each fingernail clipping was cleaned with acetone to remove any dust and debris, ensuring that there were no contaminants that could interfere with the examination of the samples. After cleaning, the clippings were properly air-dried and stored accordingly. For the analysis using Attenuated Total Reflectance Fourier-Transform Infrared

Spectroscopy (ATR-FTIR), the samples were categorized into six age groups: 1-10 years (Children), 11-20 years (Adolescents), 21-30 years (Young Adults), 31-40 years (Middle-Aged Adults), 41-50 years (Older Middle-Aged Adults), and 51-60 years (Elderly). Each age group was assigned a unique code: A, B, C, D, E, and F, respectively. **(Table 1)**

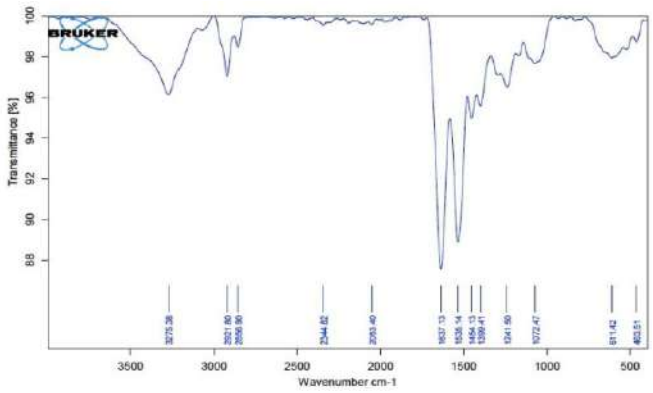
Table 1: Table Showing Age Groups and Data of Peak Intensity Range

Sample Name	Age Group	Peak Intensity
A	1-10	1452-1460 cm-1
B	11-20	1459-1479 cm-1
C	21-30	1520-1531 cm-1
D	31-40	1532-1533 cm-1
E	41-50	1530-1534 cm-1
F	51-60	1530-1535 cm-1

Spectra Acquisition and its Interpretation

The sample analysis was performed using a Bruker Alpha II ATR-FTIR spectrophotometer equipped with a diamond crystal detector, operating within a mid-range of 4000 to 400cm^{-1}. Each sample was scanned four times at a resolution of 16cm^{-1}. A background spectrum was collected without the sample on the crystal, followed by a minimum of three scans for each nail clipping sample. Pre-treatment methods, including baseline correction, smoothing, normalization (using the Standard Normal Variate (SNV) method), and first-order derivative analysis, were applied to all spectra prior to the application of chemometric techniques. The average spectra resulting from these treatments were utilized for subsequent chemometric analysis. **(Figure 2)**

Figure 2: Showing Peak intensities of Amide I and Amide II



To ensure the reliability of the data, both reproducibility and repeatability were assessed for each sample. Additionally, each sample was analyzed at one-month intervals over a six-month period to evaluate the persistence of the keratin data.

Chemometric Analysis

Principal Component Analysis (PCA) is a valuable chemometric technique particularly suited for datasets where the number of features significantly exceeds the number of instances. It simplifies complex data by reducing the original variables into a smaller set of Principal Components (PCs) that capture the directions of maximum variance within the dataset.[31]

By projecting data along these Principal Components, PCA facilitates visualization of the overall structure and relationships within the data, effectively identifying groups of similar and differing samples. The first Principal Component is especially important, as it represents the direction of the greatest variance and highlights the most significant features of the dataset. This dimensionality reduction not only aids interpretation but also enhances the efficiency of subsequent analyses.

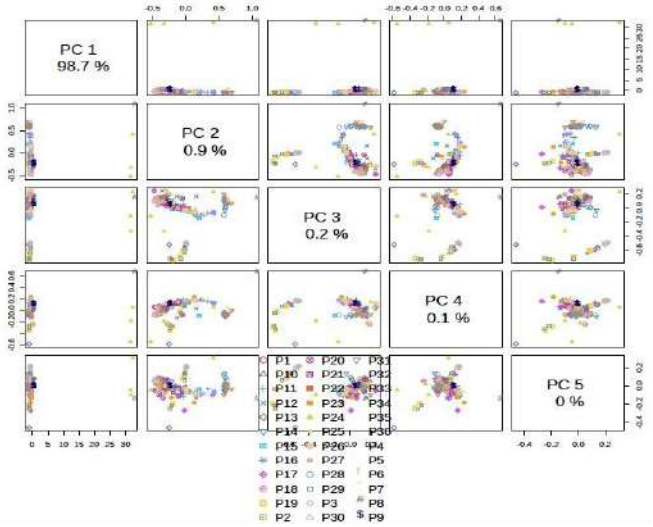
PCA is fundamentally a linear transformation that reorients the dataset into a new coordinate system. In this system, the first coordinate (the first Principal Component) captures the maximum variance present in the data, while each subsequent coordinate [30] (or Principal Component) is orthogonal to the previous one and accounts for progressively lesser variance. This transformation effectively reduces the dimensionality of the dataset while preserving as much information as possible. By converting a set of correlated variables into a smaller number of uncorrelated Principal Components, PCA simplifies the analysis and interpretation of complex data, enabling researchers to focus on the most significant patterns and relationships. This is particularly useful when the original variables are numerous and highly correlated, which can complicate visualization and understanding.

The reformulation of the dataset is achieved using eigenvalues and eigenvectors, which preserve essential information while transforming it into a new space. In PCA, the selection of significant Principal Components often relies on the Kaiser criterion, which posits that only PCs with eigenvalues greater than 1 are considered significant. An eigenvalue greater than 1 indicates that the PC accounts for more variance than an individual original variable.

Eigenvalues effectively represent the amount of variance captured by each Principal Component, reflecting the factors responsible for data compression. By focusing on these significant components, researchers can reduce

dimensionality while maintaining the most informative aspects of the dataset, thereby making analysis more manageable and interpretable. **(Figure 3)**

Figure 3: Showing PCA Analysis of Different Age Groups



Partial Least Squares Discriminant Analysis (PLS-DA)

Partial Least Squares Discriminant Analysis (PLS-DA) is a robust technique that combines variable selection with sample classification based on the extracted variables. It is particularly favored for categorization tasks, making it a powerful tool for both predictive and descriptive modeling.

As a supervised chemometric method, PLS-DA is designed to work with labeled data, enabling it to uncover relationships between the predictors and the response variable. This dual capability makes it both exploratory and quantitative. Its effectiveness has been well-established in various fields, including forensic science, where it aids in distinguishing between different classes of samples based on their chemical composition. Overall, PLS-DA is valued for its ability to handle complex datasets and provide clear insights into sample classification.[32]

RESULTS

Data Analysis and Interpretation

After the data analysis it is interpreted that each group showed a varying variation as age group 1-10 (A) showed peak intensity range from 1452-1460 cm-1 , age group 11 – 20 (B) showed peak intensity range from 1459-1479cm-1 , age group 21-30 (c) showed intensity range from 1520-1531cm-1 , age group 31-40 (D) 1532-1533cm-1 , age group 41-50 (E) showed range intensity from 1530-1534cm-1 , age group 51-60 (F) showed range intensity 1530-1535cm-1 .**(Table 1)**

SPECTRAL FEATURES

The analysis of the ATR-FTIR spectra is focused on visual peak interpretation across different age groups and sexes. [33] The absence of differences in spectra for samples from the same individual or from various locations on the same sample indicates a consistent chemical profile for fingernails, regardless of demographic factors. This finding could suggest that fingernail composition is stable and significantly influenced by age or sex.

PCA analysis has shown 98.7% variance according to age group data that comes out to be significantly amazing.

CONCLUSION

The findings of this study contribute to a growing body of evidence supporting the use of nails as a biological marker for age estimation. Earlier the nails encountered during the crime scene were analysed and examined by all the invasive methods.

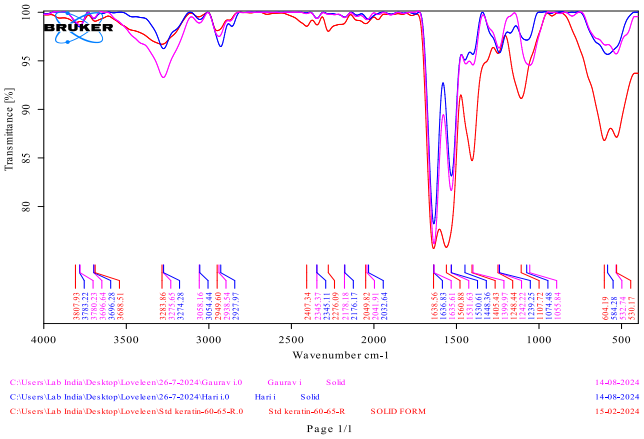
Thus the invasive techniques were time consuming and robust , therefore to challenge this techniques we have used ATR-FTIR instrumentation as main source for the examination. The ATR-FTIR technique proved to be an effective non-invasive method for analysing the chemical composition of nails, allowing for the detection of subtle changes that correlate with age. **(Table 1)** Thus it is observed that spectral changes in nail composition are consistent with the known physiological processes of aging. In individuals growing age it is seen that there is a progressive decrease in the protein content (specifically keratin) in the nails, as well as alterations in lipid composition. These changes are believed to be linked to reduced metabolic activity and the slowing of cellular turnover, which could explain the differences in nail composition across various age groups.

Earlier the traditional methods of age estimation, such as examining dental or skeletal markers, often require invasive procedures and may not be applicable in all forensic cases. Nails, on the other hand, are readily available and being non-invasive, they mark a valuable alternative for age estimation. While DNA-based methods offer high accuracy being more time-consuming and expensive. ATR-FTIR spectroscopy provides a balance between accuracy and practicality, with the added advantage of being non-destructive. **(Figure 4)**

DISCUSSION

This study aimed to explore the potential of using nail composition as a biomarker for age estimation in

Figure 3: Showing Comparison of 2 Samples with Standard of Different Ages



individuals from the Haryana and Chandigarh regions of India, utilizing Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) spectroscopy. The ATR-FTIR spectra of nails showed distinct peaks associated with various biochemical components such as proteins, lipids, and keratin. Specific variations in these spectral peaks were observed across different age groups, suggesting a correlation between nail composition and age. The study also found that as individuals age, the relative concentrations of certain functional groups (such as amide I and II bands, which correspond to protein content) and lipids in the nails significantly change. These changes were consistent with the known biochemical and physiological alterations in the human body as it ages. The analysis demonstrated that while there were some regional differences between Haryana and Chandigarh, the overall trend of age-related changes in nail composition remained consistent across both regions. This suggests that nail composition might serve as a reliable and universally applicable biomarker for age estimation, albeit with slight regional variations due to dietary or environmental influences. ATR-FTIR spectroscopy was shown to be a promising tool for non-invasive, rapid, and reliable age estimation using nail samples. The technique allows for the precise identification of biochemical markers without the need for extensive sample preparation, making it highly suitable for forensic applications, particularly in cases where other age-determination methods (e.g., dental or skeletal analysis) may be difficult or impractical. Thus , in forensic investigations, where the preservation of evidence is paramount, the use of ATR-FTIR for the identification and analysis of nails offers a promising avenue for advancing forensic science. By enabling accurate, non-invasive analysis, ATR-FTIR can provide crucial information while maintaining the integrity of evidence, thereby enhancing the overall investigative process and improving the chances of solving complex criminal cases.

Future Directions: To refine the age-estimation model, it would be beneficial to extend the study to other regions and incorporate larger age cohorts. Additionally, integrating machine learning algorithms with ATR-FTIR spectral data could improve the accuracy of age prediction by identifying complex patterns that might not be immediately apparent through visual inspection of the spectra. Investigating the relationship between specific age-related biomarkers and environmental factors could further enhance the understanding of nail composition and its use in forensic science. In conclusion, the use of ATR-FTIR spectroscopy to analyse nail composition holds promise as a reliable and non-invasive method for age estimation. The results of this study provide a solid foundation for future research and practical application in forensic science, particularly in contexts where traditional methods of age estimation may be challenging. Further studies and refinements of this technique could pave the way for its widespread adoption in forensic investigations.

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Review Article

Role of Tongue Prints and Morphology in Human Identification: A Review on an Emerging Forensic Tool

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ABSTRACT

Introduction: Forensic odontologists play a vital role in human identification, with the tongue emerging as a significant tool due to its unique features and secure position within the oral cavity. This review examines its anatomical characteristics, histopathological traits in identical individuals, and responses to causes of death, alongside widely used classification systems. The study also explores tongue abnormalities, sexual dimorphism, methodologies, and future research directions.

Materials and Method: A comprehensive literature review was conducted using PubMed/Medline, targeting articles from 2014 to 2024 containing the keywords "tongue," "print," and "identification." Data were categorized under headings like study aims, outcomes, tools, and samples, and analyzed along with cited references.

Discussion: Tongue prints are gaining recognition in forensic odontology and biometrics. Their uniqueness, even among identical twins, makes them highly reliable for identification. They also exhibit sexual dimorphism, aiding gender determination. Techniques such as visual inspection, digital photography, and sublingual vein analysis are used to record tongue prints. The tongue is particularly useful in mass disasters where identification via other means is challenging due to disfigurement. It also aids in diagnosing causes of death, such as drowning, hanging, or poisoning.

Conclusion: The tongue's unparalleled uniqueness, forgery resistance, and accessibility make it a promising tool for identification. As the only internal organ that can be protruded, it offers secure biometric applications in security, routine identification, and authentication. Despite its potential, tongue print recognition remains underexplored, warranting further research to harness its full capabilities.

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INTRODUCTION

Human identification is always an arduous job where a pivotal role is played by the forensic odontologist1. Biometric authentication as a tool for personal identification is also rising in popularity in recent years. Finger prints, facial recognition, iris and retinal scans are some of the techniques used in biometric identification of an individual.[1-3] Both hard and soft tissues in head and neck region have unique characteristics which might help in such identification.[1] Tongue prints as a biometric tool is gaining ground of lately.[4]

Distinctiveness of tongue: The tongue is a special body part. Due to its vital color, it is mentioned as the "Tongue of Life", in the Traditional Chinese Medicine.[2,4] Tongue is a

critical structure and due to its location in the oral cavity, it is under the protection from the environment outside. Superiorly it has palate, inferiorly floor of the oral cavity, bounded on lateral aspects by lower teeth, lips on the anterior side and pharynx posteriorly.

It has various functions to perform, like articulation of speech, perceiving the taste sensation and forming a bolus of food. It is the lone organ in the body which can be inspected and palpated with ease, as it can be drawn out. The morphological characteristics of the tongue including its color, form and surface details are unique for each individual[2-3,5-6] and is further proven by the fact that even identical twins have no resemblance in their tongue prints. The fact that it is unaffected by the external factors serves this as a tool for identification.[6]

A tongue print recognition system was introduced in 2007 by Liu et al.[3,7] The overall information present on the visible part of the tongue, its shape, texture is included as Tongue print. Many studies have implemented the methods such as Visual inspection and digital photography, which are time-tested.[3] The surface of the tongue may fluctuate as is controlled by the changes of the body; however, it has a largely stable geometric state over time. With this as a base, impression-based analysis is a preferred method to analyze the variations in morphological qualities of tongue.[7] The impression of the dorsal surface of the tongue along with its lateral borders is the "Lingual impression".[3]

Among the various biometric systems, tongue prints have numerous benefits over others like finger prints, retinal scan, and palm scan. The tongue is characteristic to each individual. Tongue has consistent surface textures and is not subject to variations or alterations. as it is genetically independent and is physically protected from the external environment.[3,8]

Further, in a study by Malik et al, statistically significant results (p value 0.043) were found with regard to sexual dimorphism with features present on the dorsum of the tongue like shape of the tongue, fissures, their depth and rough /smooth surface.[1] Thus, it provides assistance to disclose individual identity and in process the tongue is becoming a novel tool for biometric identification.[9]

Moreover, D Zhang et al in their study observed a recognition rate of 93.3%, establishing tongue prints as an effective aid for biometric authentication.[10] Emergent research advocates that tongue prints, in comparison to traditional biometric systems, provide a moderate-to-high accuracy rate with minimal external variability.[11] Thus, their reliability and accessibility makes the tongue prints the best tool of the majority. However, one of the few hinderances that may restrict the use of tongue prints is the pathologies and developmental abnormalities of the tongue.[9]

This review highlights the distinctiveness of tongue prints and their advantages compared to other biometric methods. Also, various practices for recording tongue prints, their classification and their utility in forensic odontology are discussed.

MATERIALS AND METHOD

A comprehensive literature review was conducted to assess the forensic significance of the tongue in human identification by searching research articles from Pub Med, Medline, Google Scholar, and Science Direct published between January 2014 and April 2024. The search was conducted using the following keywords in various combinations: "Tongue", "Tongue prints","Lingual impression","Human identification", "Biometrics", "Sexual dimorphism of tongue", "Forensic odontology", and "Cause of death and tongue." Boolean operators (AND, OR) were applied to enhance the search specificity and sensitivity.

Inclusion Criteria: Articles published in peer-reviewed journals between 2014 and 2024, Studies written in English language, Original research articles, reviews, and case reports focused on the forensic odontology, anatomy of tongue, oral histolopathology, and biometric aspects of the tongue, Studies discussing tongue morphology, tongue prints, sexual dimorphism, or the tongue's response to different causes of death, and Studies involving human subjects or cadaveric evaluations.

Exclusion Criteria: Articles not available in full text, Non-English publications, Studies focused solely on non-forensic or purely clinical/therapeutic aspects of the tongue (e.g., speech therapy, general oral pathology without forensic relevance), Animal studies and editorials without original data or substantial review content.

RESULTS & DISCUSSIONS

The tongue is assessed in living cases based on several factors, including vitality, color, shape, moisture, and movement. Its surface coating is typically a thin, uniform, clear-white layer, and any changes in these features can indicate illness, aiding in diagnosis. There are different classifications for tongue features but most widely used classification is described in Figure 1.[6]

The tongue's unique features and reactions to various causes of death make it an indispensable component of forensic analysis, aiding investigators in reconstructing circumstances surrounding a person's demise. **Table 1** explains the key role of tongue in forensic odontology.[9] **Table 2** shows difference in tongue features in living and deceased individual.[12-13]

There are different tongue abnormalities that may or may not be present in a person. These abnormalities can assist in identification during mass casualty situations and can also help in diagnosing related symptoms or conditions that could potentially lead to death, to mention a few :-

- Geographic tongue
- Hairy tongue
- Strawberry tongue
- Oral thrush
- Macroglossia
- Sjögrens's syndrome
- Leukoplakia
- Carcinoma of tongue
- Glossophryngeal neuralgia

Difference between tongue print and other biometric system have been studied in literature earlier and the features are classified in **Table 3** describing them about forensic identification purposes.[14-15]

While traditional methods for determining sex include examination of the pelvis, skull, DNA, and dentition, emerging biometric methods-such as tongue print analysis-offer promising, non-invasive, and accessible alternatives. Determination of sexual dimorphism using tongue prints is discussed in **Table 4**.[16]

However, further research involving larger sample sizes and consideration of ethnic variations is necessary to establish more conclusive evidence in this area.

With growing interest in biometric authentication and human identification, the development of a standardized procedure for recording tongue prints is essential.[2,4] Tongue prints can be obtained through various methods,

Table 1: Tongue Prints and its Role in Identification and Forensic Investigations.

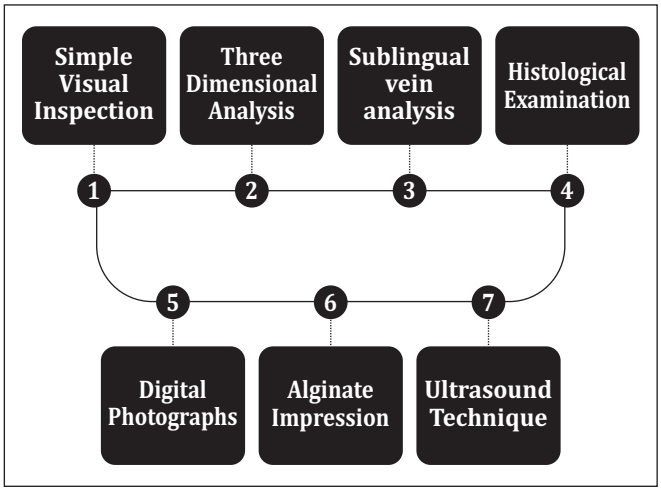
Aspect	Details
Key Role	Human identification using unique characteristics of the tongue.
Importance of Tongue	- Unique and easily examinable internal organ. - Resistant to tampering due to its position in the oral cavity.
Application of Tongue	1. Gender determination 2. Age estimation 3. Disaster victim identification (DVI) 4. Person identification
Tongue Characteristics	- Unique for each individual, even identical twins have distinct tongue prints. - Exhibits sexual dimorphism, aiding in gender identification.
Challenges Overcome	- Helps overcome human identification challenges, making it crucial in forensic investigations.

Table 2: Difference in Tongue Features in Living and Deceased Individual.

Feature	In Living Individuals	In Deceased Individuals
Color and Appearance	Pink due to blood circulation and oxygenation.	Pale or bluish due to the cessation of blood flow.
Movement	Highly flexible, capable of a wide range of movement (speaking, swallowing etc.).	Immobile due to muscle relaxation and rigor mortis.
Moisture	Moist, coated with saliva produced by salivary glands.	Dry with no saliva production, leading to shriveling.
Temperature	Maintains body temperature (around 37^0C or 98.6^0F).	Cool to the touch as the body cools down post-mortem.
Texture	Soft with papillae (small bumps) aiding taste and digestion.	Rougher or harder as dehydration affects the tissue.
Size and Position	Stable, rests comfortably in the lower part of the mouth.	May retreat protrude depending on rigor mortis and body position.

each capturing unique features for identification and diagnostic purposes. A simple visual inspection can reveal the colour, mobility, and surface textural variations of the tongue. Digital photographs are useful for documenting and identifying its shape. For three-dimensional analysis, the tongue's shape is assessed by joining three reference points, providing a detailed structural evaluation. Alginate impressions followed by cast preparation can accurately reproduce tongue features for study and comparison. Additionally, sublingual vein analysis is commonly employed in tongue diagnosis. To analyse tongue function, ultrasound techniques using a transducer placed in the sublingual area are also utilised. Tongue prints can be obtained in different ways as shown in **Figure 3**.

Figure 3- Recording and Identification of Tongue Prints.



Several studies have evaluated tongue morphology for personal identification and gender differentiation in forensic odontology. Garg et al. conducted an impression-based study on 206 individuals and found "U-shaped tongues were more frequent in males (74.3%) than females (61.0%), while V-shaped tongues were significantly more common in females (23.8%) compared to males (5.0%)". They also reported multiple "tongue fissures were predominantly observed in males (57.4%) whereas females mostly had smooth tongues without fissures (61.9%)."[1]

Similarly, Stefanescu et al. examined 270 adults and observed that sharp tongue tips were common in females, septate tips were frequent in males, and scrotal or geographical tongues were more prevalent in females.[6] In another study by Malik et al. involving 120 individuals, "U-shaped tongues were most common among males (71.7%), while V-shaped tongues were observed more in females." They also found fissured or geographic tongues more frequently in females, and "septate tongue tips were higher in females (20%) than males (8.3%)."[7] These findings indicate that tongue morphology, including shape, tip type, surface texture, and fissure patterns, shows significant gender-based variations, making it a potential

Table 3: Features Differentiating Tongue Prints from other Biometrics Systems.

Feature	Tongue Print	Other Biometric System (e.g., Fingerprints, Facial Recognition)
Uniqueness	Unique to each individual with distinct shape and surface roughness.	Fingerprints can be altered by erosion, injury or tampering.
Consistency	Physiological characteristics remain consistent and unaffected by external factors.	Retinal scans are sensitive to eye conditions like cataracts and astigmatism.
Immunity to external Influences	Insulated from the environment, ensuring stability and reliability.	Vulnerable to environmental factors, injury or intentional tampering.
Life Verification	Only living individuals can protrude their tongue for verification.	Other biometrics do not confirm life directly.
Reliability and Security	Offers superior reliability and security for biometric verification.	Can be vulnerable to forgeries or physical alternations, compromising security.

Table 4: Sexual Dimorphism in Tongue Characteristics.

Aspect	Details
Scrotal and Geographic Tongue	These features are more commonly found in female patients.
Tongue Tip Shape	Male patients typically have seperate tips, while females often have sharp ends at the lingual apex.
Tongue Length and Width	Males tend to have longer and wider tongues compared to females.

Table 5: Studies Done on Tongue Morphology and Features World Wide.

Author	Sample Size	Country	Methods Used	Result	Drawbacks	Conclusion
Corina Laura Stefanescu et at. 2014 (6)	M&F 270 (21-40 Years)	Rumania	- Alginate moulded impression - digital photographs	Scrotal tongue and geographic tongue are more commonly found in female patients	Classification on need to be formulated depending on the anatomic aspect of the tongue dorsal surface	The morphological aspect of tongue dorsal surface is unique for each individual.
Kritika Garg et al. July 2020 (7)	F:105 M:101 (21-30 Years)	Kanpur, India	- Digital photographs - Alginate moulded impression - impression cast with dental stone	- The most common tongue shape across both genders was U-shaped - Males had more scalloped borders - Multiple fissures were more common in males	Smaller than expected sample size	Gender based variations on tongue shapes, borders and fissures, which may provide insight into using tongue prints for gender determination.
Shilpa Dutta Malik et al. 2022 (1)	M:F 60:60 (18-35 Years)	Moradabad, India	- Digital photographs - Tongue impression	Most observed: - Rough surface texture (60% in male and 51.7% in female)	More studies with a larger sample size with relevance to ethnicity may be useful	Tongue prints based on tongue morphology can be a reliable source of identification with respect to sexual dimorphism.

tool for personal identification in forensic investigations. These studies have focused on different parameters such of tongue. The **Table 5** below provides a concise overview of key research findings on tongue morphology and features, highlighting their relevance to forensic identification and biometric studies.

Human identification can be a challenging task, but forensic odontologists play a crucial role in this process. The unique characteristics of the oral cavity, particularly dentition and tongue, distinguish humans from other mammals.[18] Jain AK et al. have defined "Biometric recognition, or simply biometrics, refers to the automated recognition of individuals based on their biological and behavioural characteristics"19 Zang D in 2007 discoursed different techniques such as spectral analysis, Gabor filters, and wavelet transforms that can be used for tongue image recognition, each yielding different outcomes.[10] The use of tongue biometrics in public systems such as banking was proposed in 2011.[20] In 2015 systems utilising two-dimensional dual-tree complex wavelet transform techniques for tongue recognition was anticipated.[21] Additionally in 2019, tongue scanners are currently under research and undergoing experimental testing.[22]

Histological Examination of the Tongue

Histological examination of the tongue reveals its potential as a unique biometric identifier due to its distinct morphological features. Studies have shown that the tongue's surface characteristics, such as shape, texture, and color, vary significantly among individuals, making it a reliable tool for personal identification. For instance, a study involving "300 subjects identified a predominance of U-shaped tongues (65%) and smooth surface textures (64%), pale pink was the most frequent color (57%)." While the tongue shows promise as a biometric tool, it is essential to consider the potential for variability due to factors such as age and health, which may influence its morphology.[21]

Genetic Independence: The unique morphology of each tongue suggests genetic independence, making it difficult to replicate.[6]

Role of Artificial Intelligence in Tongue Print

Liu Q in 2023, highlighted the integration of artificial intelligence with traditional tongue diagnosis, summarizing deep learning & machine learning applications in tongue image analysis and deliberated advances in calibration, detection, segmentation & disease classification, noting successful use of attention mechanisms, multiscale features, and prior knowledge.[22-25]

CONCLUSION

The human tongue is a unique organ with distinct static and dynamic characteristics that vary significantly between individuals. Its potential as a biometric authentication tool has been explored, and research indicates it is comparable to, if not superior to, existing biometric technologies.

Despite advancements in biometrics, tongue print recognition remains largely understudied and underutilized. However, with the escalating threat of identity fraud and emphasis on enhanced security, the human tongue's unique features make it an attractive solution.

The tongue offers unparalleled uniqueness, protected within the mouth and resistant to forgery. As the only internal organ protrudable from the body, it provides an accessible and secure means of identification. The growing need for reliable authentication, both locally and remotely, positions the tongue as a critical component in biometric technology. Its potential applications include high- stakes security, routine identification processes, and situations requiring absolute verification. In conclusion, the human tongue's distinctive characteristics and inherent security make it an exciting and timely solution for addressing the pressing challenges of identity verification and authentication.

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Review Article

Comprehensive Review: Rapid Chemical Tests During Autopsy for Determining Cause of Death and Time Since Death

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ABSTRACT

Determining the cause of death and estimating the time since death or post-mortem interval (PMI) are crucial aspects of forensic pathology. Rapid chemical tests provide preliminary results that can guide further toxicological and histopathological analysis. The Analysis of these tests is influenced by many factors like environmental, decomposition, and individual variability. But, still rapid chemical tests require careful validation and must be corroborated with confirmatory techniques for reliable forensic conclusion which will help in the administration of law and justice. This review explores the mechanisms, applications, and limitations of rapid chemical tests in forensic autopsies. Key tests related to poisons, drugs, metabolic disorders, and changes in body fluids are described. Challenges such as specificity, sensitivity, environmental influences, and interpretational pitfalls are discussed.

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INTRODUCTION

Forensic pathology plays a vital role in medico-legal investigations, with determining cause of death and estimating the post-mortem interval (PMI) being fundamental objectives.[1] Chemical tests provide rapid, preliminary insights that complement histopathological and toxicological analysis.

These tests helps to detect poisons, metabolic imbalances, and post-mortem biochemical changes that indicate the time elapsed since death.[2] Traditional autopsy findings, such as rigor mortis, livor mortis, and body cooling, have limitations, necessitating more objective biochemical markers.[3] Rapid chemical tests are particularly useful in forensic settings where timely results are needed to guide investigations.[4]

Specific chemical reactions can confirm the presence of toxic substances such as cyanide, carbon monoxide, and arsenic.[5] Similarly, various biochemical markers undergo significant changes after death. For example, potassium levels in vitreous humor, lactic acid buildup, and enzyme activity variations provide clues about PMI.[6] However, the interpretation of these tests is influenced by environmental factors- temperature & humidity, decomposition, and individual variability.[7]

Despite their usefulness, rapid chemical tests require careful validation and must be corroborated with confirmatory techniques for reliable forensic conclusions which will help in the administration of law and justice.[8] This review examines the principles, methodologies, and challenges associated with rapid chemical tests in forensic autopsy investigations.

DISCUSSION

Rapid Chemical Tests for determining the Cause of Death

Poison Detection

Cyanide Detection: Prussian blue test detects cyanide by forming a blue complex with ferric ions. Procedure: A sample of gastric contents or blood is treated with ferric ions and hydrochloric acid. If cyanide is present, the

solution turns blue. Mechanism: Cyanide binds to ferric ions, forming ferric ferrocyanide, which has a distinctive blue color.[9]

Carbon Monoxide (CO) Testing: Spectrophotometric analysis of carboxyhemoglobin in blood shows a cherry-red color if CO poisoning is suspected. Procedure: A blood sample is placed in a spectrophotometer to measure absorbance at specific wavelengths. Mechanism: CO binds to hemoglobin with high affinity, forming carboxyhemoglobin, which alters light absorption properties.[10]

Arsenic Detection: Marsh's test generates arsine gas, which forms a black precipitate on a heated porcelain surface. Procedure: The suspect sample is treated with zinc and acid to generate arsine gas. The gas is passed over a heated porcelain surface, forming a black metallic arsenic deposit. Mechanism: Arsine decomposes upon heating, reducing arsenic ions to elemental arsenic, which deposits as a black film.[11]

Drug and Alcohol Screening

Alcohol Estimation: The Cavett test uses potassium dichromate, which changes color upon reaction with ethanol. Procedure: Blood or urine is mixed with potassium dichromate and sulfuric acid. A color change from orange to green indicates the presence of ethanol. Mechanism: Ethanol reduces hexavalent chromium (Cr^{6+}) to trivalent chromium (Cr^{3+}), causing the color change.[12]

Opioids and Barbiturates: Marquis Reagent produces a violet hue for opioids and yellow for barbiturates. Procedure: A few drops of Marquis Reagent (formaldehyde and sulfuric acid) are added to the suspected substance. Mechanism: The reaction of formaldehyde with specific functional groups in opioids and barbiturates produces characteristic color changes.[13]

Metabolic and Endogenous Causes

Diabetic Ketoacidosis: Acetone detection in urine with Legal's test produces a red color. Procedure: Urine is treated with sodium nitroprusside and an alkaline solution. Mechanism: Acetone reacts with nitroprusside to form a red-colored complex.[14]

Uremia: Nessler's reagent detects ammonia, indicating renal failure. Procedure: A blood or urine sample is mixed with Nessler's reagent. A yellow to brown coloration suggests the presence of ammonia. Mechanism: Ammonia reacts with potassium tetraiodomercurate to form a colored complex.[15]

Acute Myocardial Infarction/Ischemia Detection

Troponin Test: Immunoassay-based detection of cardiac troponins (cTnI and cTnT) in blood indicates myocardial injury. Procedure: A blood sample is collected using aseptic conditions and tested using an enzyme-linked immunosorbent assay (ELISA) or lateral flow immunoassay. Mechanism: Cardiac troponins, released from necrotic myocardial cells, bind to specific antibodies, producing a colorimetric or fluorescence signal.[16]

Creatine Kinase-MB (CK-MB) Test: CK-MB isoenzyme levels in blood rise following cardiac injury. Procedure: A blood sample is collected using aseptic conditions and analyzed using an immunoassay or electrophoresis. Mechanism: CK-MB leaks from damaged cardiac muscle cells, serving as a biochemical marker of myocardial infarction.[17]

Myoglobin Test: Myoglobin, an early marker of cardiac ischemia, is detected through immunoassays. Procedure: Blood samples are collected using aseptic conditions and tested with lateral flow assays or ELISA. Mechanism: Myoglobin is rapidly released from ischemic cardiac muscle, appearing in circulation within hours of infarction.[18]

Nitroblue Tetrazolium (NBT) and Triphenyl Tetrazolium Chloride (TTC) Tests: These tetrazolium salts are used to detect ischemic myocardial tissue. Procedure: Heart tissue sections are incubated with NBT or TTC solutions. Viable myocardium stains deep blue or red, whereas infarcted tissue remains unstained. Mechanism: Tetrazolium salts act as redox indicators; dehydrogenase enzymes in viable cells reduce NBT to formazan (blue) or TTC to triphenyl formazan (red), whereas infarcted tissue lacks enzyme activity and remains unstained.[19]

Differentiation of Exudate from Transudate - Rivalta Test

Rivalta Test: Used to differentiate exudates from transudates in pleural, peritoneal, or pericardial effusions. Procedure: A drop of effusion fluid is added to a test tube containing acetic acid in distilled water. If a precipitate forms, the fluid is classified as an exudate; if it dissolves, it is a transudate. Mechanism: Exudates contain high protein concentrations and mucin, which react with acetic acid to form a visible precipitate, while transudates, being low in proteins, do not form a precipitate.[20]

Rapid Chemical Tests for Estimating Time Since Death

Post-Mortem Biochemical Changes

Lactic Acid and pH Levels: Post-mortem glycolysis leads to lactic acid accumulation, reducing tissue and blood pH. Procedure: Blood or tissue samples are analyzed using pH meters or lactate assays. Mechanism: Oxygen deprivation after death causes anaerobic metabolism, increasing lactic acid, which lowers pH levels.[21]

Body Fluid Changes

Potassium in Vitreous Humor: Increased potassium levels correlate with PMI. Procedure: Vitreous humor is collected and analyzed using flame photometry or ion-selective electrodes. Mechanism: Potassium leaks from intracellular compartments into extracellular fluids post-mortem, increasing its concentration over time.[22]

Hypoxanthine Levels: An enzymatic reaction detects hypoxanthine accumulation, useful in early PMI estimation. Procedure: Vitreous humor is tested using hypoxanthine oxidase, producing a color change. Mechanism: Hypoxanthine, a product of ATP degradation, accumulates after death due to halted metabolism.[23]

Decomposition Markers

Putrescine and Cadaverine Detection: Ninhydrin test produces a purple color in the presence of these amines. Procedure: Tissue samples are treated with ninhydrin reagent. Mechanism: Ninhydrin reacts with amines from protein decomposition, forming Ruhemann's purple.[24]

Adipocere Formation: Sudan III stain identifies fat saponification in prolonged post-mortem cases. Procedure: Tissue samples are stained with Sudan III, which binds to lipid components. Mechanism: Adipocere forms due to hydrolysis and hydrogenation of body fat, preserving tissues.[25]

Differential Diagnosis of Air and Putrefaction Gases - Pyrogallol Test

Pyrogallol Test: Used to differentiate atmospheric air from putrefaction gases in body cavities. Procedure: A sample of the suspected gas is introduced into a test tube containing an alkaline pyrogallol solution. If the gas is oxygen-rich (such as atmospheric air), the solution darkens due to oxidation; if it contains putrefaction gases (e.g., hydrogen sulfide, methane), no significant color change occurs. Mechanism: Pyrogallol, in the presence of an alkaline medium, rapidly absorbs oxygen and undergoes auto-oxidation, leading to a color change. However, putrefaction gases lack sufficient oxygen to cause this reaction, distinguishing them from atmospheric air.[26]

Challenges and Limitations

Specificity and Sensitivity.[27]

- False positives and negatives limit reliability.
- Cross-reactivity with medications and environmental contaminants.

Environmental and Post-Mortem Factors.[23]

- Temperature, humidity, and microbial activity influence results.
- Post-mortem redistribution complicates interpretation.

Legal and Ethical Considerations.[28-30]

- Rapid tests require confirmation by advanced analytical methods.
- Misinterpretation can impact forensic and legal proceedings.

CONCLUSION

Rapid chemical tests play a vital role in forensic autopsies, providing quick and preliminary insights into the cause and time since death. However, their limitations necessitate careful interpretation and corroboration with confirmatory techniques. Future research should focus on improving test accuracy and standardization in forensic applications which will help in the administration of law and justice.

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Review Article

The Challenges Faced by Administrators in the Implementation of Green Corridors for Cadaveric Organ Transportation- Factors to Ponder

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ABSTRACT

Organ transplantation remains a vital, life-preserving intervention for individuals suffering from end-stage organ failure. In India, however, a considerable disparity persists between the number of organs needed and those available, emphasizing the importance of the swift and efficient transport of retrieved organs. Green corridors—specialized, traffic-free routes created to facilitate rapid organ movement—are instrumental in reducing ischemic times and enhancing transplant success rates. Although major cities have reported successful utilization of green corridors, several obstacles prevent their widespread implementation nationwide. This review examines the logistical, administrative, and infrastructural challenges that impede the establishment of green corridors across India. Notable issues include poor inter-agency coordination, limited public awareness, lack of real-time traffic management systems, financial limitations, and inadequate infrastructure, particularly in rural and peri-urban regions. Furthermore, societal factors such as religious and cultural attitudes, along with inconsistencies in policy enforcement, continue to affect organ donation rates and overall transplantation efficiency. The article underscores the critical role of legal frameworks, particularly the Transplantation of Human Organs and Tissues Act (THOTA) 2014, in regulating organ donation and promoting ethical transplantation practices. To address existing challenges, a more structured, collaborative strategy is required. Measures such as the adoption of standardized operational protocols, deployment of GPS-enabled tracking systems, expanded public education initiatives, and strengthened collaboration among healthcare institutions, police, and transport agencies are essential. Enhancing these efforts will ensure the timely, safe transfer of organs, ultimately increasing the number of lives saved through transplantation.

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INTRODUCTION

Organ transplantation serves as a critical medical procedure, offering hope and survival to patients suffering from end-stage organ failure. In the Indian context, the demand for donor organs considerably exceeds their supply, thereby underscoring the importance of cadaveric donations within the transplantation framework. Nevertheless, the effectiveness of organ transplantation relies not only on securing viable donor organs but also on ensuring their prompt and efficient transportation from the donor to the intended recipient.[1]

This is where green corridors play a pivotal role. Green corridors are dedicated routes that ensure the swift and uninterrupted transportation of organs, often involving coordinated efforts between traffic police, hospitals, and transport authorities. While India has witnessed several successful implementations of green corridors, their widespread adoption faces significant challenges.[2] This article explores these challenges and discusses the factors that need to be addressed to ensure the effective implementation of green corridors across the country.

Indian needs significant organ transplants for its ailing

citizens. The gap is significant and is increasing day by day. As per the National Organ Transplant Programme data, the approximate people diagnosed with liver failure or liver cancer annually is around one lakh, out of which thirty thousand patients can be saved with a transplant, however the current liver transplant numbers in the country are not more than 1500. The shortage of organs in India remains a significant barrier to transplantation. Despite the regulatory measures established under THOTA 2014, a substantial disparity remains between the demand for and availability of donor organs. For instance, while more than 500,000 individuals in India require organ transplants each year, only a small proportion successfully receive them, primarily due to the persistent shortage of donors.[3]

The Transplantation of Human Organs and Tissues Act (THOTA) 2014 represents a landmark legislative framework in India, established to govern the removal, preservation, and transplantation of human organs and tissues for therapeutic use. The Act aims to mitigate the acute shortage of donor organs, prevent illicit organ trade, and uphold ethical standards in the field of organ donation.[4] A major challenge in the transplantation process is the narrow time frame available for organ retrieval and transplantation, closely tied to the timely declaration of brain stem death. This underscores the stringent time limitations outlined in THOTA 2014, highlighting the need for prompt organ retrieval and transplantation to maintain organ viability and improve transplantation outcomes.[3]

Brain stem death, as defined by THOTA 2014, is the irreversible cessation of all brain stem functions, including consciousness, spontaneous breathing, and vital reflexes. It is legally recognized as a form of death, allowing organs to be retrieved from deceased donors after certification by a medical board. The certification process involves rigorous clinical tests to confirm the irreversible loss of brain stem function.[4]

Besides the numerous reasons of high burden of disease, the increasing gap within supply and demand, Inadequate facilities and lack of certifications for harvesting organs particularly at government hospitals, lack of awareness, attitude of the stake holders about brain stem death and organ donation, one challenge faced by the administrators is the implementation of the green corridor for transport of the harvested cadaveric transplant organs to other certified centres for transplantation.[1]

In organ transplantation, the significant challenges is the narrow time window available for organ retrieval and transplantation. According to THOTA 2014, organs can only be retrieved after the declaration of brain stem death. However, once brain stem death is confirmed, there is a very short period during which organs must be retrieved, preserved, and transplanted into the recipient. This time-sensitive process requires meticulous coordination among medical teams, transplant coordinators, and regulatory authorities.[4]

The Act promotes deceased organ donation and mandates the establishment of regulatory bodies like the National Organ and Tissue Transplant Organization (NOTTO) to oversee organ allocation and ensure transparency. However, logistical challenges, such as the timely identification of brain stem dead donors, rapid transportation of organs, and coordination among transplant centres, often hinder the process.[5]

The need for a prompt organ transportation is essential to minimize wastages and improve transplant outcomes in the recipients following the organ transplantation. This correspondence examines the difficulties encountered in establishing multiple green corridors tailored for the transport of 1st multiple cadaveric organs harvested at one of an institute of national importance. In addition, it emphasizes the need for cooperation among different stakeholders such as healthcare providers, transport organizations, and government agencies in an attempt to create functional and interconnected systems capable of saving lives.[6]

A green corridor is a well-organized and well-defined pathway aimed at facilitating the speedy transport of organs, usually by ambulances. The main function of green corridors is to reduce the time gap between organ extraction and transplanting, given the very short preservation periods related to some organs. For example, a heart lasts only 4 to 6 hours after extraction, a liver lasts 12 hours, and kidneys can remain for 24 hours.[7] Green corridors are not merely speeding up transport; they are crucial steps towards saving lives. In the past few years, this initiative has gained a lot of momentum in India, particularly in cities where various successful organ transplants have taken place. But the systematic utilization of green corridors is a gigantic task, especially in rural and semi-urban areas.[2]

In the last decade, India has made an impressive advancement in the field of organ transplantation. The formation of the National Organ and Tissue Transplant

Organization (NOTTO) and the various State Organ and Tissue Transplant Organizations (SOTTOs) has been critical in enhancing the efficiency of the organ donation and allocation networks.[4] As of today, the implementation of green corridors remains non-uniform and is largely perceived in urban sectors. Rural India and small-town regions usually do not possess the required infrastructure and interagency coordination to facilitate such programs on a large scale. This difference between urban and rural regions puts into focus the need to embrace a systematic and holistic approach to the overall development of green corridors.[1] The administrator at the institute where harvest will be done, besides ensuring timely arrival of the organ harvesting teams from other recipient institutes and has to ensure their timely departure for successful reimplantation at the recipient institutes.

Challenges in Implementing Green Corridors

Logistics and Administrative issues

The establishment of green corridors requires collaboration between multiple governmental agencies, each with its regulations regarding road traffic, emergency services, and organ transportation.[8] Additionally, the absence of dedicated lanes for emergency vehicles in many cities exacerbates the problem. Specialized ambulances equipped with advanced life-support systems are also limited in number, further complicating the process.[9]

Coordination and Communication

Creating a green corridor requires seamless coordination between multiple stakeholders, including hospitals, traffic police, and transport authorities. Any breakdown in communication may lead to delays, jeopardizing the success of the transplant. A major challenge faced by the administrator is finding the right escalation matrix among these agencies and getting necessary permission for creation of the corridor in a limited time. These challenges become more profound when the decision of create a green corridor is taken after office hours (beyond 18.00 hours). The absence of unified guidelines, a centralized communication system to coordinate between hospitals and transport authorities and policies can lead to lot of confusion as well as delays, and ultimately, loss of viable organs.[10]

Public Awareness and Participation

Public awareness about green corridors and their importance remains low. Many commuters are unaware of the critical nature of organ transportation and may resist traffic diversions, leading to delays. For instance, during the creation of a green corridor, traffic may be halted or diverted, which can cause inconvenience to the public. Without proper awareness campaigns, such measures may face resistance from the community.[11] Traffic congestion is part of every city now hence dedicated lanes need to be created; this also needs public awareness and cooperations as many times vehicles start driving in these dedicated corridors creating a hindrance to the corridor. Further the issues of public as well as holy festivals like Sawan/ Karthik or Ramzan, religious gatherings or harvest season may need special transport arrangements and barricading in a short time.[10] Moreover, cultural and religious beliefs often hinder organ donation rates, reducing the availability of organs for transplantation. Misconceptions about organ donation, such as the fear of disfigurement or religious objections, further compound the problem.[12]

Technological Limitations

The absence of real-time traffic monitoring systems and advanced route optimization tools is another major hurdle. While some cities have adopted GPS-based tracking systems, their implementation is not uniform across the country.[9] Although real-time organ viability monitoring systems and GPS tracking are available, however with absence of a defined guidelines they are not incorporated in transport protocols and ambulances. Further there is need to spread awareness amongst the stake holders that even though an ambulance which at most of the instances is outsourced vehicle for the hospital, need to have certain features which are essential for tracking of these vehicles.[11-14] The use of emerging technologies, such as drones, for organ transportation in remote areas is still in its infancy. Although drones have been successfully used in other countries for organ transportation, their adoption in India faces regulatory and logistical challenges.[8]

Financial Constraints

The creation and maintenance of green corridors require significant financial investment. From upgrading road infrastructure to training personnel and procuring specialized vehicles, the costs can be prohibitive.[15] For instance, equipping ambulances with advanced life-support systems and GPS tracking devices requires substantial funding.[11-13] Limited funding for public awareness campaigns further compounds the problem. Many states in India lack the financial resources to invest in green corridor infrastructure, leading to disparities in

implementation [15].

Infrastructure & Climate limitations

Adequate infrastructure is a must for establishing green corridors. Many roads are narrow, poorly maintained, and prone to traffic congestion, making it difficult to create green corridors. Additionally, the absence of dedicated lanes for emergency vehicles in many cities exacerbates the problem.[1,10-12] Almost every city has its own shortcomings when we talk of road infrastructure and access points for emergency vehicles, these which are a necessity for swift transportation. Further capacity of the ambulances to gain speed above 100 km/hr etc, lack of awareness of the ambulance drivers to driver the vehicle above the prescribed speed limit, difficult terrain can be major hindrances for creation of the green corridors. The issues of other factors like monsoon rains, landslides especially in hilly terrains and floods and cyclones in a coastal zone, fogs in winters or tractors and trolleys pile up near a highway factory, or possibility of a broken-down vehicle leading to traffic pileup also has to be kept in mind prior to setting up of a green corridor as the administrator besides ensuring timely arrival of the organ harvesting team and has to ensure the timely departure of the organs.[8-10]

Active Engagement of the Emergency Department

Most of the institutes and recognized teaching medical institutions have a fully functional emergency department. In one of national institute this department also has a functional air ambulance. However, availability of air ambulance and conducive landing conditions also can pose a challenge for creating of organ corridor. The active engagement and coordination with this department which specializes in emergency management may also help. [10,14,15]

DISCUSSION

Effective implementation of green corridors requires concerted effort from numerous stakeholders. The policymakers, physicians, traffic management authorities, and the public need to come together in addressing the challenges and developing a robust organ transport system.[16] There is a need to develop a national policy for green corridors to facilitate harmonization in their implementation. The government can create a national task force that would coordinate the implementation of green corridors and adhere to uniform procedures.[2,17] The policy would include uniform procedures for establishing green corridors, coordination protocols among the stakeholders, and monitoring and evaluation mechanisms. The gap in funding can be bridged through the collaboration between private health facilities, government institutions, and non-governmental organizations (NGOs).[18] Corporate social responsibility (CSR) initiatives can be used to support infrastructure development and public awareness campaigns.[11,18]

Intelligent traffic management systems and advanced route optimization technologies has the capability to improve the operational effectiveness of green corridors. Research into advanced solutions, including drone-supported organ transport, can provide feasible solutions to the challenges faced in remote areas.[19] Training transport officials, traffic police, and healthcare officials in green corridor procedures is also required. Traffic police need to be trained to manage traffic diversion effectively. A task force specifically organized for organ transportation would prevent redundancy and ensure quicker response times.[10,11]

Country-wide campaigns emphasizing the life-saving capability of organ donation and the role played by green corridors in facilitating early transplantation can promote organ donation and green corridors by altering public attitudes. Incentives or reward schemes for organ donors and their families can also be utilized to promote donation.[14,20] Research into advanced solutions, including drone-supported organ transport, can provide feasible solutions to the challenges faced in remote areas. Consolidation of studies and data are needed to fill the gaps and improve existing systems. In addition, more investment in health units in conjunction with awareness campaigns will help ensure green corridor sustainability.

CONCLUSION

Green corridors are a lifeline for patients awaiting organ transplants. While India has made progress in this area, significant challenges remain. Addressing these challenges requires a concerted effort from all stakeholders, supported by policy reforms, technological innovation, and community engagement. This is an urgent call to action for administrators, healthcare professionals, lawmakers, transportation agencies, and the community to work together, innovate, and ensure that important organs reach recipients in need as soon as possible. By overcoming these hurdles, India can ensure that every organ reaches its destination in time, saving countless lives and setting a benchmark for healthcare excellence.

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Review Article

Comparative Analysis between Various Age Estimation Formulas in an Indian Perspective - A Review

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ABSTRACT

This overview reviews the last decade's progress in dental age estimation from Indian research, focusing on methods like Dimerjian's, Cameriere's, Kvaal's, and Alquatani's, assessing accuracy and suitability.

Systematic article search was conducted using Pubmed, Embase, and Google Scholar using precise keywords to identify research conducted on the Indian population deriving new age estimation Indian specific formula. Our selection encompassed population studies conducted across diverse Indian regions, including the northern, southern, eastern, and western areas, with an emphasis on publications available until 2022.

Our analysis reveals that some of these methods yielded suboptimal results when specifically applied to Indian populations. Consequently, few Indian researchers have developed new population-specific regression formulas that have demonstrated improved accuracy. This review provides a concise overview of the most widely used age estimation methods worldwide, alongside Indian population-specific formulas derived from diverse sample sizes. These formulas can serve as valuable references for future research endeavors.

This review is a brief summary highlighting the studies that underscored the significance of formulating population-specific age estimation models, recognizing the variations in dental maturation observed across different geographical regions, and developing their own population-specific formula for a particular subset of the Indian population.

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INTRODUCTION

Age estimation holds vital significance in the realms of forensic identification and medico-legal contexts. It assumes a pivotal role in narrowing down search parameters for both unidentified deceased individuals and living persons. While calculating chronological age through birth certificates remains a valid approach, the unfortunate reality is that birth registration isn't universally enforced across all nations.

Data amassed by the United Nations Children's Fund (UNICEF) during the period of 2006 to 2016 reveals that the registered birth rate for children under 5 years old in South Asia stood at 60%, with India recording a mere 72%. This statistic underscores a staggering figure of nearly 10 million out of 26 million annual births lacking proper birth records.[1]

Given that children represent a nation's future, the pressing concern of juvenile crimes, rising instances of immigration, and documented cases of child abuse on a global scale renders age assessment in minors increasingly crucial from a medico-legal standpoint. Furthermore, precise age evaluation in the pediatric demographic is gaining prominence within domains like forensic medicine, endocrinology, and orthodontic treatment planning.[2]

Various bodily components such as long bones, skull

bones, and secondary sexual characteristics have historically been employed for age estimation, though many of these become unreliable due to the harsh circumstances surrounding certain deaths accidents or burns in contemporary and historical cases. Among these, teeth stand out as the most resilient organs, least affected by taphonomic processes. The dental age assessment, in particular, is regarded as a dependable, uncomplicated, and expeditious method for gauging age.[3]

The importance of age estimation extends to exposing age-related fraud in sports. Sports authorities like the Sports Authority of India (SAI) and the Ministry of Youth Affairs frequently call upon medical and dental experts to determine the ages of individuals suspected of falsifying their ages. In the "National Code against Age Fraud in Sports" report, age estimation evaluation involves comprehensive dental examination and orthopantomogram (OPG) analysis, in conjunction with other medical and radiological assessments. This underscores the broad and critical scope of age estimation, spanning from forensic contexts to sports integrity.[4]

Age estimation is critical in resolving a variety of concerns. It protects children from exploitation, such as child labor and early marriages. We can ensure that children receive adequate rights, services, and opportunities by appropriately determining their age. Calculating a child's age also helps to identify those who could be at risk or in need of specialized support. It is a crucial instrument for developing policies and actions that support children's rights and well-being.

This scientific paper aims to comprehensively review and analyze the advancements, methodologies, and techniques employed in dental age estimation using radiographs over the past decade. In particular, the focus will be on exploring innovative approaches and novel contributions within the context of the Indian population. The paper aims to identify unique and region-specific trends in dental age estimation by systematically examining the various formulas derived from these studies.

The objective of the review is to synthesize decadal trends and evaluate the accuracy and applicability of the age estimation formulas developed by Indian authors on a specific population of India using established techniques and methods like Dimerjian's,[4] Camereire's,[5] and Kvaal's.[6] Each of these methods is described along with tables discussing the various populations studied using panoramic radiographs, both males and females in different age groups and illustrating any age estimation formula developed by these authors.

MATERIAL AND METHOD

This paper is narrative review and search is based on Pubmed, Embase, and Google Scholar using specific keywords to find studies done on the Indian population that used Dimerjian's, Cameriere, Kvaal, and Alquatani London Atlas methods for dental age estimation. It included population publications available from more than a decade, 2010 till now. Using keywords like age estimation formula, ("Dental age estimation" OR "tooth age estimation") AND ("Demirjian" OR "Cameriere" OR "Kvaal") AND ("India" OR "Indian population").

Inclusion Criteria: Original research articles conducted on Indian populations, Studies that proposed or validated a formula or regression model specific to the Indian population, Articles published in English language, Studies including children, adolescents, or adults for dental age estimation, Studies with a clearly defined sample size and region (e.g., north, south, east, or west India).

Exclusion Criteria: Case reports, editorials, conference abstracts, letters to the editor.

Studies not conducted on Indian subjects, Studies not using the mentioned four methods,

Articles that do not provide sufficient data for table extraction (e.g., lack of sample size, formula, or region), Studies combining Indian with non-Indian populations without separating results.

Data Extraction was done in a simple manner to make it more presentable, easy-to-read tables, allowing readers to quickly reference relevant studies without navigating multiple sources. The focus was on clarity, comparison, and accessibility.

- Author(s) and Year
- Region of India
- Sample size and age range
- Method used
- Population-specific formula (if provided)
- Brief inference

RESULT

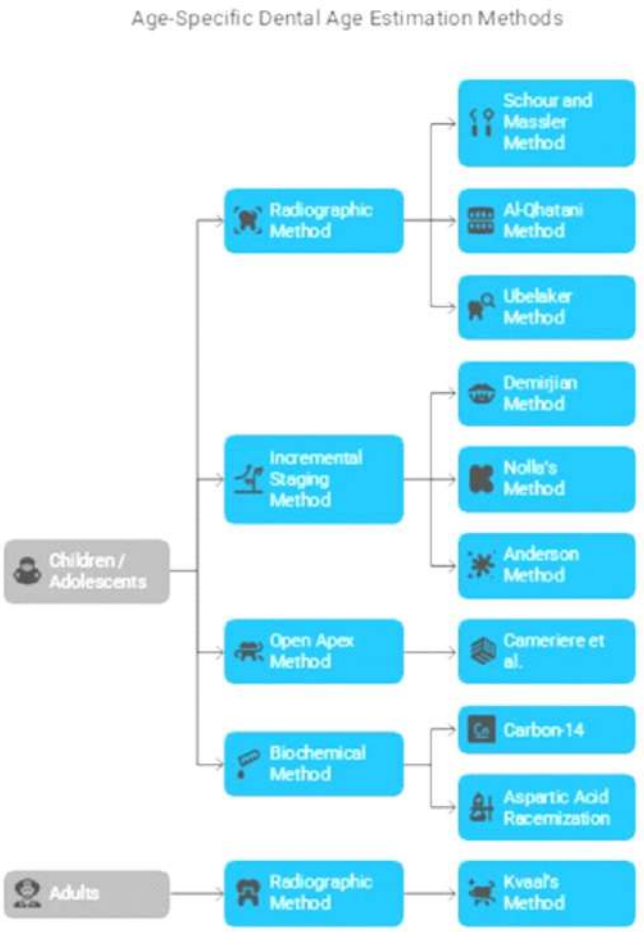
In this review, emphasis is given to Indian formulas derived from original methods that have been proven by researchers to either be useful or not in different Indian populations. The **Tables (1,2 and 3)** describe the

important details relevant to choosing a formula if the population-specific study has to be conducted in the future with a bigger sample size or if age estimation has to be done for any legal purposes. The reason of choosing these 3 specific methods are that these methods are not only accurate but also widely used throughout the world.

DISCUSSION

Accurate age assessment plays a vital role in both the identification of human remains and in legal situations involving living individuals. From a forensic perspective, it is essential for determining whether a person is a juvenile or an adult, especially in cases involving crime, immigration, or lack of valid age documentation. Unlike skeletal maturation, which is more susceptible to environmental and hormonal influences, dental maturation remains relatively stable. This has led to growing interest in dental age estimation as a more reliable and valid technique for age assessment in forensic investigations.[4-6]

Age specific dental age estimation methods are described in flowchart specifying methods used for children and adults most commonly **(Figure 1)**.



Dimerjian's method is an incremental staging method. This method is useful in estimating the age of children and adolescents. The advantage of this method is its accuracy and reliability. It utilizes advanced techniques and algorithms to estimate age based on various factors, such as skeletal development and dental maturity. This method has been extensively researched and validated, making it a valuable tool in age determination, especially in cases where accurate birth records are unavailable. It helps ensure that individuals receive appropriate rights and protections based on their age.[4] Indian formula derived from Dimerjian's method **(Table 1)** shows various studies done in different Indian populations using this method, and formula is only derived population specific to Karnataka in 2011.[7] Population studies mentioned in the table 1 have only compared original Dimerjian's formula with Ashith Acharya formula. Hence in future more studies can be done to derive population specific formula.

The Cameriere method is primarily used for age estimation in forensic and anthropological contexts. It utilizes dental development, such as tooth mineralization and eruption patterns, to estimate a person's age. This method is particularly useful when other traditional methods, like birth records or skeletal analysis, are not available or inconclusive. It helps forensic experts, anthropologists, and researchers in determining the age of individuals, which can be crucial in investigations, identification processes, and population studies.[5] Indian formula derived from the Cameriere method **(Table 2)** shows various studies done in different Indian populations using this method and formulas derived population specific.

Kvaal age estimation method is used for calculating the chronological age of humans with the correlation between age and pulp size on panoramic dental radiographs. Because secondary dentin deposition causes the tooth pulp to shrink with advancing age, it can be utilized as an indication of age. Since this is a continual process, it can be used to estimate age even in people who are older than 25. Teeth can be examined using radiology in a quick, non-invasive procedure that doesn't involve extraction.[6]

In the review it was found that the studies which are done in India from 2010-2022 on different population **(Table 3)** none of them derived population specific formula but concluded that Kvaal age estimation method provides a quantitative and objective approach to estimating age based on dental radiographs. Therefore, for adults age estimation this method can be used widely in different

Table 1: Indian Formula Derived from Dimerjian's Method for Age Estimation.

S. No	Author	Aim	Study Population	Sample size OPG (M:F)	Age Years	Result	Formula	Inference
1.	Ashith B Acharya[7]	To estimate age in Indians using Demirjian's 8 teeth method	Karnataka	547 199: 348	7-25	Dimerjian's formula resulted in inferior age prediction in Indians	Males=27.4351-(0.0097xS2)+(0.000089xS3) Females=23.7288-(0.0088xS2)+(0.000085xS3)	Indian specific formula gave better age estimation than original formula
2.	Akhil,et al (2019)[8]	To validate age using Dimerjian's eight teeth method and to compare the effectiveness of Demirjian's formula and Indian specific formula	Kanyakumari	150	8-24	Mean Absolute Error was less between chronological age and estimated dental age which was calculated using Indian-specific formula, compared with the values obtained using Demirjian's formula	NA	Indian specific formula is more reliable in age estimation of Kanyakumari population
3.	K Pratyusha et al (2017)[9]	To evaluate the reliability of Demirjian's, Cameriere's and modified Cameriere population-specific equation methods in dental age estimation	West Godavari District Andhra Pradesh	60	9-14	The estimated age was closer to chronological age using cameriere population specific regression equation difference was more in Demeirjian's method followed by cameriere method	NA	Cameriere's population-specific regression equation exhibited a least significant difference in chronological and dental age assessment in children.
4.	S.Sarkar et al (2012)[11]	To assess the applicability and to compare the methods of dental age estimation by Dimerjian's method and same method as modified by willems	Haryana	70 37:33	9-16	Overestimation of age among males was found by both methods and among female both methods underestimated the age.	NA	Willems method has proved to be more accurate for age estimation among Indian males and Dimerjians method for Indian females

5.	S.Sarkar et al (2012)[11]	Evaluate age in children, adolscents and young adults using Dimerjians 8 teeth method	Tamil Naidu	100 50:50	5-24	Dimerjians formula underestimated the mean dental age in males and female, where as Indian specific formula was approximating with chronological age.	NA	Acharya's formula is more effective in evaluative dental age.
6.	Chandra-mohan et al (2018)[12]	To assess and compare dental age using Demerjian's methodwith Chronological age.	Karnataka	200	11-16	There was statistically significant difference between DA and CA	NA	Demerjian;s method can be applied with a suitable correlation factor
7.	Grover et al (2012)[13]	Accuracy of dental age estimation and its comparison with chronological age using Demirjian and willem's	Haryana	215	6-15	Willems method was found to be more accurate.	NA	High correlation coefficient between both chronological and obtained dental age.

Table 2: Indian Formula Derived from Cameriere et al. Method for Age Estimation.

S. No	Author	Aim	Study Population	Sample size OPG (M:F)	Age Years	Result	Formula	Inference
1.	Prabhakar Ramasetty Attiguppe et al (2016)[14]	To estimate the age in children by using Cameriere's method.	Karnataka	150	6-15	Model Was found to be statically significant	Age=10.522+ 0.712(N0)- 5.040(x4)	Cameriere method can be used for age assessment in children for forensic as well as legal contexts.
2.	Sanjana M et al (2022)[15]	To establish new formula for age estimation using Cameriere European formula.	Western India	311	4-15	No statistically significant difference was found between the predicted and actual age using regression equation.	Age =11.664-2.806 (x5)=0.602(N0)- 0.487(s)-0.819(g)	New regression formula developed will be more accurate for age assessment.
3.	Preeti Sharma and Vijay Wadhwan (2020)[16]	To evaluate and compare the accuracy age estimation using Cameriere's method and London atlas of Tooth development	Meerut UP	335	5-15.99	No significant difference was observed for both genders with two method	NA	London Atlas is simpler to use and more accurate than Cameriere's method

4.	Komal Ghiya et al (2022)[17]	To estimate the age by radiographic prediction method and to validate the equation of Cameriere.	Ahemdabad Gujrat	300	5-15	Second premolar variable was not significant and thus had to be removed.	Age=10.019-0.277g+ 0.635N0-0.758S+ 0.082N0	Cameriere's equation does not fit for the Ahemdabad population and thus needs to be modified
5.	Palak H Shah et al (2022)[18]	To determine applicability of Cameriere's and Drushini's methods .	Gujrat	300	21-60	The individual regression formula was derived for all the teeth and were then used separately to calculate age	For pulp /tooth area ratio of maxillary canine age=49,212-83,637xAR For AR of mandibular canine age=47,018-64,320xAR For TCI of mandibular first premolar age= 26.436+0.42xTCI For TCI of mandibular second premolar age= 24.939+0.494xTCI For TCI of mandibular of first molar age= 21.231+0.604xTCI for TCI of mandibular of second molar age=22.903+ 0,590xTCI	

Indian regional population.

CONCLUSION

This review has meticulously examined Indian formulations rooted in validated original methods, demonstrating their effectiveness across diverse Indian populations. The inclusion of comprehensive tables provides essential details crucial for formula selection, especially in the anticipation of future population-specific studies necessitating larger sample sizes or in the context of age estimation for legal purposes. The deliberate choice of these three methods is underpinned by their global prevalence, renowned accuracy, and widespread utilization, reaffirming their significance in the realm of research and practical applications. This comprehensive analysis contributes to the foundation of knowledge essential for informed decision-making in scientific endeavors pertaining to Indian populations and beyond.

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Table 3: Indian Formula Derived from Kvaal et al. Method for Age Estimation.

S. No	Author	Aim	Study Population	Sample size OPG (M:F)	Age Years	Result	Formula	Inference
1.	Dolly Badrakiya et al (2022)[19]	Testing the Kvaal's method for chronological age estimation using intraorsl periapical radiograph of maxillary canine.	Gujarat	100 52:48	21-70	Pearson product moment correlation coefficient indicated that among the ratios A1 (length of pulp and the tooth), A2(length of pulp and root) A4 (between length of tooth and root) were less statistically significant compared to A3 (width of pulp and root) which was more significant.	NA	Ratio(A3) is good indicator and thus linear regression was derived by this variable.
2.	Samta Mittal et al (2016)[20]	Estimation of the chronological age of subjects by Kvaal's method and also testing validity of regression equation given by Kvaal et al	Delhi NCR	152 96:56	14-60	No significant difference between the mean of the chronological age and the estimate age was observed	NA	Result give an inference of feasibility of this technique by calculations of regression equations on digital panoramic radiograph.
3.	Pooja S et al (2016)[21]	To estimate the accuracy of age evaluation by Kvaal's method	Maharashtra	50 27:23	15-57	Pearson product moment correlation coefficient PCC between age and the morphological variables showed that among them X1 (pulp length to tooth length) X2 (pulp length to root length), X3 pulp width to root width) were statistically significant.	NA	X1,X2 ,X3 were good indicators of age estimation.

4.	Ridhima Sharma et al (2010)[22]	To evaluate age estimation using Kvaal's method.	Rajasthan	50	15-60	Coefficient of determination R^2. was strongest for mandibular first premolar indicating age can be estimated better with this tooth.	NA	Feasibility of Kvaal method for age estimation in set sample.
5.	Shruti k et al (2014)[23]	Evaluating the accuracy of age estimation formula of Kvaal developed for Norwegian population.	Karnataka	200	20-50	Using Kvaal's formula standard error of estimated age was more in Indian population as compared to Norwegian population.	NA	Formula which was derived from Norwegian population is not applicable for Indian population.

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A Case Series

Murder by Strangulation with Varied Degree of Associated Violence

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ABSTRACT

Asphyxial deaths due to constriction of the neck are a common occurrence worldwide. Forensic pathologists often face challenges in precisely differentiating between suicidal, homicidal, or accidental manners of such deaths. In many suspicious cases, perpetrators may tamper with evidence and attempt to conceal the victims' identities.

The present case series highlight the spectrum of injuries from isolated neck findings to multisystem trauma in deceased individuals who were found at abandoned or secluded locations, such as near jungle areas, industrial zones, and residential communities. The Comprehensive and meticulous autopsies were performed, and the cause of death was determined in each case.

In these types of cases, police investigations, crime scene details, and suspect confessions play a crucial role in concluding the possible manner and final cause of death. Additionally, the collection of samples and other related investigations can contribute to the arrest of the culprits.

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INTRODUCTION

Over the years, homicides or murders can be committed using a variety of methods, such as firearms, sharp and pointed weapons like knives, blunt or other weapons. Historically, shooting and stabbing have been the most common killing techniques.[1] However, some offenders prefer to use their body as a weapon, like hands, feet, or fists to kill another person, leading to asphyxiation, among others, which is a life-threatening condition.

Strangulation is a form of asphyxia caused by the constriction of the neck, either manually or by a ligature, without suspending the body and where the constricting force is other than the weight of the deceased's body.[2] Manual strangulation can be attempted by applying pressure to the neck with the hands, elbow, or knee, feet (mugging) of another person. Ligature strangulation can be attempted by placing a ligature around the neck or by other means without suspending the body and by applying force on it so as to constrict the neck and the neck structures.

Various mechanisms of death are associated with strangulation. Asphyxial death occurs when the windpipe is compressed so suddenly that it completely blocks the passage of air, preventing the body from getting enough oxygen or removal of air from the lungs. This rapidly renders the individual unconscious, preventing calls for assistance and potentially leading to instantaneous death. Similarly, the blood supply to the brain, whether arterial or venous, can be disrupted, leading to cerebral ischemia and venous congestion. In some cases, reflex vagal inhibition of the heart and fracture dislocation of the cervical vertebrae may occur following compression of the neck.[3-4]

Case 1

A 23-year-old female domestic worker had an arranged marriage with a man from Uttar Pradesh. They both travelled to UP for a marriage function, but her husband sustained a leg fracture and remained in his native village for four months. Meanwhile, the deceased returned to Chandigarh to resume her employment. During this period, she became involved in an extramarital affair with a

delivery person. When the deceased's husband returned to Chandigarh, he harboured suspicions about her extramarital relationship. One day, the deceased went to the market to purchase medicines for her ill husband. Subsequently, her lifeless body was discovered in an abandoned, bushy plot in the industrial area of Chandigarh. She was pronounced dead on arrival, and her body was brought to GMCH 32 mortuary for post-mortem examination. **(Figure 1)**

Autopsy Findings

- **External injuries over Neck :**
- Bluish purple contusion of size 2cm x 1cm present over the right side of neck at the level of thyroid cartilage, being 5cm above the middle of right clavicle and 3.5cm away from midline.
- Bluish purple contusion of size 3cm x 1.5cm present over left side of neck, below the level of thyroid cartilage, being 3cm above the middle of left clavicle and 2cm away from midline.
- Brownish abrasion of size 1.3cm x 0.5cm, curvilinear in shape, present over right side of neck, 5cm below chin and 4cm below right angle of mandible.
- Brownish abrasion of size 0.8cm x 0.3cm present 2cm below the above abrasion towards midline.
- On exploration, the underlying subcutaneous tissue and neck muscles were found to be contused, along with tearing of the sternocleidomastoid muscle on the left side. Bruises and frank hemorrhages were present in the surrounding tissues - base of the tongue, larynx, pharynx along with fracture of hyoid bone. Fracture of left clavicle was present.
- Uterus was gravid, measuring 20cm x 10cm x 5cm and weighed 550Gms, Placenta with male fetus of 4 to 5 months, weighing 412Gms was present.
- Cause of Death was opined as asphyxia due to manual strangulation/ throttling.

Case 2

A 60-year-old female patient with Alzheimer's disease had been unwell for the preceding 10-15 days. Due to her condition, she frequently experienced memory lapses and a tendency to wander to nearby houses, before eventually returning home. However, on one occasion, she failed to return, prompting her husband and son to file a missing person report. Her lifeless body was subsequently discovered in a jungle area adjacent to Sector 54, Chandigarh. She was pronounced dead on arrival, and her body was brought to the mortuary of GMSH, Sec 16, for post-mortem examination. **(Figure 2)**

Figure 1: Case 1

Figure 2: Case 2

Autopsy Findings

- **External injuries over Neck :**
- Bluish contusion of size 4.5cm x 2cm present over the upper part of right side of neck, below the jawline, 2.5cm below the angle of mandible and 5cm behind the symphysis menti.
- Two reddish contused abrasions of size 3.5cm x 1cm and 1.5cm x 1cm, respectively, were present just above the left angle of the mandible on the jawline, being 7cm and 9cm away from symphysis menti.
- Two reddish abrasion of size 2cm x 0.5cm and 1cm x 0.4cm with faint interrupting area present over upper part of left side of neck 3cm below the left angle of mandible, 6.5cm away from midline.
- On exploration, multiple contusions and frank hemorrhages were present at places on subcutaneous tissue underlying the neck and strap muscles of the neck - sternocleidomastoid, omohyoid and sternohyoid. Similarly, bruising was present on the base of the tongue, thyroid cartilage, larynx, and pharynx. Fracture and displacement of hyoid bone was present along with extravasation of blood in surrounding tissues.
- **Associated Sharp weapon injuries:**
- Missing left ear along with the surrounding skin, which was muscle and soft tissue deep.
- Incised wound, semicircular in shape, present at the upper aspect of left cheek, 9cm away from ala of nose and 2cm above the angle of the mandible with clean cut margins and regular edges, measuring 6.5cm at the base and 4.5cm perpendicularly upwards, in the center. At the lower end, the injury extended as a curvilinear incised wound, measuring 4cm at the base, with a 1.5cm sized skin tag separating the lower part from the upper part of the injury.
- **Associated Blunt weapon injuries:**
- Bluish contusion of size 2.5cm x 0.5cm, present, placed vertically over lower aspect of right side of face, the upper pole being 1.5cm away from the angle of right corner of mouth and the lower pole touching the jawline.
- Diffuse Bluish contusion, 8cm x 5cm, present over mouth, the lower aspect of face on left side, and going till the jawline. On exploration, upper central and lateral incisors of both sides were missing. Mucosal tears were present underside of both the upper and lower lip, with extravasation of blood in the surrounding tissues.
- Fracture and displacement of right 2 to 9 and left 3 to 7 ribs, along the midclavicular line, with extravasation of blood in surrounding tissues.
- Cause of Death was opined as asphyxia due to manual strangulation/ throttling.

Case 3

A 23-year-old young male went out in the evening with his friend, with whom he had previously argued about 3 to 4 months back. Afterwards, he did not return home that night, and his lifeless body was later discovered lying in a dense, bushy area outside the housing society in Sector 51 B, Chandigarh, with two belts wrapped around his neck. He was pronounced dead on arrival, and an autopsy was conducted at the Government Medical College and Hospital, Sector 16, Chandigarh. **(Figure 3)**

Autopsy Findings:

- **External injuries over Neck:**
- Multiple curvilinear reddish abrasions present over the front and right side of neck, the size varying from 1.5cm x 0.2cm to 0.8cm x 0.2cm, extending over an area of 12cm x 10cm from the midline to the right side of the neck, horizontally and from the level of thyroid cartilage to 3.5cm above the suprasternal notch in midline, vertically.
- On exploration hematoma and frank hemorrhages were present at places on strap muscles of the neck - omohyoid, sternothyroid and thyrohyoid, along with thyroid cartilage and subcutaneous tissues. Base of tongue, larynx, pharynx and surrounding tissues are congested. Hyoid bone was intact.

Cause of Death was opined as asphyxia due to manual strangulation/ throttling.

Case 4

A 47-year-old Haryana Special Police Officer after completing his night duty, gave lift to two unknown individuals on his motorcycle. The three individuals proceeded to Gurudwara Mohali, Sector 56, where they engaged in a conversation and then walked towards a nearby jungle area. The following morning, a deceased body was reported in the area. Upon investigation, the SPO's mobile phone, purse, and motorcycle were found to be missing. A blood-stained stone and a sharp-edged weapon were discovered near the scene. He was brought dead and autopsy was conducted in GMSH 16. **(Figure 4)**

Figure 3: Case 3

Figure 4: Case 4

Table 1: Summary of the Cases.

Case No.	Age/Sex	Muscles Injured	Neck Bone Fractured	Type of Strangulation	External Features	Other Associated Injuries
1	23/F	Sternocliedo-mastoid	Hyoid	Manual	Facial Congestion	Fracture Clavicle
2	60/F	Sternocliedo-mastoid, Omohyoid, Sternohyoid	Hyoid	Manual	Subconjunctival Hemorrhage Cyanosis on Nailbeds,	Fracture Multiple Ribs
3	23/M	Omohyoid, Sternothyroid,	None	Manual	Clotted blood in oro-nasal cavity	
4	47/M	Thyrohyoid Omohyoid	Hyoid/ Thyroid	Manual/ Ligature	Subconjunctival Hemorrhage	Cranio -cerebral Damage

Autopsy Findings

- **External injuries over Neck:**
- Reddish contused abrasions of size 2.5cm x 0.5cm and 1cm x 0.5cm, and pin head-sized, were present over the right and left side of upper part of neck, 1.5cm and 1cm lateral to midline.
- Reddish contusion abrasion of size 2cm x 1.5cm, was present on lower 1/3 of left side of neck, 3.5cm above supraclavicular notch.
- Reddish contusion abrasion of size 10cm x 0.5cm was present over the mid front of neck on right side starting 7cm below the chin in midline, going downwards ending 8cm below the right angle of mandible.
- Reddish contusion abrasion of size 5cm x 0.5cm, present over mid front of neck, crossing the above injury, with interrupting normal skin on the left side, going upwards ending 2cm below the left angle of mandible.
- On exploration, hematoma was present over the salivary gland and omohyoid muscle. Base of tongue, larynx, pharynx and surrounding tissues were

congested. Fracture and displacement of superior cornu of thyroid cartilage and hyoid bone was present, with extravasation of blood in surrounding tissues.

Associated Sharp Weapon Injuries

- Incised wound of size 2cm x 0.5cm, present obliquely, over left frontal region of scalp, 6cm above the outer aspect of left eyebrow.
- Incised wound of size 1.5cm x 0.5cm present obliquely over left fronto-parietal region 3 cm behind the above injury towards midline.
- Incised wound of size 2cm x 0.8cm present over left fronto-parietal region, 2cm behind the above injury, away from midline.

Associated Blunt Weapon Injuries

- Reddish contusion abrasion present over an area of 10cm x 4cm on right cheek and lower part of nose.
- Two lacerated wounds present over chin measuring 2.5cm x 0.5cm x muscle deep and 1.5cm x 0.4cm x muscle deep surrounded by reddish abrasion contusion.
- Fissure fracture over right anterior cranial fossa, fracture of right orbital bone, fracture of nasal bone, fracture of right zygoma and maxilla present.
- Subarachnoid hemorrhage present over bilateral parieto occipital region.
- Cause of death was opined as combined effect of asphyxia due to strangulation and craniocerebral damage.

DISCUSSION

The human neck is highly vulnerable to life-threatening injuries. Intentional simulation and dissimulation of criminal acts are common behaviours exhibited by perpetrators, which forensic investigators frequently encounter during investigations.[5] The nature of violence against the neck is diverse, as several anatomical structures in the neck can collapse within minutes, even without leaving obvious traces.

Homicidal strangulation cases are often misrepresented as suicides or, less commonly, accidents.[6] This is due to the neck's small diameter, lack of bony protection of the vital structures, and close association with the airway, spinal cord, and major blood vessels. Compression of the neck is a critical area of investigation for forensic experts when examining unnatural deaths in medico-legal contexts.[7]

The bodies of the cases described were discovered in abandoned urban locations, mimicking suicide or accident, and were associated with external blunt and sharp/ pointed weapon injuries. Framing the final opinion of cause of death as strangulation during the autopsy process was challenging. However, meticulous and thorough post-mortem examination is the key to unlock such complex issues.

Manual strangulation is a leading cause of violent deaths, as it restricts blood flow and oxygenation to the brain through external pressure on the neck. The features in strangulation-related deaths can vary. In the present case series, the investigators considered various elements, such as local neck injuries, signs of vascular compression, other injuries on different body parts, the intensity and duration of the force used, the victim's intoxication status, whether the strangulation was manual or by use of a ligature, the motive, and the type of violent behaviour. To determine the cause, mode and manner of death, each observation was analyzed and evaluated in the light of the history, crime scene photographs, and post-mortem findings.

In the first case, the husband discovered that his wife had an extramarital affair, leading him to attempt strangulation. Literature indicates that up to 10% of homicide deaths among women in North America involve strangulation, often in the context of domestic violence against women, making it a global problem.[8] Strangulation is a common form of intimate partner violence (IPV), a type of domestic violence where the aggressor asserts control over the victim's life or death.[9] Intimate partners can be current or former spouses, boyfriends, girlfriends, dating partners, or ongoing sexual partners. Typically, women are strangled by male members of their own household. Manual strangulation is a well-known form of IPV, with most victims being women strangled by a male domestic partner.[10-11]

Again, as demonstrated in Case 2, strangulation is considered the easiest method to attempt murder on women, as the elderly, as they generally exhibit less physical defense, compared to men. When a man attempts to strangulate an elderly woman, little strength is required, and he can easily overpower her. It is highly unusual for a woman to do the same to another woman. The elderly are more vulnerable and at risk because they are less defensive and may have pre-existing conditions that contribute to death following physical assault. According to British data, strangulation is the most common form of homicide in

females, followed by the use of sharp instruments.[12] To ensure the rapid demise of the victim, the assailant may employ additional means of physical attack. In the present case, the victim was strangled, and her left ear was incised and missing. The female victim also suffered from Alzheimer's disease.

In Case 3, the male victim belonged to a younger age group. It is less common for a man to strangulate another man, as a male victim can typically defend himself more easily. In this case, the deceased was under the influence of alcohol and was strangled to death without significant resistance. The deceased's hyoid bone was not fractured. According to literature, the average age for fractures of the thyroid and hyoid bones is 42 years, with a range of 20 to 63 years. The likelihood of fractures increases with age due to increased chondral calcification.[13]

In Case 4, the deceased had requested sexual gratification from other males, as the deceased was homosexual. In sexual homicide, strangulation, asphyxiation, and beating are the most commonly used killing methods. As the literature indicates, the most common murder motives are associated with emotional outbursts driven by anger, jealousy, or sadism, which are often linked to strangulation.[14] In this case, strangulation was attempted using both ligature and manual means. A ligature mark in the form of a friction abrasion was present on the front of the neck, along with contusions around the jawline. Head injury as well as additional injuries such as facial bone fractures due to blunt force and incised wounds on the head caused by a sharp weapon were also present.

CONCLUSION

- A careful, systematic, and unbiased approach is crucial when investigating cases of potential strangulation, avoiding preconceived notions or assumptions based on the history.
- Strangulation should be strongly suspected whenever the forensic examination reveals a combination of findings, such as abrasions and contusions on the neck and jawline, fingernail abrasions, fingertip contusions, haemorrhages in the strap muscles of the neck, and fractures of the neck bones.
- A comprehensive evaluation of the crime scene, autopsy findings, and other evidence is essential to determine the cause of death, mode of death, and manner of death in these complex medico-legal cases.
- Strangulation is a common form of IPV; so domestic violence should be considered in females presenting with throat complaints.
- The most sensitive test for subtle strangulation injuries is MRI.

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A Case Report

A Case of Fatal Leopard Attack in the Western Ghats of Tamilnadu

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ABSTRACT

A case of leopard attack is presented with history of a 28 years old lady, who was attacked by a leopard in a hilly residential area. The lady who sustained penetrating injuries to the neck by leopard claws, died after 7 days of hospitalization. Underlying cause of death was due to leopard claws induced neck injuries and its complications. Generally leopard attack cases are rare, in that most of the cases are due to leopard bite attack. In our case, death was due to leopard claws induced neck injuries.

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INTRODUCTION

Leopard attacks are only rarely encountered among all animal attacks throughout the world.[1,2] Usually leopards avoid contact with people, but humans may occasionally be targeted as prey.[3] Leopard attack cases are under reported due to lack of monitoring programme and standardized reporting protocol. Neck injuries are the most commonly documented injuries in big cat attack.

Leopard usually attack its prey by biting over the neck and causing death by injuries to the major vessels of the neck.[1] Big cat wounds generally present as abrasions, puncture or tears. The probability of crush injury with devitalized tissue increases with force and bluntness of the teeth.[3] One such case of ours which had injuries over neck, made by such leopard claws is presented with autopsy findings.

CASE REPORT: As per the history furnished by the police, a 28 years old female was out to collect water from nearby water source at Ellamanna forest region along with five other people in her village at around 5 O' clock in the morning. While returning after collecting the water, she was attacked by a leopard. The leopard clawed into the victim and she sustained injuries mainly over the neck region, back of left ear and front of right chest. The victim was first taken to Pandalur Government Hospital at 7 O' clock in the morning.

First aid was given and she was referred to Ooty Government Medical College & Hospital the same day. Based on medical records perused from Ooty Government Medical College & Hospital, patient was hospitalized and treated with case findings of two lacerations, laryngeal tissue deep over front of neck, one laceration noted over left mastoid region and abrasions over the front of chest **(Figure 1)**.

Figure 1: Injuries Before Treatment Procedure.

Primary repair was done for laryngo-tracheal injuries with tracheostomy on the same day. On postoperative day 5, patient had complaints of cough and breathlessness with suspicion of mucous plug obstruction in the right bronchus. On postoperative day 6, patient was referred to Coimbatore Government Medical College & Hospital for tertiary care management. Appropriate investigations were done like USG abdomen and pelvis, Echo, bilateral lower limb doppler and reports were normal.

HRCT chest showed pneumomediastinum, ground glass opacity in right upper lobe, consolidation in right lower lobe with subpleural ground glass opacity in left lower lobe suggestive of pneumonia and was treated accordingly. In spite of all the treatment, patient developed hypoxia and went into sudden cardiopulmonary arrest and died.

The body was brought for postmortem examination. During autopsy, on external examination, the body of a young female of moderate built and nourishment with:

1) Open tracheostomy wound noted over front of neck.
2) Sutured horizontal wound of length 9cm noted over the front of upper part of neck. On removal of sutures, lacerated wound of size 8cm x 0.5cm x muscle deep (muscles found sutured) noted over front and more of left side of upper part of neck.
3) Sutured horizontal wound of length 7cm noted over the front of middle part of neck, 3cm below injury No. 2. On removal of sutures, laceration of size 6cm x 0.5cm x muscle deep (muscles found sutured) noted **(Figure 2)**.
4) Sutured wound of length 2 cm noted over left mastoid. On removal of sutures, lacerated wound of size 1.5cm x 0.5cm x 0.5cm deep noted.
5) Curvilinear scratch abrasions covered with black scab, 3 in numbers of sizes 0.8cm x 0.3cm, 0.5cm x 0.3cm & 0.4cm x 0.2cm noted over front of upper part of right chest.
6) Multiple abrasions covered with black scab of varying sizes ranging from 2cm x 1 cm to 0.5cm x 0.5cm noted below chin, outer aspect of left side of abdomen, back of left chest and back of left shoulder.

Figure 2: External Injuries Seen During Autopsy.

On bloodless dissection of neck, extravasation of blood in the superficial layers of upper part of neck noted. Horizontal sutured lacerated wound of size 3.5cm x 0.5cm x laryngeal deep noted over front of middle part of larynx, which corresponds to injury No. 2. Oblique sutured lacerated wound of size 2.8cm x 0.4cm x cartilage deep noted over front of cricoid cartilage and 1st tracheal ring, which corresponds to injury No. 3 **(Figure 3 & 4)**.

On dissection of chest cavities, lungs were edematous, deep red in color with increased weight and density, on cut section - exuded some greenish grey purulent fluids from some areas of lungs. Upon sectioning, notable congestion was observed in all other internal organs examined. Lungs were preserved and sent for Histo-Pathological examination and report showed features of pneumonia **(Figure 5)**. The opinion as to cause of death was given as death of pneumonia as a consequence of laryngo-tracheal injuries due to leopard attack.

DISCUSSION

A fatal attack by a big cat is an extremely rare cause of death in humans.[4] The leopard is the 4th largest big cat in the world. For its size, the leopard is the most powerful big cat next to jaguar in the world. Leopard's are capable of

Figure 3: On Bloodless Dissection of Neck.

Figure 4: Image Showing Laryngotracheal Injuries.

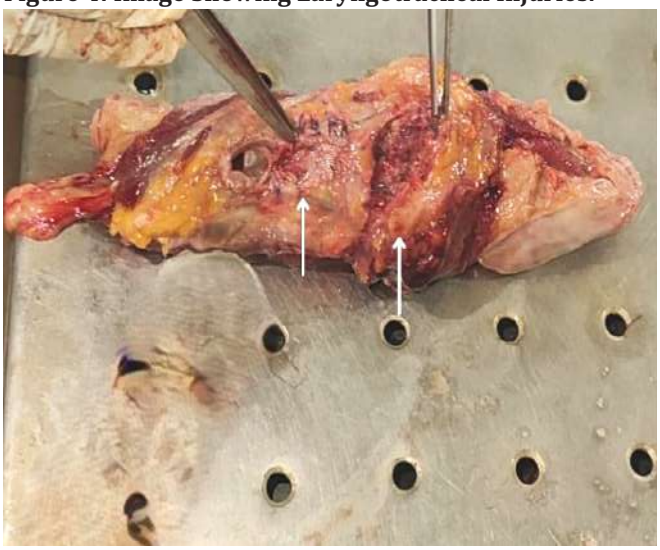
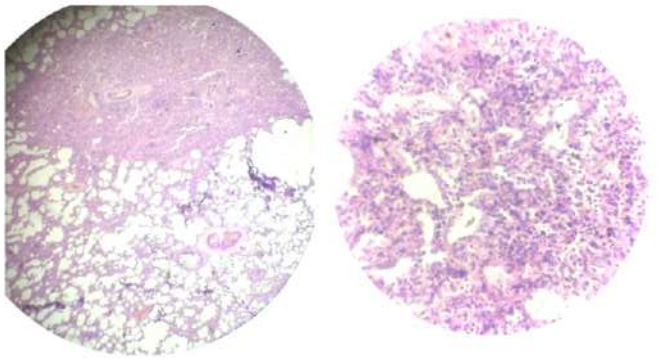


Figure 5: HPE Slides Showing Features of Pneumonia.



dragging their prey up into trees, even when the prey weighs more than the leopard itself. Leopard's possess some of the most impressive hunting abilities in the animal kingdom, showcasing their remarkable adaptability, stealth and physical prowess. It is a more skillful hunter than the lion or cheetah.[2]

In the wild, Leopard's are known to exhibit surplus killing behaviour, where they take down more prey than necessary to satiate their hunger.[2,4] Leopard's typically dispatch their prey quickly, often targeting vulnerable areas such as the nape and sides of the neck.[5] This precise and lethal approach allows them to minimize struggle and ensure a successful hunt. Its attacks are often aimed at injuring the great vessels of the neck, with subsequent exsanguination, and crushing the spine with a possible lesion to the spinal cord.

On rare occasions, the attacks can leads to an open cranial injury with injury to the brain.[1] In our case the victim was attacked by a leopard mainly by its claws and the victim sustained injuries over the front and left side of neck and right side of chest. Based on the characteristics, location and nature of the wounds on the victim's body, it is evident that the leopard's claws, measuring 2.5cm - 3cm, inflicted severe injuries to the victim's neck, indicating an intense and deliberate attack.

In all the reported cases death was due to leopard bite attack, here in our case, it was the leopard claw induced neck injury which turned out to be fatal. The wounds discovered on the victim's body corresponded with the dimensions of the leopard claws and with findings on the carcasses of animals killed by leopard in the wild.[1-2, 6-7] Big cat bites are more prone to infection as it consists of more toxic organisms. Treatment beyond 6-12 hours raises the probability of infection.[8]

CONCLUSION

The case presented here is unique in that, it is a fatal leopard claw induced neck injuries which as stated earlier occurs very rarely throughout the world. The conclusion of the Medico-Legal investigation was that the underlying cause of death was death due to pneumonia as a consequence of laryngo- tracheal injuries due to leopard attack. There is a need to improve the trauma services in the hilly areas to facilitate this type of health emergency.

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A Case Report

Survival and Mortality in Paraquat Poisoning: Lessons from Two Adolescent Cases

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ABSTRACT

Paraquat (PQ) is a widely used herbicide with high lethality, especially when ingested. Despite its agricultural utility, PQ poses a significant health hazard due to its potential for accidental or intentional poisoning. This report describes two adolescent cases of PQ poisoning with contrasting outcomes. The first case involved a 14-year-old who consumed a smaller quantity of PQ and responded favourably to early hemoperfusion, supportive care, and antioxidants, eventually making a full recovery.

The second case, a 15-year-old who ingested a larger amount, presented late with severe renal dysfunction and progressive pulmonary fibrosis, ultimately resulting in death despite intensive care. These cases illustrate the dose-dependent toxicity of PQ and the critical importance of early recognition, prompt decontamination, and aggressive supportive therapy. With no definitive antidote available, management focuses on organ support and mitigating oxidative damage. The contrasting outcomes emphasize the need for early intervention to improve survival in PQ poisoning.

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INTRODUCTION

Paraquat (PQ) is a widely used, fast-acting herbicide known for its high human toxicity, especially when ingested. PQ induces toxicity through redox cycling, generating reactive oxygen species that cause oxidative stress, lipid peroxidation, and tissue damage. The lungs and kidneys are particularly affected, with pulmonary fibrosis and acute kidney injury as hallmark complications. Clinical effects are dose-dependent, ranging from mucosal irritation to multiorgan failure and death.

Despite extensive research, no specific antidote exists, and treatment is mainly supportive. Early hemoperfusion, antioxidants, and organ support may improve survival if initiated promptly. This manuscript presents two adolescent cases of PQ poisoning, highlighting the management challenges and underscoring the critical importance of early intervention for better outcomes.

Case 1

A 14y/o adolescent boy presented with alleged history of consumption of 10-15ml of 24% Paraquat (PQ) 3 days back, was managed with IVF, Pantoprazole and Ondansetron by local doctor. At presentation had fever and vomiting for 3 days, multiple, painful and progressive oral ulceration making food intake difficult for the child. Vitals were stable on examination, painful ulcerations over tongue and hard palate. Chest was clear, no visible signs of distress and rest of the systemic examination was normal.

On evaluation, his blood counts were within normal limits, but urea was 100.8 and creatinine was 2.71mg/dL with eGFR of 43 ml/kg per 1.73m2. Although hemoperfusion was started urine output deteriorated from 1.2ml/kg per hour to 0.7 ml/kg per hr, urea and creatinine raised till 172.8 mg/dL and 3.37mg/dL respectively. Hemoperfusion was done with Urine paraquat levels and Renal Function

Test (RFT) monitoring, after 4 cycles of hemoperfusion urine paraquat levels fell from 10mcg/mL to <3mcg/mL and renal functions normalized. Local application of Triamcinolone for the ulcerations in oral cavity. Dexamethasone, N-acetyl cysteine and Vitamin C, E were started on day 9 of admission, child was started on minimal liquid diet until he could swallow without pain or restriction, further started consuming regular diet. Chest X-ray (CXR) and respiratory examination was within limits. He was discharged in stable condition with advice to follow regularly with serial CXR for pulmonary fibrosis.

Case 2

A 15-year-old boy presented after intentionally ingesting ~30 ml of a green herbicide containing 20% w/v paraquat, consumed 24 hours earlier in a suicide attempt. He developed vomiting within three hours and was managed at a local hospital with gastric lavage, IV fluids, antiemetics, and H2 blockers. He became oliguric with rising serum creatinine and developed painful oral ulcers, trismus, and dysphagia, prompting referral to our tertiary centre.

On admission, he was conscious, oriented, and hemodynamically stable. Examination showed oral erosions and oropharyngeal ulcerations but no respiratory distress or neurological signs. Lab tests revealed severe renal dysfunction (serum creatinine 11.6 mg/dL, urea 211 mg/dL), while chest radiography and echocardiography were unremarkable. Due to the risk of oesophageal perforation, upper GI endoscopy was deferred. He was started on haemodialysis and supportive care, including IV hydration, proton pump inhibitors, and close monitoring. His condition initially improved with increasing urine output and stabilization of renal function.

However, on day five, he developed sudden cough, breathlessness, and severe hypoxemia (SpO_2 70%). Despite intubation and mechanical ventilation, his oxygenation worsened, likely due to progressive pulmonary fibrosis. Serial chest X-rays showed evolving bilateral infiltrates **(Figure 1, 2 & 3)**. He suffered a rapid cardiovascular collapse and, despite 40 minutes of aggressive CPR, could not be revived.

DISCUSSION

PQ is a contact poison, a herbicide, trade name for N, N-dimethyl-4,4-bipyridium dichloride which is toxic to humans when ingested and is lethal.[1] The majority of intentional poisoning fatalities were due to pesticide ingestion, primarily organophosphates and aluminium

Figure 1: Normal Lung Fields (Day 1 of Admission).

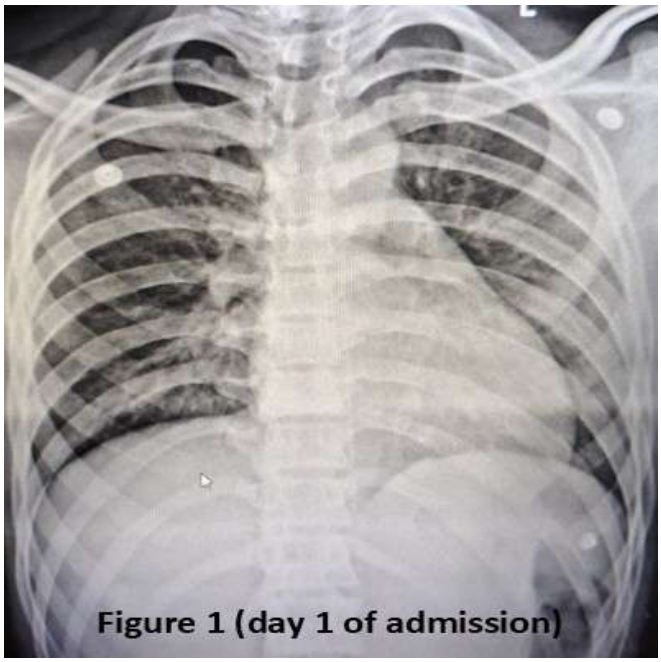
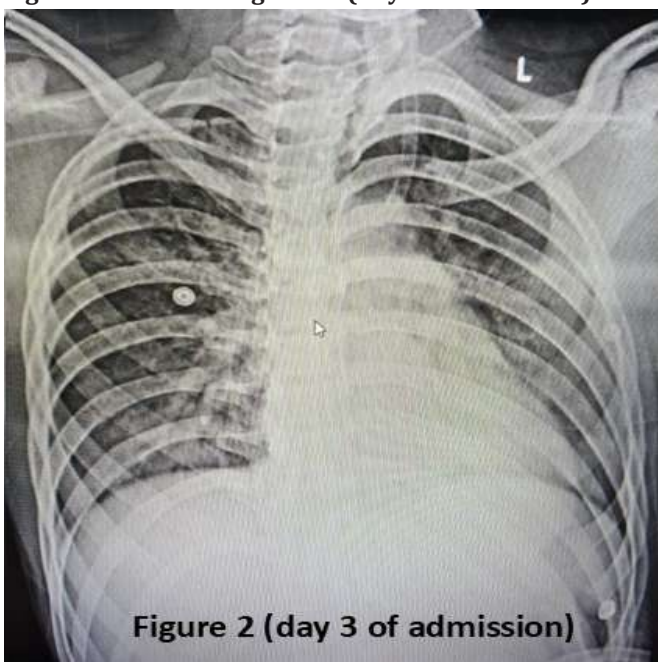


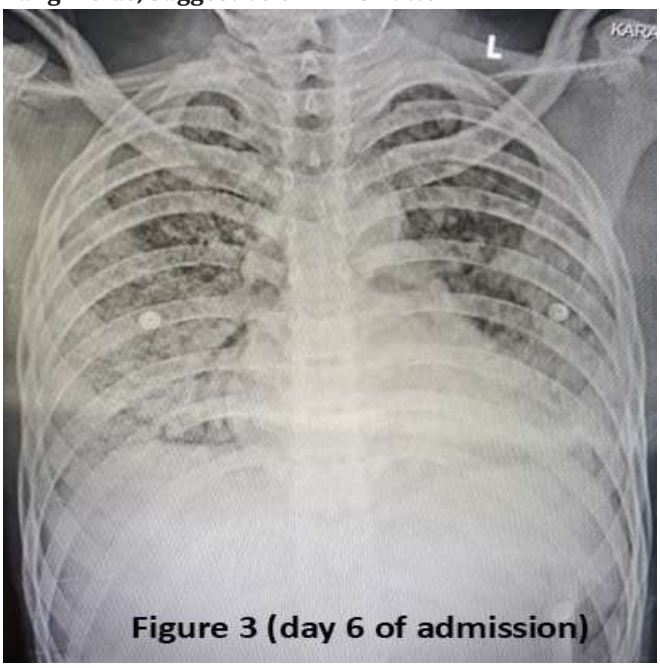
Figure 2: Normal Lung Fields (Day 3 of Admission).



phosphide (14.28%), followed by corrosive agents such as paraquat (11.82%).[2] Higher mortality rates are due to its inherent toxicity, which is dose dependent and lack of effective treatment.

PQ is majorly excreted by kidneys, hence highest concentration is in renal tubules leading to impaired renal functions, but is incompletely excreted, leading to accumulation of PQ in organs like liver, lung and heart causing multiple organ dysfunction. Lung being the main target organ, after uptake it undergoes redox reaction and

Figure 3: Shows Multiple Air Space Opacities in Both Lung Fields, Suggestive of ARDS Pattern.



interferes with mitochondrial electron transport, produce free radicals and induces lipid peroxidation injury.[3] Impaired renal functions lead to accumulation of Creatinine, which metabolizes into 5-hydroxy-1-methylhydantoin (HMH), endogenous antioxidant. It decreases inflammation, improve lipid peroxidation injury caused by PQ.[4]

Clinical presentation of PQ poisoning depends on ingested dose, if ingestion is <20mg/kg-low dose toxicity can cause local irritation (oral and GI mucosa), 20-40mg/kg-moderate doses cause injury to kidneys, liver and lung leading to respiratory failure within 2-3weeks, >40mg/kg-high doses can cause pulmonary fibrosis, respiratory failure and death within 1-7days.[1]

Patient who ingest in smaller quantities predominantly present with kidney and lung injury like our child in case 1 and are classified as moderate severity, mortality in this group is still >50%.[5] When consumed in larger doses (50-100ml) patient may present in multiorgan dysfunction, and death within days.[6]

Although, there are no standard treatment guidelines for the management of PQ poisoning, it is mainly conservative as there is no specific antidote. Strict monitoring for derangement in renal and liver function tests, respiratory failure, mucosal injuries is necessary. Chest radiograph if any clinical suspicion of pneumomediastinum, fibrosis or pneumothorax are suspected and Computed tomography (CT) of chest to detect early lung fibrosis.[7] Additional monitoring that can be done is the urine Sodium Dithionite Test which can detect paraquat levels upto 1mcg/mL.[8]

Initial decontamination by removing clothes, giving a single dose of activated charcoal for patients who give their consent, have open and stable airway. However, gastric lavage to be avoided due to corrosive nature of the poison. According to a metanalysis hemodialysis (HD) efficacy on survival of patients with PQ poisoning is questionable but quantity of consumption, time by which first HD was started and number of HD has an impact on the outcome.[9]

Hemoperfusion (HP) is more effective than hemodialysis.[10] In a dog model it was suggested that HP done beyond 2hr of poisoning is ineffective in preventing uptake of poison by the lungs,[11] however HD done after 2-4hrs can decrease the plasma concentration of the PQ.[7] A recent Cochrane meta-analysis concluded that patients who received glucocorticoid with cyclophosphamide in addition to standard care had slightly reduced mortality at admission, with little or no effect on mortality at three months.[11]

However, in our child immunosuppression and antioxidants were started on day 9 of admission. Since the mechanism of action of the poison is oxidative stress mediated, antioxidants have been involved in protective effect against PQ poisoning.[13]

Favourable prognostic factors include younger age, exposure through percutaneous or inhalational routes, lower quantities of paraquat exposure, and milder degrees of leucocytosis, acidosis, and organ dysfunction (renal, hepatic, and pancreatic) at the time of admission.[14-15] For better visualization and practical application, the stepwise management of paraquat poisoning has been organized into a comprehensive flow chart (flow chart). The survival of our first patient can likely be attributed to the smaller quantity of poison ingested, absence of pancreatic, hepatic, or respiratory failure, lack of acidosis, and timely, effective supportive care.

In contrast, the second patient had both renal impairment and respiratory failure due to developing pulmonary fibrosis, with ingestion of a larger quantity of paraquat. As he presented 24 hours after ingestion, serum and urine paraquat levels could not be measured. Diagnosis was based on clinical history and documented evidence of ingestion. The delayed presentation also eliminated the opportunity for early hemoperfusion, which might have improved his outcome.

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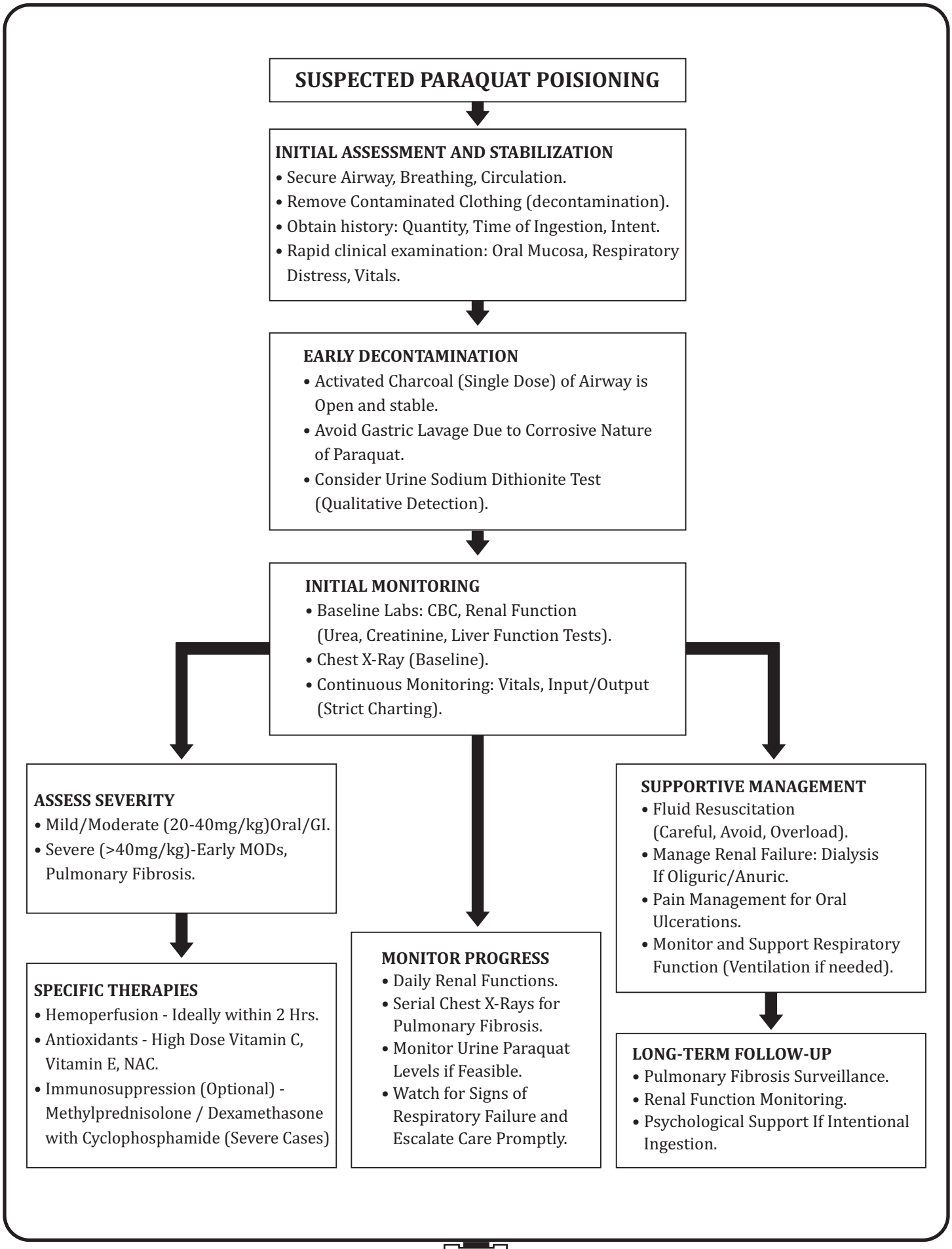
SUSPECTED PARAQUAT POISIONING
INITIAL ASSESSMENT AND STABILIZATION
• Secure Airway, Breathing, Circulation.
• Remove Contaminated Clothing (decontamination).
• Obtain history: Quantity, Time of Ingestion, Intent.
• Rapid clinical examination: Oral Mucosa, Respiratory Distress, Vitals.
EARLY DECONTAMINATION
• Activated Charcoal (Single Dose) of Airway is Open and stable.
• Avoid Gastric Lavage Due to Corrosive Nature of Paraquat.
• Consider Urine Sodium Dithionite Test (Qualitative Detection).
INITIAL MONITORING
• Baseline Labs: CBC, Renal Function (Urea, Creatinine, Liver Function Tests).
• Chest X-Ray (Baseline).
• Continuous Monitoring: Vitals, Input/Output (Strict Charting).
ASSESS SEVERITY
• Mild/Moderate (20-40mg/kg)Oral/GI.
• Severe (>40mg/kg)-Early MODs, Pulmonary Fibrosis.
SPECIFIC THERAPIES
• Hemoperfusion - Ideally within 2 Hrs.
• Antioxidants - High Dose Vitamin C, Vitamin E, NAC.
• Immunosuppression (Optional) - Methylprednisolone / Dexamethasone with Cyclophosphamide (Severe Cases)
MONITOR PROGRESS
• Daily Renal Functions.
• Serial Chest X-Rays for Pulmonary Fibrosis.
• Monitor Urine Paraquat Levels if Feasible.
• Watch for Signs of Respiratory Failure and Escalate Care Promptly.
SUPPORTIVE MANAGEMENT
• Fluid Resuscitation (Careful, Avoid, Overload).
• Manage Renal Failure: Dialysis If Oliguric/Anuric.
• Pain Management for Oral Ulcerations.
• Monitor and Support Respiratory Function (Ventilation if needed).
LONG-TERM FOLLOW-UP
• Pulmonary Fibrosis Surveillance.
• Renal Function Monitoring.
• Psychological Support If Intentional Ingestion.

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A Case Report

A Forensic Odontology finding of Linear Enamel Hypoplasia: A Case Report

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ABSTRACT

Introduction: Linear enamel hypoplasia (LEH) is a dental anomaly characterized by symmetrical, horizontal defects on tooth enamel, commonly linked to physiological stress during childhood. It serves as an important marker of systemic disturbances and has significant forensic applications. LEH reflects disruptions in enamel formation due to factors such as malnutrition, systemic diseases, or stress during childhood. LEH can provide valuable information about the individual's age and health at the time of defect development, aiding in identification, especially when other methods are limited.

Case Presentation: This report presents a 40-year-old male who died and was referred to Cipto Mangunkusumo Hospital, Jakarta, following collapse during work. Clinical examination revealed bruises and open wounds on the lips, dental caries, attrition, and LEH on most maxillary and mandibular teeth.

Discussion: Enamel hypoplasia can be categorized as either pits, grooves, or linear defects. The advantage of examining enamel hypoplasia in forensic identification is its ability to provide insights into the age and health of an individual at the time the defect occurred. LEH provides insight into an individual's environmental conditions during development. The pattern might vary according to ethnicity, making it useful in narrowing down the identity especially when combined with dental radiography and histological analysis

Conclusion: LEH is a non- invasive way to obtain extra forensic evidence that might help with the identification. process in cases where a person's body is found in a condition of advanced decomposition where DNA analysis might not be feasible.

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INTRODUCTION

Teeth abnormalities can be idiopathic, inherited, or caused by environmental factors. Because dental enamel is distinct and remains unchanged after its initial development, any disturbances occurring during its formation become permanently recorded on the surface of the tooth. Amelogenesis imperfecta is a genetic enamel abnormality that results from the structure of enamel developing. Environmentally caused enamel abnormalities fall into one of three categories:

(1) diffuse opacities

(2) delimited opacities

(3) hypoplasia.[1]

The enamel is a highly mineralized and calcified tissue. Number of elements, both environmental and genetic, must interact for enamel to form. To create high-quality enamel, these elements must be appropriately coordinated. Hypoplasia results from any disruption in this synchronization. Mineral deficiencies, vitamin deficiencies, malnutrition, systemic diseases such as hypoparathyroidism, hypothyroidism, and renal disease, medications (e.g tetracycline), contaminants from environment such as heavy metals, fluoride, and a host of other conditions are frequently linked to enamel hypoplasia. A variety of hypoplasia is caused by a number

of environmental variables that act for varying lengths of time and at different times. There are variations in the rates and intervals at which tooth enamel forms.[2]

Any disruption that takes place during a specific time period physically shows up in the enamel section that is developing at that moment. Because not all tooth structure is affected, environmental hypoplasia is distinct from hypoplasias resulting from genetic origin (such as amelogenesis imperfecta).[3-4]

In general, enamel hypoplasia is often triggered by disturbances that occur during the secretion phase, but can also be affected by problems at the formation and maturation stages. Therefore, it is important to take care of the mother's health during pregnancy to support healthy tooth development in the foetus.[5]

LEH is typified by numerous, symmetrical, ring-like abnormalities that affect every surface of the teeth. It is considered a general marker of physiological stress during the formation of teeth, with abnormalities reflecting sudden interruptions in the enamel production process.[6-7] The estimated age at which they developed can be determined because LEH appears in alignment with the normal pattern of enamel growth increments or is indicated by wider spacing between successive perikymata on the outer enamel surface.[8-9]

Enamel hypoplasia is among the non-specific indicators of how a population physically responds to environmental influences. It is studied in both past and present populations to assess the comparative adaptive success of groups living in different social, geographic, ecological, or historical settings.[10]

This article will discuss LEH in a male dead body, examined by a forensic odontology dentist in Cipto Mangunkusumo Hospital, Jakarta.

Case Presentation

On September 14, 2024, there was a need for a visum et repertum on the body of a 40- year-old man. The incident happened during the night shift change, around 1AM. The victim unexpectedly fell from his chair, causing his lips to hit the table. He managed to get up and walked out of the room holding his left chest, but soon collapsed and lost consciousness. The male was immediately taken to Cipto Mangunkusumo Hospital, Jakarta for further examination.

On intraoral examination, on the outer left upper lip, there were two purplish bruises measuring 2x1 cm and 0.5x0.5 cm as shown as **Figure 1**. On the left outer lower lip, there were 2 open wounds with uneven edges on the base of the lip mucosa measuring 2x1 cm and 0.1x0.5 cm in the surrounding area with blisters measuring 1x0.1 cm and 0.3x0.3 cm as shown as **Figure 2**. On dental examination, teeth 17 and 26 were missing ante mortem, caries on teeth 18 and 45, and attrition on almost all tooth surfaces. There was a view of enamel defects, which is LEH on almost all maxillary and mandibular teeth as shown as **Figure 3, 4, 5**.

Figure 1. Bruises wound on the left upper lip. Blunt trauma to the upper lip, such as from impact with a hard object, can rupture small blood vessels beneath the skin, leading to bruising and swelling. The resulting contusion typically appears as a bluish or purplish discoloration and may be accompanied by pain or tenderness in the affected area.

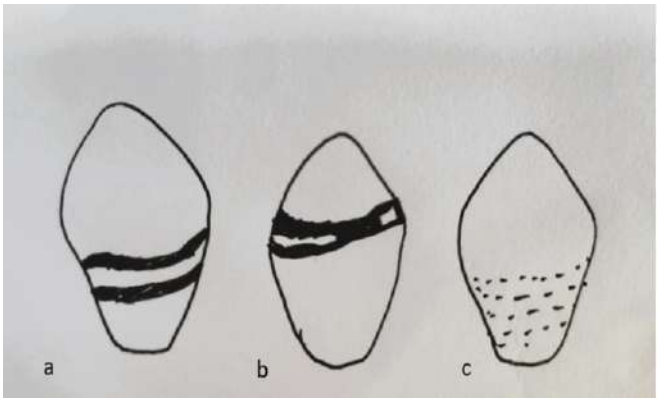
Figure 2. Open wound with the surrounding area with blisters on the lower lip. An open wound on the lower lip with surrounding blisters caused by blunt trauma may result from a strong impact that splits the lip tissue and damages the surrounding tissue. The force can cause both tearing of the soft tissue and localized blistering due to pressure and friction at the site of impact.

Figure 3. The right lateral view of the maxilla and mandible shows LEH, characterized by horizontal grooves or lines on the tooth surfaces indicating past disturbances in enamel formation during development.

Figure 4. The left lateral view of the maxilla and mandible reveals LEH, evidenced by horizontal defects on the tooth surfaces, suggesting episodes of developmental stress during tooth formation.

Figure 5: The anterior view shows LEH as horizontal grooves or lines on the front teeth, indicating past disruptions in enamel development.

Figure 6: Linear enamel hypoplasia can appear in different configurations depending on the severity of the developmental disturbance: (a) lines are shallow, horizontal markings on the enamel surface; (b) grooves are deeper, more pronounced linear depressions; and (c) pits are small, localized indentations. (illustration by author) (13)



DISCUSSION

These developmental defects can include tooth malformations, crown dilatation, crown duplication, root dilatation, sequestration of the permanent tooth germ, disruptions in the eruption of permanent teeth, and partial or total arrest of root formation They can also include mild changes in enamel mineralization that result in simple yellow-brown discoloration. The permanent teeth's developmental stage at the time of injury, their connection to the primary teeth's roots, and the force's direction and magnitude all affect the kind and severity of the disruptions. Enamel hypoplasia can occur at various stages of tooth development, but mainly

relates to a specific phase in the enamel development process during odontogenesis. This process is divided into three main stages:

1. **Bud Formation Stage:** This is the initial stage of tooth development, during which tooth tissue begins to form. Enamel defects are universally recognized as markers of significant physiological stress, as they originate from cellular disruptions during critical stages of tooth development namely histodifferentiation, apposition, or mineralization regardless of their duration or persistence.
2. **Secretory Stage:** At this stage, ameloblast cells are responsible for producing enamel. Disruptions due to nutritional deficiencies (e.g. vitamin D deficiency), may cause the enamel produced to be thinner or incomplete, resulting in enamel hypoplasia.
3. **Maturation Stage:** This is the stage where the formed enamel undergoes mineralization and maturation

process. Disruptions at this stage due to maternal health conditions or medication use can contribute to hypoplasia and result in enamel that is not as strong or as good as it should be.[10-11]

A number of issues, including malocclusion, tooth sensitivity, poor aesthetics, and a propensity for dental cavities, can result from hypoplasia. Since most teeth are easily prone to decay, the mildest type of LEH is frequently misdiagnosed as decay and the teeth would have already been affected by the decay process before the LEH was discovered. A novel categorization of caries linked to hypoplasia was established by Caufield PW; this type of caries primarily affects young children who are at or below the poverty line and is typified by primary teeth that are structurally compromised and more susceptible to dental caries.[12]

Although the prevalence of enamel hypoplasia in the general population ranges from 6% to 32%, we could only find a small number of case reports on it in scholarly sources. According to its clinical manifestation, enamel hypoplasia in humans is categorized by the Federation Dentaire International as either pits (one or more, shallow or deep, of enamel loss <2 mm broad, enamel loss in microscopic areas), or regions of partial or whole missing of tooth crown enamel.

When the process of enamel formation is disrupted, enamel hypoplasia occurs. Since the central and lateral incisors, canines, and first molars begin mineralizing in the first year of life, they are the teeth most often affected. As mineralization of the premolars, second molars, and third molars does not commence until around three years of age or older, these teeth remain unaffected. In this instance, the main concerns were LEH, malocclusion, tooth sensitivity, poor aesthetics, and a tendency toward dental cavities. In its mildest form, LEH is sometimes misdiagnosed and treated as decay before the disease is identified.[5,7]

The two main types of stress that cause enamel defects are inadequate materials for matrix formation or mineralization and disrupted cellular function. A lack of enamel thickness caused by a disturbance in the matrix apposition stage of tooth enamel formation is known as enamel hypoplasia. Since hypoplastic anomalies can result from a variety of diseases and dietary variables, they are believed to have a general origin.

Only the portion of the tooth that is presently forming will be impacted by metabolic disturbances; therefore, the placement of the defect on the tooth crown provides an opportunity to determine the age of the individual at the time of defect development. When viewed at a macro level, hypoplasia appears as different patterns of lines, grooves, or pits on the surface of the tooth. In this case, lines pattern appears in almost maxillary and mandibular teeth.

Physiological stress during childhood can disrupt the development of enamel, leading to the emergence of localized hypoplastic defects on the outside of teeth. Although these deformities can take many different forms, including pitting, furrowing, or irregular depressions, the most frequently described type is LEH. Stress episodes cause high cortisol levels to alter enamel matrix secretion, which in turn inhibits protein synthesis. The connection between stress and hypoplastic abnormalities in the setting of social rank from archaeological sites has been the subject of numerous investigations.

Numerous topics have been discussed, such as the relationship between weaning and the incidence of LEH and variations in subsistence tactics. Varying degrees of population stress, linked to periods of food scarcity or cultural amelioration, high status, or more "privileged" ancient societies get affected by LEH. Records also exhibit that LEH has positive relationships when analyzed in relation to age-at-death, suggesting that longevity may be impacted by extreme childhood stress.[13-14]

On the surface of the tooth, hypoplasia appears as lines, grooves, or pits as shown in **Figure 6** grouped in different configurations. In this case, LEH appears as lines type.

Considering the nature of the research, the distinction made by many authors about hereditary hypoplasia should be disregarded. According to Goodman and Rose 7, in most modern populations, individuals with hereditary defects are rare (<1%). The diagnosis of inherited structural abnormalities according to them are:

(1). While environmental anomalies might influence either the main or secondary dentition or individual teeth, hereditary structural anomalies typically affect both the primary and secondary dentition.

(2). While environmental anomalies influence both enamel and dentin, hereditary structuralaanomalies typically affect either or both.

(3). While environmental structural anomalies are mainly ordered horizontally, hereditary structural anomalies typically result in diffuse or even vertical orientation derangements.[5,13-14]

The first one involves qualitative enamel anomalies, which

are mostly brought on by disruptions in the enamel's mineralization. While the size and shape of the crown are typical at eruption, the enamel's powdery nature causes it to tear away from the teeth very quickly. Teeth are often dark, and the enamel surface is fragile and irregular.

The second kind, known as hypoplasia or aplasia of enamel, is associated with a quantitative decrease in the quantity of enamel matrix that is put down during amelogenesis. Usually dark brown in color, the damaged teeth may occasionally mimic enamel hypoplasia.[15-16]

Jan´czuk has noted that darkening of the primary and secondary teeth occurs in genetic illnesses that have lower enamel quality. Because there were no distinctive discolorations and the flaws were placed horizontally on the surface of the teeth, hereditary factors may be ruled out as the source of the condition in the population under study, taking into consideration the aforementioned concerns. Because of environmental factors and the lack of proper surface alterations, fluorosis may also be disregarded. However, Rose pointed out that, regardless of a person's developmental stage, long-term exposure to fluorine can discolor tooth crowns brown and, in the end, cause pits to form on the surface of teeth.[15-16]

Forensic odontology involves the careful collection, analysis, and interpretation of dental evidence for legal purposes. Teeth, being the hardest and most durable structures in the human body, are among the last to decompose after death. Because each person's oral cavity is unique, dental patterns are highly individualistic. This field plays a vital role in identifying individuals through dental remains, particularly in mass disaster scenarios or criminal incidents such as terrorist attacks, aviation and transportation fires, accidents, mass killings, child abuse cases and sexual assaults. Identification typically relies on assessing distinctive dental features like microdontia, anodontia, crowding, ectopic eruptions, spacing and diastema which can be observed through dental records or radiographs.[17-18]

These features are genetically determined and cannot be tampered with or eliminated by perpetrators. By understanding the types and genetic basis of dental anomalies, forensic experts can better analyze these characteristics for matching postmortem and antemortem data, aiding in the confirmation of identity. Additionally, genetic pedigree analysis can provide further insights into the evidence and potential suspects. Nonetheless, the lack of antemortem dental records or poor-quality remains can hinder investigations. Recent advances in genetic technologies, including genome sequencing and gene editing, have accelerated progress in forensic odontology. Integrating genetics with dental forensics can significantly enhance investigative outcomes.[17]

The advantage of examining enamel hypoplasia in forensic identification is its ability to provide insights into the age and health of an individual at the time the defect occurred. Enamel formation occurs during specific stages of tooth development, with each tooth forming over a period of months or years. When an individual experiences physiological stress, such as malnutrition or disease, during tooth development, it can lead to disruptions in enamel production. By examining the timing, extent, and distribution of these enamel defects across different teeth, forensic odontologists can infer the individual's age at the time the hypoplasia occurred, which can help narrow down the timeframe in which the person lived. This information is particularly useful when combined with other forensic evidence, such as skeletal analysis, to determine an approximate age at death.[19]

LEH also provides insight into an individual's life history and the environmental conditions they were exposed to during development. Stressors that impact enamel formation, such as childhood diseases, malnutrition, or trauma, can leave distinct marks on the enamel, often as horizontal lines or pitting. In cases where identifying an individual through traditional means, such as fingerprints or DNA, is not possible, enamel hypoplasia can serve as a supplementary method for reconstructing an individual's past. It helps forensic experts understand the broader context of an individual's life, including potential social, environmental, or medical circumstances, by highlighting periods of physical stress or hardship during their early years.[13,16,19]

In cases of unidentified human remains, particularly those where only skeletal remains are found, the analysis of LEH can offer a valuable link to identifying a person's origin or demographic characteristics. The pattern of enamel hypoplasia might vary according to geographic location or ethnicity, making it useful in narrowing down the identity of the deceased, especially when combined with other forensic techniques such as dental radiography and histological analysis. Furthermore, when an individual's body is discovered in a state of advanced decomposition, where DNA analysis might not be viable, enamel hypoplasia serves as a non-invasive method to gather additional forensic evidence that can aid in the

identification process.[19]

CONCLUSION

LEH represents a significant developmental defect that can offer valuable insight in forensic contexts, particularly in cases where conventional identification techniques such as DNA analysis are compromised or unavailable. The presence and morphological patterns of LEH serve as indicators of systemic physiological stress experienced during childhood, contributing to the reconstruction of biological profiles. Given its resistance to postmortem degradation, LEH can function as a reliable supplementary marker in the identification of unknown remains. Emphasizing its forensic relevance underscores the potential of dental anthropology in broadening the scope of human identification in challenging scenarios.

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A Case Report

Scavengers at the Crime Scene : How Animal Activity Obscures Forensic Evidence

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ABSTRACT

When an individual dies, scavenging animals, such as wild predators, dogs, foxes or birds, often feed on the remains, especially if the body is left exposed in an outdoor or isolated environment. While animal predation is a natural process, it can unintentionally complicate the determination of the cause of death, especially in cases of homicide. In some instances, scavenger activity at the site of injury can obscure vital forensic evidence, making it difficult to distinguish between pre-existing injuries inflicted by humans and those caused post-mortem by the animals. This phenomenon can mask crucial details and potentially lead to misinterpretations of the circumstances surrounding a death. We report and discuss one such case in which a dead body was recovered in the open field, where stray dogs were found to be eating away at the flesh around the neck of the body. After conducting an autopsy and considering all circumstantial evidence together, what seemed like a case of post-mortem animal predation turned out to be a case of homicide. Thorough examination ensures that natural processes do not conceal criminal acts and that justice is not undermined by misinterpretation of evidence.

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INTRODUCTION

Animal predation on a dead body, particularly at the site of an injury, can pose significant challenges for forensic experts as they rely heavily on visible injuries, wounds, and patterns of trauma to determine whether death resulted from homicide, accidental causes, or natural events. In cases where animals have scavenged the body, the damage they inflict can create confusion; scavengers may gnaw, bite, or tear at exposed flesh, particularly around existing injuries, and their actions can distort or completely alter the original wounds.

For example, animal bite marks or claw scratches may be misinterpreted as signs of violent human infliction, leading investigators to incorrectly assume that the victim was attacked before death. Furthermore, an animal's predatory actions can obscure the true location of a fatal wound or mask signs of defensive wounds, which are important indicators in homicide investigations.[1]

The process of postmortem predation can be particularly deceptive if the animal activity occurs near or at the site of injury on the victim.[2] For instance, scavengers might begin feeding on the body shortly after death, particularly in cases where the deceased's injuries make them more vulnerable to animal attacks.

If the body exhibits clear signs of animal interference-such as dismemberment or missing body parts-investigators may suspect that the victim experienced additional trauma postmortem, which could complicate the homicide investigation. The timing of scavenger activity and its impact on the remains may create the false impression of a prolonged postmortem period, when the death could have occurred much earlier.[3-5]

In addition to physical injury masking, the presence of animal predation can interfere with other important forensic investigations, such as determining the time since death.[6-7] Scavengers can alter the decomposition timeline, as animals may accelerate the breakdown of tissue and bone. This may lead forensic experts to misjudge the interval between death and discovery, further complicating the investigation. As a result, distinguishing

between animal-caused trauma and human-inflicted injury becomes crucial, as investigators must determine the true sequence of events to accurately establish the cause of death.[8]

Furthermore, different types of animals can cause varying degrees of damage, complicating the identification of a predatory animal. Larger predators like wolves, jackals or coyotes can cause significant tissue disruption, while smaller animals, such as rodents, may leave minimal, less detectable evidence. Domestic pets, particularly dogs, are also known to scavenge human remains, sometimes leading to a blend of animal and human-inflicted injuries.[9-11] Forensic professionals must consider these factors when evaluating the overall condition of the body, ensuring that animal predation is not mistaken for additional injuries resulting from foul play.

Case History

The police officials, after receiving information from the local authorities, reached an open field near a farm in the Mansa district of Punjab, where they discovered a partially decomposed body of an adult male lying in a supine position. Stray dogs were observed snatching at the body parts, particularly on the neck region. Miscellaneous papers were recovered from the deceased's clothing, which, along with the presence of multiple tattoos and a physical deformity of the right foot, facilitated in identification of the deceased.

The autopsy was conducted on the same day; on preliminary examination, it was observed that all the clothing worn by the deceased was smeared with dried stains of mud, the shirt was found to be irregularly torn at multiple sites on its upper half, while the rest of the clothing were intact. Also, multiple grey and brownish black coloured fibres suggestive of hairs were found loosely all over the clothing. After the removal of clothes, it was observed that rigor mortis was passed off, there was greenish discolouration on the front of the abdomen, and a fixed post-mortem staining at the back of the body.

On general examination, skin and subcutaneous tissue of the scalp, along with muscles on the right side of the face, were missing, exposing the periosteum of the skull vault and bones of the facial skeleton. The neck structures were missing, exposing the muscles and fascia overlying the vertebral column of the neck, which were covered with mud **(Figure 1)**.

The most evident injury noted was a lacerated wound,

Figure 1: Showing Exposed Periosteum of the Skull Vault and Bones of the Facial Skeleton. The Neck Structures were Missing, Exposing the Muscles and Fascia Overlying the Vertebral Column of the Neck.

measuring 41.2cm x 16.4cm x 8cm on the scalp and right side of the face, extending to involve the front and sides of the neck. Over the scalp, there was loss of skin and subcutaneous tissues on the frontal, right temporal, right parietal region, upper half of the occipital region and over a portion of the left parietal region, exposing the periosteum of the skull vault. Similarly, the right side of the face showed loss of skin, subcutaneous tissues, and muscles, exposing the bones of the facial skeleton and teeth. Over the neck region of the wound, posteriorly, a portion of the skin and subcutaneous tissues were found to be intact. The tongue, pharynx, larynx, thyrohyoid complex, oesophagus and surrounding neck structures were missing up to the level of the sternoclavicular joint and the remaining tissue fragments, tracheal ring and neck vessels were found lacerated with irregular margins and presence of tissue tags **(Figure 2)**. The transverse processes of the 5th and 6th cervical vertebrae, and the spinous processes of the 6th and 7th cervical vertebrae, were found to be fragmented, with no evidence of blood effusion, suggesting a post-mortem nature. Multiple post-mortem scratch abrasions suggestive of animal claw marks were also observed just below this wound and on the upper half of the front of the chest, which had a pale base with no extravasation of blood at the margins; the injury varied in size from 0.5 cm x 0.5 cm to 1.2cm x 0.5cm **(Figure 3)**. In addition, multiple reddish contusions were observed on the left side of the face involving the left cheek, left orbit and on the left temporal region of the scalp. There was another reddish

contusion measuring 4.6cm x 3.2cm on the front of the left side of the chest, situated just to the left of the neck wound **(Figure 3)**. On further dissection, a wedge-shaped defect on the front of the body of the 5th cervical vertebra, measuring 1.2cm x 0.2cm x 0.5cm, was observed with clean cut margins. At this site, bevelling of the lower edge and undermining of the upper edge was noted with extravasation of blood at the margins of the defect **(Figure 4)**. X-ray of the Head and neck, along with chest X-ray of the deceased, was done, which did not reveal any metallic fragments or projectiles.

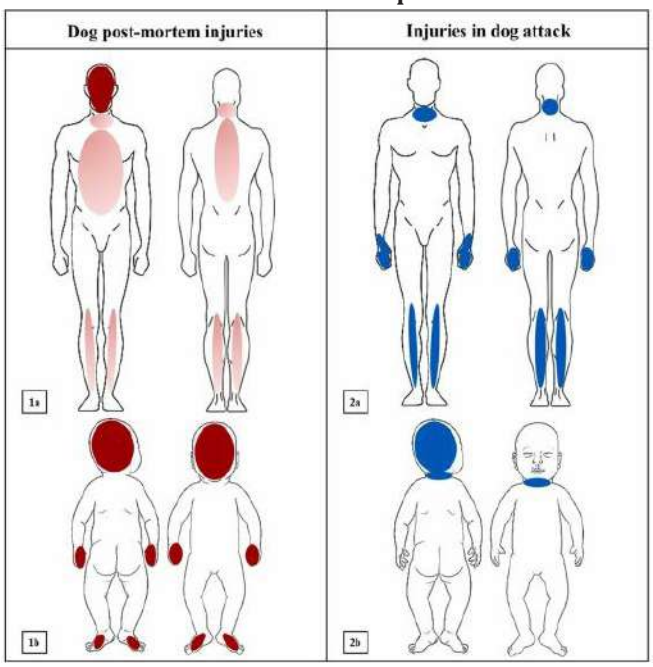
Since no abnormality or pathology was detected in the remaining tissues and organs on cut section, and the toxicological analysis of visceral organs reported to be negative for the presence of common poisons hence, the cause of death was opined as cut-throat injury to the neck caused by a sharp-edged weapon, and the manner was specified as homicidal.

Figure 2: Showing the Lacerated End of the Trachea Caused by Scavengers.

Figure 3: Showing Scavenging Activity Over the Front of the Neck.

Figure 4: Showing the Clean Cut Wound with Bevelling of the Lower Edge and Undermining of the Upper Edge with Extravasation of Blood at the Margins of the Defect.

Figure 5: Differential Diagnosis of Dog Attack in Post-Mortem and Antemortem Depredation.[14]



DISCUSSION

Bites from domestic animals such as dogs typically present in the form of broad soft tissue defects with curved margins at the site of the wound and puncture holes due to the canine teeth; The bite marks result from the action of three bevelled-edged incisors, a single pointed canine, four premolars, and two molars in the upper jaw (maxilla) or three in the lower jaw (mandible). In our case, though there were no specific tooth marks, the margins of the wound on the head and over the front of the neck were irregular, suggestive of a muscle-tearing effect, along with the

presence of multiple scratch abrasions due to claws, commonly observed in predation by canines.[12] If the teeth marks are identifiable, a detailed analysis of bite marks could have been done, such as measuring the intercanine distance, along with saliva swab sampling and genetic testing, which involves molecular analysis of biological samples taken from injuries on the deceased body, as well as the use of species-specific short tandem repeat (STR) markers for dogs, cats, and other wild animals.[3,7,12-13] Studies involving comparative analysis of attack patterns and the distinction between antemortem and post-mortem injury sites on the human body have offered valuable insights into animal behaviour and the manner of death. In case of post-mortem depredation, damage is mostly on the exposed and unclothed part of the body, and removal of skin and muscle from the face is the first action of scavengers. Face mutilations can be extensive, including defleshing and removal of eyes, lips, nose, ears or scalp with the presence of depressed fractures. Scavenging of neck structure, including bones, represents extension of face attack.[2,7,14] However, in contrast to what is indicated in Figure 5, the tissues of the chest and legs of the deceased in our case were spared. This could be due to the early intervention of the local authorities, who drove the dogs away from the scene after the discovery of the dead body.

Perimortem trauma or injuries are a grey zone in forensics, as assessment of the injuries becomes difficult; though occurring after death, they essentially show the same features as antemortem injuries. In contrast, post-mortem injuries can be determined by the absence of vital responses like marginal inflammation, hemorrhagic infiltration. Also, the absence of defensive injuries can be considered in the overall evaluation of antemortem vs postmortem injuries.[6] In our case, despite features of early decomposition, the distinction between the antemortem and post-mortem injuries could be grossly appreciated, particularly the observation of a wedge-shaped defect in the body of the cervical vertebra, which was caused by a blow with some sharp-edged weapon, as determined by the presence of clear-cut margins and bevelling. However, in the absence of any soft tissues surrounding the defect, it could not be ascertained whether the great vessels of the neck or the trachea had been severed by the blow or not, and such a defect reaching posteriorly up to the body of a vertebra indicated that the cut must have been deep enough to injure either or both. The transverse processes of the 5th and 6th cervical vertebrae, and the spinous processes of the 6th and 7th cervical vertebrae, were found to be fragmented, with no evidence of blood effusion. This may have resulted from an initial fracture of the transverse processes caused by a sharp weapon, followed by animal activity targeting the fractured ends. Such a sequence could explain the postmortem nature of the wound at that location. Injuries like this can easily lead a forensic expert to question whether the trauma occurred before scavenging began or if it was solely caused by animal predation. Internal organs did not appear to be pale in appearance ruling out death due to exsanguination. Additionally, the presence of multiple fresh contusions indicated the probability of a struggle with the perpetrator before the infliction of fatal injury to the neck. This, in turn, was followed by a post-mortem predation of the tissues by scavenger dogs, which was responsible for the mutilational effect on the head and neck. The sequence of events were later corroborated by the investigating officer as the accused confessed upon the crime after confronting the findings of post-mortem report.

CONCLUSION

Animal predation poses a significant challenge in forensic investigations, particularly when it obscures evidence of homicide. Scavenging activity can alter or destroy soft tissue and skeletal structures, potentially mimicking perimortem injuries or erasing critical signs of trauma. This interference complicates the establishment of corpus delicti-the essential proof that a crime, specifically a homicide, has occurred.

When predation masks or modifies the wounds, it can hinder the ability to determine cause and manner of death, potentially leading to misclassification of homicide as accidental or natural death or even preventing the recognition that a death occurred at all. Therefore, forensic experts must carefully differentiate between postmortem animal damage and genuine traumatic injuries through detailed taphonomic analysis, genetic analysis and recognition of vital responses in tissue.

By accurately identifying animal predation and understanding its impact on the remains, forensic investigators can better preserve the integrity of corpus delicti, ensuring that natural processes do not conceal criminal acts and that justice is not undermined by misinterpretation of evidence.

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Format of Application for Membership

To

The General Secretary
Punjab Academy of Forensic Medicine & Toxicology (PAFMAT)

Dear Sir,

I wish to become a Life Member / Annual Member of PAFMAT. I am furnishing the required particulars below with a request to enrol me in the academy. The fee of Rs. 2500 / Rs. ---- for Life Membership / Annul Membership is enclosed as a Demand Draft with No_____ Of _____Bank, in the name of PAFMAT, SBOP Chandigarh along with my two passport size photographs.
I have gone / will go through the rules and regulations of the academy and I agree to abide by the same.

PARTICULARS

1. Full Name (in block letters)
2. Father's / Husband's name
3. Date of Birth
4. Qualification (with name of university & date of passing)
5. Official Designation & Place of Posting
6. Permanent Address
7. Address for Correspondence (subsequent change of address to be intimated)
8. Phone No. & Email

Place Yours Sincerely

Date

(Signature)

FOR USE OF PAFMAT

Membership Accepted with Life / Annual membership No. / PAFMAT / /

Dated

Treasurer **Secretary** **President**

Note: Payment can be made by NEFT in the account of academy (A/c No. 2082101026802, IFSC Code: CNRB0002082, Canara Bank, Gopal Nagar, Amritsar) after telephonic talk with President/Secretary/Treasurer. Scanned copy of the filled form can be send by E-mail to secretary.


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MMCMSR
Sadopur - Ambala

Glimpse of PAFMATCON 2024-25 of Punjab Academy of Forensic Medicine & Toxicology

Held on 21-22 March 2025 at Department of Forensic Medicine and Toxicology, HIMS Dehradun (HP) India

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