Volume 47
Issue 4
December 2025

JIAFM

Journal of Indian Academy of FORENSIC MEDICINE

Official Publication of the Indian Academy of Forensic Medicine

find this journal online
at http://journals.sagepub.com/home/iaf
ISSN: 0971-0973
E-ISSN: 0974-0848

ISSN: 0971-0973
Online ISSN: 0974-0848

Journal of Indian Academy of Forensic Medicine an official publication of Indian Academy of Forensic Medicine (IAFM) is published quarterly—in April, July, October & December by Sage.

Please visit the Journal's submission site https://peerreview.sagepub.com/iaf to upload your manuscript. Please note that manuscripts not conforming to the guidelines may be returned.

To view the guidelines, please visit journals.sagepub.com/home/aom and click on 'Submit Paper' tab.

Annual Subscription: Individual rate (print only) ₹5,180, $130, and £70; institutional rate (print) ₹9,010. For orders from Pakistan, Bangladesh, Sri Lanka and the Maldives, SAARC rates apply: individuals £80; institutional rate £120. Prices include postage. Print only subscriptions are available for institutions at a discounted rate.

Orders from the Americas should be sent to Sage Publications Inc, 2455 Teller Road, Thousand Oaks, CA 91320, USA (Tel: 00 800 818 7243/ E-mail: journals@sagepub.com).

Orders from the UK, Europe, the Middle East, Africa and Australasia should be sent to Sage Publications Ltd, 1 Oliver's Yard, 55 City Road, London, EC1Y 1SP, UK (Tel: +44 (0)20 7324 8500/ E-mail: subscription@sagepub.co.uk).

Inquiries from India/South Asia about single issue rates, availability of back issues or print only rates for institutions, advertising and permission requests should be sent to Sage Publications India Pvt. Ltd, Emaar Capital Tower-2, Floor-10th, Unit-003, Near Guru Dronacharya Metro Station, Mehrauli-Gurgaon Rd, Sikanderpur, Sector 26, Gurugram, Haryana 122 002, India, (Tel: (+91)0124-4092914/4092910/E-mail: customerservicejournals@sagepub.in). Inquiries from the Americas should be sent to the California address (above), while those from the UK, Europe, the Middle East, Africa and Australasia should be sent to the London address (above).

Claims: Claims for undelivered copies may be made no later than three months following the month of publication. The publisher will supply replacement issues when losses have been sustained in transit and when reserve stocks permit.

Abstracting and Indexing: Please visit http://journals.sagepub.com/home/iaf and click on 'Journal overview and metrics' tab on the right-hand side to view a full list of databases in which this journal is indexed.

Change of Address: Four weeks' advance notice must be given when notifying change of address. Please send the old address label to ensure proper identification. Please specify the name of the journal and send change of address notification to the Sage office through which you subscribe to the journal.

Printed and published by Sonia Kumar on behalf of Indian Academy of Forensic Medicine at Sage Publications India Pvt. Ltd, Emaar Capital Tower-2, Floor-10th, Unit-003, Near Guru Dronacharya Metro Station, Mehrauli-Gurgaon Rd, Sikanderpur, Sector 26, Gurugram, Haryana 122 002, India and printed at Repro Books Limited, Khasra No. 13/19, 22, 17/2, 9/1/1, Dharuhera, Village Malpura, Haryana 123110, India.

Editor-in-Chief: Dr Ravindra B Deokar

MD (FM), LLB, LLM(HR), ACME, PGDFAO, FAIMER, EPGDHA (TISS), MBA (HAHCM)

E-mail id: Jiafmeditor@gmail.com (M): +91-9423016325

Volume 47 Issue 4 December 2025

Journal of Indian Academy of Forensic Medicine

Sage
www.sagepub.com

www.iafmonline.in

Journal of Indian Academy of Forensic Medicine

Governing Council (2025-2028)

Registration No. 349, Panaji, Goa

Official website - www.iafmonline.in

Journal of Indian Academy of Forensic Medicine

EDITORIAL BOARD

Volume 47 Issue 4 December 2025

Journal of Indian Academy of Forensic Medicine

Contents

Review Articles

Case Reports

Contemporary Issues in Bioethics

Journal of Indian Academy
of Forensic Medicine
47(4) 343–345, 2025

DOI: 10.1177/09710973251413853
journals.sagepub.com/home/iaf
Sage

Ravindra B Deokar[1], Rajesh C Dere[2] and Praveen Arora[3]

Keywords

Medical ethics, biomedical research, technological advancement, artificial intelligence, genetic engineering

Introduction

Bioethics is a branch of applied ethics that deals with the interdisciplinary study of social, philosophical, and legal issues arising in life sciences, medicine, technology, nonhuman biological environment, and public policy.[1] It mainly focuses on the implications of biomedical research, medical practice, and patient care. It includes a wide range of topics such as medical ethics, biomedical research ethics, and environmental ethics.[2]

Bioethics examines the ethical, social, and legal perspectives of biomedical research and the field of medicine. Key bioethical issues involve mainly genetic engineering and its use in medicine, data security and data privacy, informed consent and patients' engagement, Artificial intelligence (AI) in healthcare, ethical concerns of reproductive technologies, access to equitable and affordable healthcare, and ethics related to end-of-life care.[3–5]

Contemporary bioethics is a field that addresses the ethical perspective and implications of rapid technological and scientific advancements in medicine. It is crucial to formulate new policies and standard practices respecting the rights of patients to promote social justice and equitable, affordable treatment for all. Medical ethics frequently deals with matters of life and death. It is deeply concerned with the rights of the patient, confidentiality, informed consent, competency of health professionals, carelessness, advance directives, biomedical research, technological advancement, and various topics related to serious healthcare concerns, including the increasing use of AI in healthcare.[6,7]

Contemporary Issue in Bioethics

These are complex and multifaceted issues involving the following main key concerns in healthcare.

Data Security and Data Privacy

It deals with protecting and keeping the data safe to avoid unauthorized access and its misuse. It protects data from theft, corruption, and misuse, ensuring the confidentiality of the sensitive data. Various methods used for this are encryption, access control, data masking, and real-time monitoring. Data security is important for abiding by regulatory compliance, maintaining customer trust, and protecting against cyber threats. Various challenges in maintaining data security and data privacy are insider threats, cloud security, and AI-driven threats. There is a need to implement comprehensive data security strategies to mitigate the risk of data breaches and cyber theft.

Genetic Engineering

It deals with the manipulation of the organism's deoxyribonucleic acid (DNA) to enable advancement in medicine, biotechnology, agriculture, and related fields by altering its characteristics. It involves direct manipulation of an organism's genes using technology to get an advanced genetically modified organism (GMO). Various techniques used in genetic engineering include recombinant DNA technology,

[1]Department of Forensic Medicine and Toxicology, Lokmanya Tilak Municipal Medical College and LTMG Hospital, Mumbai, Maharashtra, India
[2]Department of Forensic Medicine and Toxicology, Topiwala National Medical College and BYL Nair Hospital, Mumbai, Maharashtra, India
[3]Forensic Medicine and Toxicology, Sri Aurobindo Medical College and PG Institute, Sri Aurobindo University, Indore, Madhya Pradesh, India

Corresponding author:
Ravindra B Deokar, Department of Forensic Medicine and Toxicology, Lokmanya Tilak Municipal Medical College and LTMG Hospital, Sion, Mumbai, Maharashtra 400022, India.
E-mail: Ravideo803@gmail.com

gene editing such as clustered regularly interspaced short palindromic repeats-CRISPR-associated protein 9 (CRISPR–Cas9) (a revolutionary tool for editing of DNA), gene cloning, gene silencing or gene knockdown, protoplast fusion, and related methods. Genetic engineering offers multiple benefits but raises serious ethical concerns regarding biodiversity, safe food, and potential unintended consequences on the ecosystem.[8,9]

Therapeutic and medicinal applications of genetic engineering include cancer treatment, gene therapy, drug research, plant breeding improvements, and synthesizing hormones and enzymes. Main safety concerns of genetically modified food are the potential to provoke allergic reactions, the transfer of genes from food to human cells, and causing further consequences. Strict disciplinary regulations and monitoring are required from governments to assess and manage the risks associated with the development and release of GMOs.[10] There is a need for appropriate, balanced scientific advancements with ethical concerns of equity, consent, and long-term consequences.

Informed Consent and Patient's Engagement

It is a free voluntary agreement between two consenting parties where all information about the patients' health, the options of treatment are explained to the patient in her own language, mentioning the consequences, and allowing the patient to choose the options freely, voluntarily, without any undue coercion. It facilitates improving the patients' engagement and improves outcomes. The ethical and legal requirements of informed consent in healthcare are important in ensuring professional standards and protecting patients' rights.[11]

AI in Healthcare

AI is the game-changer and is transforming the medical field with scientific advancements in diagnostics, personalized medicine, and enhanced surgical precision.[6,12] The key ethical principles of autonomy, beneficence, non-maleficence, and justice are important in AI-driven decision-making. There are various legal challenges with grave concerns on data privacy and security, intellectual property, AI errors, regulatory approval processes, and international regulations. As AI system is becoming more autonomous, the question of fairness, decision-making, and responsibility needs to be addressed appropriately. There is a need of multidimensional, global, adaptive, harmonized framework for the application of AI in healthcare. There should be disciplinary collaboration between healthcare providers, technologists, legal experts, and policymakers for ethical AI adoption, with fostering trust to improve public engagement.[12]

Equitable Access and Affordable Healthcare

Every individual has a fair opportunity to achieve the best potential health, irrespective of economic, social, and environmental differences. The government needs to make appropriate efforts to secure the same by providing appropriate financial protection, ensure no discrimination on ground of gender, race, religion, and related factors. Necessary strategies to be adopted to address the inequalities to target the societal and systemic factors.

Cyber-attacks Against Medical Devices and Systems

The more interconnectedness of various medical devices with the implementation of hospital information management systems led to an increase in cybersecurity concerns, leading to patient harm, erosion of trust, and potential economic impact. Effective strategies need to be implemented to mitigate such issues are frequent updates, cybersecurity-integrated design, education and awareness, and regulatory enforcement.[13]

Policies and Legislation

The relationship between the ethical issues and policy and legislation is multifaceted and complex. Ethical considerations always play a leading role in the formulation of public policies and their implementation.[14] Ethical leadership in formulating robust public policies will contribute to enhance development and welfare of the people at large. Effective implementation of ethics and public policies hand-in-hand in healthcare governance will have a significant impact on the country's development.

Conclusion

Biomedical and life sciences research is the main driver of scientific development, leading to improvements in the quality of life. It may lead to human rights violations, discrimination, and injustice. National and international policies are based on the legal implications and changing societal needs of biomedical research and technological advancement.

Various national and international bodies, committees, and commissions are formed to address the issues and to advise governments on appropriate public policy. Modern medical ethics is going to be more complex day by day, and there is a need to engage bioethicists, society, and healthcare professionals to explore the ethical concerns with the technological and scientific advancements in the field of medicine.

ORCID iD

Ravindra B Deokar https://orcid.org/0000-0003-1539-1035

References

1. Mandal J, Ponnambath DK and Parija SC. Bioethics: A brief review. *Trop Parasitol* 2017; 7(1): 5–7. DOI: 10.4103/tp.TP_4_17
2. UNESCO and Bioethics. *Make bioethics everyone's business*. 2015. Available from: UNESCO and bioethics: Make bioethics everyone's business-UNESCO Digital Library.

3. World Health Organisation. *Global health ethics*. Available from: http://www.who.int/ethics/en/.
4. Ghooi RB. The Nuremberg code-A critique. *Perspect Clin Res* 2011; 2: 72–76. DOI: 10.4103/2229-3485.80371
5. Kahn Peter A. Bioethics, religion, and public policy: Intersections, interactions, and solutions. *J Relig Health* 2016; 55: 1546–1560.
6. Deokar RB and Patil SS. Artificial intelligence in healthcare and biomedical research: Ethical aspects. *J Forensic Med Sci Law* 2024; 33(1): 1–4. DOI: 10.59988/jfmsl.vol.33issue1.1
7. Deokar RB, Dere RC and Patil SS. Looking at recent evolution in toxicology through legal lens. *J Indian Acad Forensic Med* 2025; 47(1): 7–11. DOI: 10.1177/09710973251371356
8. Capecchi MR. Generating mice with targeted mutations. *Nat Med* 2001; 7(10): 1086–1090. DOI:10.1038/nm1001-1086
9. Maryanski JH. *Genetically engineered foods*. Center for Food Safety and Applied Nutrition at the Food and Drug Administration. Archived from the Original on 9 July 2009. 1999
10. What is genetic modification (GM)? CSIRO.
11. Nijhawan LP, Janodia MD, Muddukrishna BS, et al. Informed consent: Issues and challenges. *J Adv Pharm Technol Res* 2013; 4(3): 134–140. DOI: 10.4103/2231-4040.11677
12. Deokar RB, Dere RC and Patil SS. Genomics and precision medicine in forensic medicine. *J Indian Acad Forensic Med* 2025; 47(2): 123–125. DOI: 10.1177/09710973251381715
13. Deokar RB and Patil SS. Cybercrime: Medicolegal perspective. *J Forensic Med Sci Law* 2025; 34(1): 1–3. DOI: 10.59988/jfmsl.vol.34issue1.1
14. Pham T. Ethical and legal considerations in healthcare AI: Innovation and policy for safe and fair use. *R Soc Open Sci* 2025; 12(5): 241873. DOI: 10.1098/rsos.241873

Does India Need a Separate Cephalic Index Value? An Autopsy-based Study of the Cephalic Index on the Delhi Population

Journal of Indian Academy
of Forensic Medicine
47(4) 346–352, 2025

DOI: 10.1177/09710973251412498
journals.sagepub.com/home/iaf
Sage

Jitendra Kumar[1], Yogesh Tyagi[2], Mohan Singh Meena[3] and Afzal Haroon[1]

Abstract

Cephalic Index has been one of the most studied topics in Physical Anthropology. With the advancement of DNA technology, Racial theories are changing drastically. Still, the concept of the cephalic index is relevant in the present context for various reasons like correction of sagittal synostosis, making of head-worn objects like earphones, helmets, etc., Identification, and Cosmetic and Facial reconstruction purposes. Very few studies have been done to measure the cephalic index after reflection of the scalp on cadavers. The present study was done on cases coming for autopsy at the tertiary hospital in the capital of India. A more accurate result for the measurement of the cephalic index has been obtained, which will be helpful for identification purposes in skeletonized bodies. This was a cross-sectional, prospective, and observational study. Two hundred two post-mortem cases (46 females and 156 males) satisfying our inclusion and exclusion criteria in the age group of 7–85 years were examined for skull length and skull breadth as per the standard criteria after reflection of the scalp using a digital vernier caliper, and the cranial index was calculated. The mean biparietal length for the males, females and overall were 133.43, 130.60, and 132.79 (in mm), respectively. The mean occipito-frontal size for the males, females and overall were 172.14, 164.56, and 170.41 (in mm), respectively. The mean cranial index for the males, females and overall were 77.61, 79.46, and 78.04, respectively, that is, all in the category of the Mesati-cephalic. The most typical skull type in both sexes was Mesati-cephalic (male 48.1% and female 41.3%). The second most common was Dolichocephalic (20.5%) among males and Brachycephalic (26.1%) in females, respectively.

Keywords

Forensic anthropology, identification, cranial index, cadaver, ancestry, race

Received 15 March 2025; **accepted** 16 December 2025

Highlights

- A more accurate result for the measurement of the cephalic index has been obtained, which will be helpful for identification purposes in skeletonized bodies, as the study was done after reflection of the scalp on cadavers.
- The mean cranial index of the Delhi population for the males, females and overall was 77.61, 79.46, and 78.04, respectively, that is, all in the category of the Mesati-cephalic.
- We observed that 80.69% of the study population, with 81.41% males and 80.43% females, belong in the cephalic index range of 72.5–84.9.

We propose that a cephalic index value of 72.5–84.9 or any more precise value after further studies can be used to identify people of the Indian geographical region, as they have distinct morphological traits.

[1]Department of Forensic Medicine, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh, Uttar Pradesh, India
[2]Department of Forensic Medicine, Vardhman Mahavir Medical College and Safdarjung Hospital, New Delhi, India
[3]Department of Forensic Medicine, Rajshree Medical Research Institute, Bareilly, Uttar Pradesh, India

Corresponding author:
Jitendra Kumar, Department of Forensic Medicine, Jawahar Lal Nehru Medical College, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.
E-mail: dr.jitendrak2@gmail.com

Introduction

The history of the cephalic index goes back to the Swedish professor of anatomy, Andres Retzius (1796–1860), who first applied it in Physical Anthropology to classify human remains found in Europe.[1] Further human individual's head shapes were classified correctly (Hyper-dolichocephalic, Dolicho-cephalic, Mesati-cephalic, Brachy-cephalic and Hyper-Brachy-cephalic) by the Stewart and range for each category was decided (1936).[2]

Since then, cephalic index has been one of the most studied topics in Physical Anthropology. With the advancement of DNA fingerprinting, Racial theories are changing drastically. Still, the concept of a cephalic index is relevant in the present day as well for various reasons other than race identification, like correction of sagittal synostosis, making of head-worn objects like earphones, helmets, etc., Identification, Cosmetic and Facial reconstruction purposes.

For forensic purposes, identifying skeletal remains is challenging; the cephalic index can play a significant role in some instances. Most studies on the cephalic index have been done on living subjects. So, applying the same values for the race determination on the skeletal remains poses a risk of scalp thickness bias. For this, we need to develop data on skull parameters after reflection of scalp tissues.

With these lacunae, the present study was done on cases coming for autopsy at the tertiary hospital in the capital of India, and the cephalic index was calculated after the reflection of the scalp tissues. A more accurate result for the measurement of the cephalic index has been obtained, which will be helpful for identification purposes in skeletonized bodies. Also, the study was done on the population of Delhi with the objective of finding a cephalic index value in the Delhi region. The advantage of calculating the cephalic index value from the capital of India is that Delhi is a cosmopolitan city where people from different parts of India reside. So, the result of the cephalic index value of Delhi may reflect the cephalic index of India.

Material and Methods

The study was conducted in the Department of Forensic Medicine & Mortuary of Atal Bihari Vajpayee Institute of Medical College & Ram Manohar Lohia Hospital, New Delhi. The study was conducted over six months. We obtained written and informed consent from the deceased's parents/guardians/relatives. This was a cross-sectional, prospective, and observational study. Study populations were dead bodies coming for the Medico-legal post-mortem examination at the mortuary. A convenient sample size of about 200 cases was taken. The inclusion criteria were all dead bodies coming into the morgue for post-mortem examination during this period, while the exclusion criteria were: (a) Bodies with skull deformity, (b) bodies with fracture of the skull, (c) known cases of bone pathology, (d) severely burned bodies, (e) declared bodies of foreign origin. Ethical Clearance for the study was obtained from the Institutional Ethical Committee of Atal Bihari Vajpayee Institute of Medical College & Ram Manohar Lohia Hospital, New Delhi vide File No. 488(24/2021)/IEC/ABVIMS/RMLH/ 558 dated 02.06.2021.

Methods

Bodies coming for post-mortem examination were included in the study as per our exclusion and inclusion criteria. Bodies satisfying our criteria were examined for various skull measurements after reflection of the scalp using a vernier caliper. A digital Vernier caliper of Insize brand (Code no.1108-300) with a range of 0–300 mm/0–12 and measurement accuracy of +0.003 mm was used for all the skull measurements. In the present study, all measurements were carried out by a single, well-trained member of our team to minimize variability. Standard anthropometric techniques were employed using a calibrated digital vernier caliper, with measurements recorded to two decimal places. Although intra- and inter-observer reliability testing was not performed separately, given the standardized methodology and single-observer design, the scope for variation is minimal. The following measurement criteria were followed:

Head Length: It was measured as a straight distance between the glabella (a point above the nasal root between the eyebrows and intersected by the midsagittal plane) and the opisthocranion (The distal-most end placed on the external occipital protuberance in the midsagittal plane)

Head Breadth: It was measured as the maximum transverse diameter between two euryons (the lateral-most point placed on the sides of the head). Cephalic Index was calculated as:

*Cephalic index = Maximum breadth of skull/ Maximum length of skull * 100*

Depending upon this index, the types of head shapes are grouped into the following categories (Table 1). Microsoft Excel was used for data registration, and IBM SPSS 31.0.0 (Statistical Package for Social Science) for statistical analysis. We applied descriptive statistics and calculated data in the

Table 1. Showing Different Kinds of Skulls and Their Cephalic Index Value.

S. No.	Types of Skulls	Cephalic Index
1.	Ultra-dolichocephalic	<65.4
2.	Hyper-dolichocephalic	65.5–69.9
3.	Dolicho-cephalic	70.0–74.9
4.	Mesati-Cephalic	75.0–79.9
5.	Brachy-cephalic	80.0–84.9
6.	Hyper-Brachy-cephalic	85.0–89.9
7.	Ultrabrachycephalic	>90.0

Table 2. Showing Measurement of Head Length (Occipito-frontal Length) (in mm).

Head Length (in mm)	Overall	Male	Female
Minimum	148.15	148.15	149.64
Maximum	188.59	188.59	183.61
Average (mean)	170.41	172.14	164.56
Median	170.97	172.68	163.51

Table 3. Showing the Distribution of Head Length in the Study Population.

Distribution of Head Length Head Length (in mm)	Male [Percentage Out of Total Males (156)]	Female [Percentage Out of Total Females (46)]
140.1–150	1 (0.6)	1 (2.2)
150.1–160	3 (1.9)	9 (19.6)
160.1–170	51 (32.7)	29 (63.0)
170.1–180	90 (57.7)	6 (13.0)
180.1–190	11 (7.1)	1 (2.2)

Table 4. Showing Measurement of Head Breadth (Biparietal Length) (in mm).

Head Breadth (in mm)	Overall	Male	Female
Minimum	109	109	114.15
Maximum	149.92	149.92	149.84
Average (mean)	132.79	133.43	130.60
Median	133.16	133.41	131.74

form of mean, median and percentage. Standard deviation and confidence interval for the overall cephalic index value were calculated using an online statistical tool (calculator.net). ANOVA for comparison of the difference in the Male and Female cephalic index values from Table 9 was performed using social science statistics available online.

Results

A total of 202 Post-mortem cases (46 females and 156 males) in the age group of 7–85 years were examined. The mean occipito-frontal length for the males, females and overall were 172.14, 164.56, and 170.41 (in mm), respectively (Table 2). Among males, 90.1% of the Occipito-frontal length (Head length) was 160.1–180 mm. Among females, 82.6% of the Occipito-frontal length (Head length) was 150.1–170 mm (Table 3). The mean biparietal length for the males, females and overall were 133.43, 130.60, and 132.79 (in mm), respectively (Table 4). Biparietal length (Head breadth) was 120.1–140 mm for 85.3% and 89.1% of the male and female study population, respectively (Table 5). The mean cranial index for the males, females and overall were 77.61, 79.46, and 78.04, respectively, that is, all in the category of the Mesati-cephalic (Table 6). The median value of the cranial index for the males, females and overall was 77.31, 78.52, and 77.65, respectively, that is, all in the category of the Mesati-cephalic (Table 6). The population distribution of the cephalic index was maximum in the cranial index range of 72.5–84.9 with about 81.41%, 80.43%, and 80.69% for males, females and overall, respectively (Table 7). The most typical skull type in both sexes was Mesati-cephalic (male 48.1% and female 41.3%) (Table 8, Figures 1–3). The second most common type of skull was Dolichocephalic (20.5%) among males and Brachycephalic (26.1%) among females (Table 8, Figures 1–3). The standard deviation for the overall cephalic index value was found to be 4.706 with a confidence interval of 0.331. On performing ANOVA on Table 9, for comparison of the Male and Female cephalic values, there is no significant sexual variation noted with the F-ratio value: 3.48, and the p value is .069 (>.05).

Table 5. Showing the Distribution of Head Breadth in the Study Population.

Distribution of Head Breadth Head Breadth (in mm)	Male [Percentage Out of Total Males (156)]	Female [Percentage Out of Total Females (46)]
100.1–110	1 (0.6)	Nil
110.1–120	2 (1.3)	4 (8.7)
120.1–130	39 (25.0)	16 (34.8)
130.1–140	94 (60.3)	25 (54.3)
140.1–150	20 (12.8)	1 (2.2)

Table 6. Showing Cranial Index Value of the Study Population.

Cephalic Index	Overall	Male	Female
Minimum C.I.	61.93	61.93	70.41
Maximum C.I.	92.01	92.01	90.35
Average (mean)	78.04	77.61	79.46
Median	77.65	77.31	78.52

Discussion

Delhi, the capital of India, is considered to be representative of the people of India. The present study on measuring the cephalic index was done on the population of Delhi in a tertiary care hospital on the dead bodies after reflection of the scalp tissues. Identifying the skeletal remains is one of the significant challenges for an autopsy surgeon. As most studies on the cephalic index have been done on living subjects,

Table 7. Showing the Distribution of the Cephalic Index in the Study Population.

Distribution of Cephalic Index	Male [Percentage Out of Total Males (156)]	Female [Percentage Out of Total Females (46)]	Overall [Percentage Out of Total Study Population (202)]
Cephalic Index			
<60	Nil (0)	Nil (0)	Nil (0)
60.0–65.4	1 (0.6)	Nil (0)	1 (0.5)
65.4–69.9	6 (3.8)	Nil (0)	6 (3.0)
70.0–72.4	11 (7.1)	3 (6.5)	15 (7.4)
72.5–74.9	21 (13.5)	6 (13.1)	26 (12.9)
70–74.9	32 (20.5)	9 (19.6)	41 (20.3)
75–77.4	42 (26.9)	8 (17.4)	50 (24.8)
77.5–79.9	33 (21.2)	11 (23.9)	44 (21.8)
75–79.9	75 (48.1)	19 (41.3)	94 (46.5)
80–82.4	18 (11.5)	4 (8.7)	22 (10.9)
82.5–84.9	13 (8.3)	8 (17.4)	21 (10.4)
80–84.9	31 (19.9)	12 (26.1)	43 (21.3)
85–87.4	5 (3.2)	4 (2.2)	9 (4.5)
87.5–89.9	5 (3.2)	1 (2.2)	6 (3.0)
85–89.9	10 (6.4)	5 (10.9)	15 (7.4)
>90	1 (0.6)	1 (2.2)	2 (1.0)

Table 8. Showing the Distribution of Skull Shapes in the Study Population in Percentage.

Distribution of Skull Shapes (in Percentage)	Cephalic Index Distribution in Males	Cephalic Index Distribution in Females	Overall Cephalic Index Distribution In Both Sexes
Ultra-dolichocephalic	0.6	0	0
Hyper-dolichocephalic	3.8	0	3
Dolicho-cephalic	20.5	19.6	20.3
Mesati-cephalic	48.1	41.3	46.5
Brachy-cephalic	19.9	26.1	21.3
Hyper-brachy-cephalic	6.4	10.9	7.4
Ultrabrachy-cephalic	0.6	2.2	1

using the same data on the skeletal remains increases the chances of systematic bias. For this, identification of the race and facial reconstruction can be better possible if data are

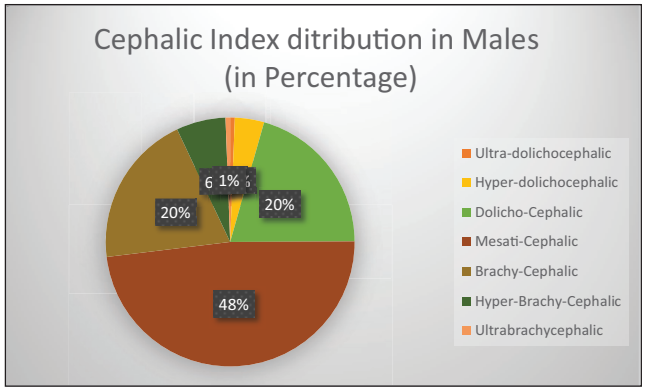

Figure 1. The Distribution of Skull Shapes Among Males.

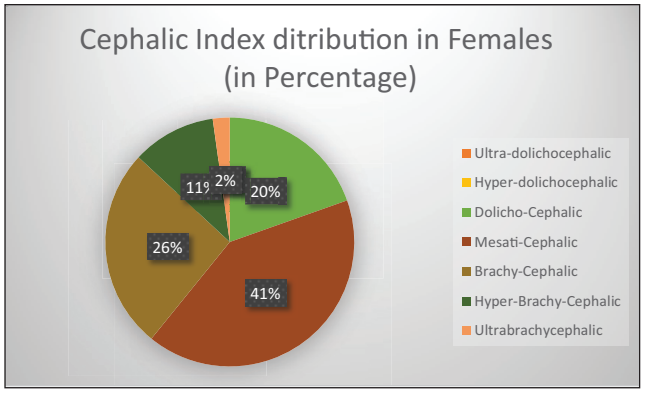

Figure 2. The Distribution of Skull Shapes Among Females.

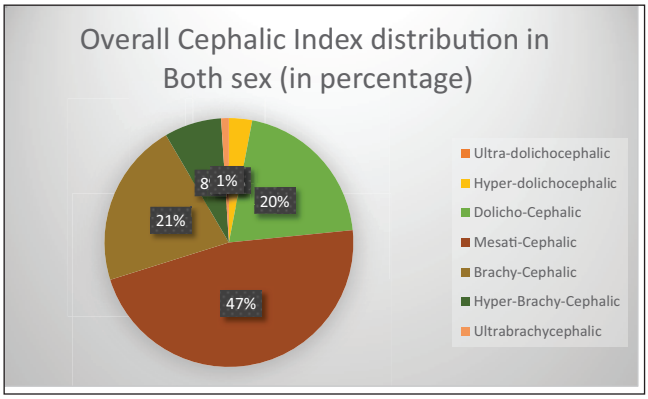

Figure 3. The Overall Distribution of Skull Shapes in the Study Population.

available in skeletonized conditions. Sharma RN found that due to the difference in the soft tissue thickness, the cranial index is two units higher among living subjects than that measured on the dried human skull.[3] Many studies have reported that readings of the measurement with soft tissue give higher values than those without soft tissue.

Interestingly, soft tissue thickness differs not only individually but also locally from one site to another. Chakrabarti

Table 9. Comparative Analysis of Cephalic Index Values in Various Study Populations in India.

S. No.	Name of Researchers (Year)	Population Studied	Mean Cephalic Index		
			Male	Female	Overall
1.	Bhargava & Kher (1960)[5]	Bhils of Central India			76.98
2.	Bhargava & Kher (1961)[5]	Barelas of Central India			79.8
3.	Basu (1963)[6]	Kayasthas of Bengal			79.5
4.	Shah & Jadhav (2004)[7]	Gujrat	80.42	81.0	80.81
5.	Mahajan et al. (2010)[8]	Punjab	81.34	85.75	85.53
6.	Khair et al. (2011)[9]	Mumbai	81.28	75.22	78.48
7.	Salve et al. (2011)[10]	Andhra Pradesh	75.68	78.20	76.94
8.	Yagain et al. (2012)[11]	Karnataka	77.92	80.85	79.38
9.	Salve & Chandrashekhar (2012)[12]	Mumbai	73.19	76.84	74.23
10.	Gujaria & Salve (2012)[13]	Maratha	77.08	79.02	78.14
11.	Gujaria & Salve (2012)[13]	Andhra	76.28	78.16	77.32
12.	Gujaria & Salve (2012)[13]	Gujrati	80.42	81.20	80.81
13.	Nair et al. (2012)[14]	Bhopal	81.24	80.31	81.21
14.	Desai et al. (2013)[15]	Karnataka	77.69	75.35	82.53
15.	Gupta et al. (2013)[16]	Haryana	74.74	76.83	
16.	Patro et al. (2014)[17]	Odisha	77.28	78.38	77.75
17.	Shah et al. (2015)[18]	Gujrat	70.61	81.17	77.2
18.	Kumari et al. (2015)[19]	Andhra Pradesh	79.25	80.21	
19.	Kumar & Nagar (2015)[20]	Delhi	73.75	75.22	74.40
20.	Shah et al. (2015)[18]	Non-Gujrati	77.15	77.38	75.5
21.	Seema & Verma (2016)[21]	Punjab	80.52	84.32	85.53
22.	Setiya et al. (2018)[22]	Madhya Pradesh	77.65	78.13	77.89
23.	Khanduri et al. (2021)[23]	Uttar Pradesh	75.59	77.94	76.67
24.	The present study (2021)	Delhi	77.61	79.46	78.04

et al.[4] noted that calculations should be done without soft tissue to find a precise cephalic index. Given the above, the present study adds to the available data on the cephalic index of the Indian population, particularly for the skeletal remains.

In the present study, the cephalic index ranges from 61.93 to 92.01, with a mean value of 78.04. Among all the participants in the survey, Mesati-cephalic was the dominant head shape, followed by Brachycephalic and then Dolichocephalic type. The mean cephalic index for females (79.46) was higher than for males (77.61) in our study. The second most common among males was found to be the Dolichocephalic type, followed by Brachycephalic and vice versa in the case of females. The general tendency of the study population was toward Mesati-cephalic and Brachycephalic cranial index values. Data from the present study were compared with earlier studies conducted in the various parts of India on the cephalic index, as tabulated in Table 9.[5–22]

Findings of our study on Delhi population are similar (Mesati-cephalic) to studies done by Khair et al. (2011)[9] on Mumbai population, Salve et al. (2011)[10] on Andhra population, Yagain et al. (2012)[11] on Karnataka population, Gujaria and Salve (2012)[13] study on Maratha and Andhra population, Patro et al. (2014)[17] on Odisha peoples, Shah et al. (2015)[7] studies on Gujrat population, Setiya et al. (2018)[22] on Madhya Pradesh population and Khanduri et al. (2021)[23] studies done on the peoples of Uttar Pradesh of India.

The shape of the skull is affected by multiple factors, including genetic and environmental factors.[24] Tropical regions are found to have longer heads (Dolichocephalic), while temperate climatic zones present more of a round head shape (Mesocephalic or Brachycephalic).[25] India has a remarkable climate pattern, with tropical in the South and temperate in the northern region. So, the skull shape also shows variations in different areas. Most studies point to the tendency of Indian skull cephalic index values toward brachycephalization, which the present research supports.

Brachy-cephalization of the skull and changes in the shape of the head in the population over a long period a known phenomena reported in various literature.[26–28] The literature points out that such changes over the period are mainly due to the changes in the standard of living, a drop in infant mortality and movements of the people. This needs to be assessed in

the Indian population by further studies with large sample sizes and comparing data from previous studies chronologically for the best results.

Does India Need an Indian Cephalic Index?

Coon (1965)[29] divided the human species into four races: Caucasoid, Mongoloid, Australoid, and Negroid, based on morphological traits like skin color, differences in eyes, nose, skull shape, blood group, etc. Indians have not been included in the above four races and are considered mixed. However, India is one of the world's oldest civilizations, with people residing there for a long time. Still, Indians are not recognized as a separate race. In the present study, we observed that 80.69% of the study population, with 81.41% males and 80.43% females, belong in the cephalic index range of 72.5–84.9. Also, Indians have distinct morphological traits from Caucasians, Mongoloid, Africans and Australians. The classification of the head shapes with cephalic index values is not a precise natural classification, but an observed, convenient classification by different scientists. So, we propose that for the convenience of identity and other purposes, a cephalic index value of 72.5–84.9 or any more precise value can be used to identify people of the Indian geographical region. We suggest conducting more studies comprising a more extensive study population and broader geographical coverage to establish a more accurate value.

Limitations of the Study

The study is limited by the lack of data on genetic and regional variations, factors that could influence the results and restrict their wider applicability. In addition, the relatively small sample size reduces the strength of the conclusions, making this work preliminary in nature. Broader generalization would require validation through larger, multi-regional studies with more diverse populations.

Conclusion

The present study shows that a significant population of Delhi belong to the Mesati-cephalic category of head shapes. The mean cranial index of females is greater than that of males. The tendency of the population is more toward Brachycephalic than Dolichocephalic. More than 80% of the Delhi population falls under the cephalic index range of 72.5–84.9. The results of this study can be used by anthropologists and forensic experts for various anthropological studies in future and may help forensic experts identify unknown bodies.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

Ethical approval for the study was obtained from the Institutional Ethics Committee of Atal Bihari Vajpayee Institute of Medical College and Ram Manohar Lohia Hospital, New Delhi (File No. 488(24/2021)/IEC/ABVIMS/RMLH/558), dated June 2, 2021.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent

Informed written consent was obtained from the next of kin of the deceased.

ORCID iD

Jitendra Kumar https://orcid.org/0000-0003-0644-5935

References

1. Karthikeyan RK and CS. Cephalic index: A review. *Int J Med Rev Case Rep* 2019; 3(12): 857–860.
2. Stewart TD. Anthropometry. Anthropometric nomenclature. I. The cephalic (length–breadth) index. *Am J Phys Anthropol* 1936; 22(1): 97–140.
3. Sharma KD. Biological diversity: Criteria of racial classification. In: Naidu JM (ed.) *Physical Anthropology*. 4th ed. New Delhi: Indira Gandhi National Open University, 2011, pp.32–48.
4. Chakrabarti JS, Choudhury P and Chakraborty, PN. A study of cephalic index of Bengali subjects of Tripura for determination of race. *J Med Soc* 2018; 32(2): 91–97.
5. Bhargava I and Kher GA. A comparative anthropometric study of Bhils and Barelas of Central India. *J Anat Soc India* 1961; 10: 26–33.
6. Basu A. Anthropometry of the Kayasthas of Bengal. *J Anat Soc India* 1963; 20(3): 5.
7. Shah GV and JH R. The study of cephalic index in students of Gujarat. *J Anat Soc India* 2004; 53(1): 25–26.
8. Mahajan A, Khurana BS, Seema et al. The study of cephalic index in Punjabi students. *J Punjab Acad Forensic Med Toxicol* 2009; 10: 24–26.
9. Swapnali K, Deepika B and Swati W. Study of cephalic index among the students of Mumbai region. *Indian J Appl Res* 2013; 3(11): 232–234.
10. Salve VM, Thota, NR and Anupama P. The study of cephalic index of Andhra region (India). *Asian J Med Sci* 2011; 2: 53–55.
11. Yagain VK, Pai SR, Kalthur SG, Chethan P and Hemalatha I. Study of cephalic index in Indian students. *Int J Morphol* 2012; 30(1): 125–129.
12. Salve VM and Chandrashekhar CH. A metric analysis of Mumbai region (India) crania. *J Indian Med Assoc* 2012; 110(10): 690–693.
13. Gujaria I and Salve VM. Comparison of cephalic index of three states of India. *Int J Pharma Bio Sci* 2012; 3: 1022–1031.
14. Nair SK, Anjankar VP, Singh, S, et al. The study of cephalic index of medical students of Central India. *Asian J Biomed Pharm Sci* 2014; 4(28): 48–50.

15. Desai SD, Shaik HS, Shepur MP, et al. A craniometric study of South Indian adult dry skulls. *J Pharm Sci Res* 2013; 5(2): 33–34.
16. Gupta S, Patnaik V, G V, et al. Cranial anthropometry in 600 North Indian adults. *Int J Anat Res* 2013; 2: 115–118.
17. Patro S, Sahu R and Rath S. Study of cephalic index in southern Odisha population. *J Dent Med Sci* 2014; 13(1): 41–44.
18. Shah T, Thaker MB and Menon SK. Assessment of cephalic and facial indices: A proof for ethnic and sexual dimorphism. *J Forensic Sci Criminol* 2015; 3(1): 101.
19. Kumari KL, Babu PVSSV Kumari PK, et al. A study of cephalic index and facial index in Visakhapatnam, Andhra Pradesh, India. *Int J Res Med Sci* 2015; 3(3): 656–658.
20. Kumar A and Nagar M. Morphometric estimation of cephalic index in North Indian population: A craniometrics study. *Int J Sci Res* 2015; 4(4): 1976–1982.
21. Seema and Verma P. The study of cephalic index in North Indian population. *Int J Morphol* 2016; 34: 660–664.
22. Setiya M, Tiwari A and Jehan M. Morphometric estimation of cranial index in Mahakaushal region of Madhya Pradesh: A craniometrics study. *Int J Sci Stud* 2018; 6(1): 143–146.
23. Khanduri S, Malik S, Khan N, et al. Establishment of cephalic index using cranial parameters by computed tomography in a sampled North Indian population. *Cureus* 2021; 13(6): e15421.
24. Susanne C and Sharma PD. Multivariate analysis of head measurements in Punjabi families. *Ann Hum Biol* 1978; 5(2): 179–183.
25. Bharati S, Som S, Bharati P, et al. Climate and head form in India. *Am J Hum Biol* 2001; 13(5): 626–634.
26. Olusanya AA, Aladelusi TO, Atiba, FA, et al. Craniometry of Nigerian skulls: A cadaveric study and review of the literature. *East Cent Afr J Surg* 2021; 26(4): 168–172.
27. Jantz RL and Jantz, LM. The remarkable change in Euro-American cranial shape and size. *Hum Biol* 2016; 88(1): 56–64.
28. Min YS, Oh CS, Hong JH, et al. Ancient to modern secular changes in the cranial/cephalic index in Korea: Historical brachycephalization and recent debrachycephalization. *Anat Sci Int* 2020; 95(3): 363–373.
29. Coon CS and Hunt EE. *The Living Races of Man*. London: Macmillan, 1974.

Radiological Age Estimation from Manubriosternal and Xiphisternal Joints

Journal of Indian Academy
of Forensic Medicine
47(4) 353–359, 2025

DOI: 10.1177/09710973251412019
journals.sagepub.com/home/iaf
Sage

Sushobhita Singh[1] and Tejasvi Pandey[2]

Abstract

Age estimation is one of the most important pillars for identification purposes. The present study aimed to estimate the age of individuals from Prayagraj, Uttar Pradesh, by analyzing radiological images of the sternum obtained through computed tomography (CT) scans. A total of 150 participants (75 males and 75 females) aged between 20 and 70 years were included in the analysis. CT images were systematically examined for the degree of sternal fusion at the manubriosternal and xiphisternal joints, categorized into three stages: no fusion, partial fusion, and complete fusion. The analysis revealed an age-related progression in sternal fusion, with younger individuals exhibiting no fusion, while partial and complete fusion became more prevalent with age. Males demonstrated higher rates of complete fusion compared to females, especially in the xiphoid-body region. Chi-square tests showed a significant correlation between sex and manubrium-body fusion but not body-xiphoid fusion. Regression analysis indicated that manubrium-body fusion accounted for 39.8% of the variance in age. Kruskal–Wallis tests further supported significant differences in median ages across fusion stages. This study highlights the strong correlation between sternal fusion and age, with females generally experiencing earlier fusion. The findings underscore the utility of sternal fusion as a reliable age estimation tool in forensic assessments, considering sex-specific differences in ossification.

Keywords

Personal identification, age estimation, sternum, skeletal remains and computed tomography scans

Received 28 October 2024; **accepted** 16 May 2025

Introduction

Personal identification establishes and verifies a person's individuality by using certain features or qualities.[1] Bones play a crucial role in identification, particularly in forensic anthropology cases involving morality and criminals.[2] When human bodies are discovered, especially if skeletonized, charred, or mutilated bones provide valuable clues for identification.[3] Certain human bones exhibit significant sex differences, as these bones display distinct characteristics in males and females.[4] Typically, the pelvic and cranial bones are used for analysis, but if these are unavailable, the sternum can provide important information about the individual's age.[5] In the current world of forensic science, MRI, computed tomography (CT) scans, and X-rays are commonly used to examine bone samples.[6] Sternum is a long, flat, widened bone situated in the center of the chest, usually called the breastbone.[7] It is composed of three sections: the manubrium, the body, and the xiphoid process (Figure 1). The present study was planned to use 3D CT images of the sternum of living people whose ages were confirmed from their birth certificates or other legal documents. This study included observation of the fusion of the manubriosternal and xiphisternal joints.

Numerous studies, such as Sahu et al.,[8] Selthofer et al.,[9] Ghorbanlou et al.,[10] Ashley,[11] Gautam et al.,[12] Singh et al.,[13] and Silajiya et al.,[14] have estimated age by analyzing the different fusion joints of the sternum (manubriosternal and xiphisternal joints). The main aim of the present study was to ascertain the age of people in the Prayagraj region in Uttar Pradesh by analyzing radiological images of the sternum obtained via CT scans. The findings contribute to the research

[1]Lovely Professional University, Jalandhar, Punjab, India
[2]Department of Forensic Science, School of Bioengineering and Bioscience, Lovely Professional University (LPU), Phagwara, Punjab, India

Corresponding author:
Tejasvi Pandey, Department of Forensic Science, School of Bioengineering and Bioscience, Lovely Professional University (LPU), Phagwara, Punjab 144411, India.
E-mail: Tejasvi.25999@lpu.co.in

on age estimation through sternal fusion, offering insights into forensic identification techniques.

Materials and Methods

This prospective study was conducted on individuals who presented to the Kriti Scanning Center for thoracic CT scans undertaken for various medical purposes. Eligible participants were approached, informed about the objectives and procedures of the study, and those who agreed to participate provided written informed consent. Following consent, their CT images were obtained as soft-copy datasets. A total of 150 participants were included in the study, comprising 75 males and 75 females, with ages ranging from 20 to 70 years. The data were collected over a six-month period, from February 2024 to August 2024. The residential identity of each participant was verified through their national identification document (Aadhaar card) to confirm their place of origin.

The CT images were collected in the axial orientation with a slice thickness of 1 mm. Furthermore, sagittal and coronal reformatted images were generated at the workstation for comprehensive evaluation. The scanning was done in the Radiology Department of Kriti Scanning Center, Prayagraj; all patients were scanned using a 384 Multi Detector CT (MD-CT) Scanner. Images obtained have high resolution and have all fine detailing. The images were categorized by age and sex. Five distinct age groups were therefore identified: 30–40 years, 20–30 years, 40–50 years, 50–60 years, and 60–70 years (Table 1).

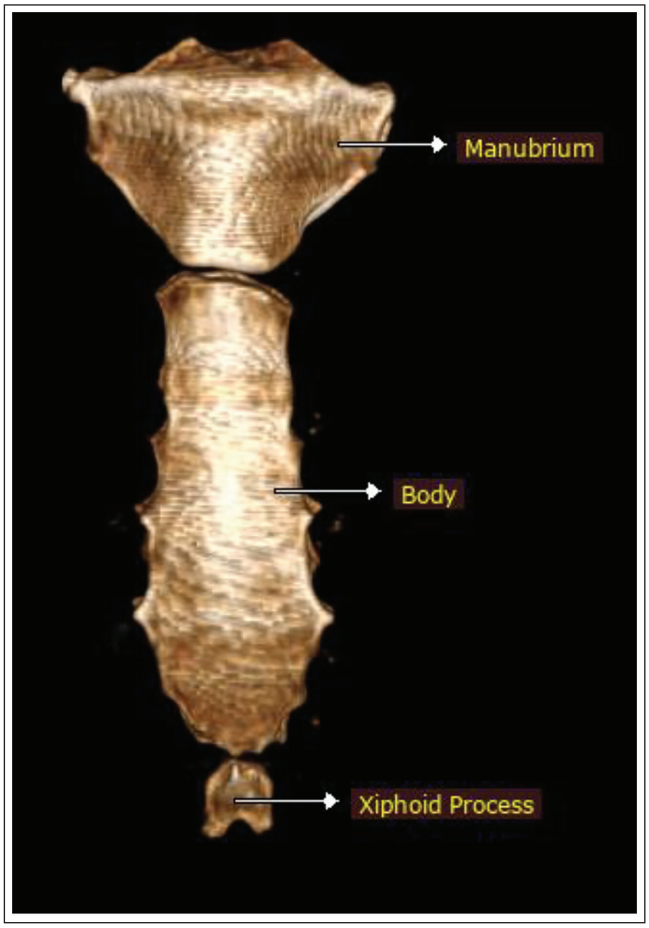

Figure 1. Parts of the Sternum.

Structural image analysis was performed to estimate age by analyzing the ossification points of the sternum utilizing 3D CT imaging. The measurements were obtained using mouse-driven techniques within the Radiant DICOM viewer software. All CT examinations conformed to a standardized 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 120 kV. The relationship between fusion degrees and the assessment of chronological age was conducted through the examination of the manubriosternal and xiphisternal joints. For analysis, different fusion centers were analyzed and categorized according to the fusion between the sternum: Type a: no fusion; Type b: partial fusion and Type c: complete fusion (Figure 2). Statistical analysis was conducted using SPSS software version 20.0, with significance set at a p value of less than .05. Descriptive statistics were employed to demonstrate how fusion occurred over the entire sample. Chi-square tests and regression analyses were performed to investigate the relationships between sternal fusion types, sex, and age. The Kruskal–Wallis test assessed the variations in median ages across the three fusion stages of males and females and pooled samples.

Result

The findings of the study demonstrate a clear age-related progression in the fusion of both the manubrium–body (M+B) and body–xiphoid (B+XP) joints of the sternum. As shown in Table 2, graphically presented in Figure 3, males exhibited minimal fusion in younger age groups, with fusion gradually increasing in frequency and advancing in stage with age. Older males commonly presented with partial or complete fusion. A similar age-related trend was observed in females Table 3, where early adulthood was characterized by predominantly unfused joints, while advanced age groups demonstrated higher occurrences of partial and complete fusion presented in Figure 4.

Fusion of the xiphisternal joint (B+XP) also followed a comparable biological progression in both sexes, as

Table 1. Showing Division of Samples According to Sex and Age.

Age	20–30 Years	30–40 Years	40–50 Years	50–60 Years	60–70 Years
Male	15	15	15	15	15
Female	15	15	15	15	15

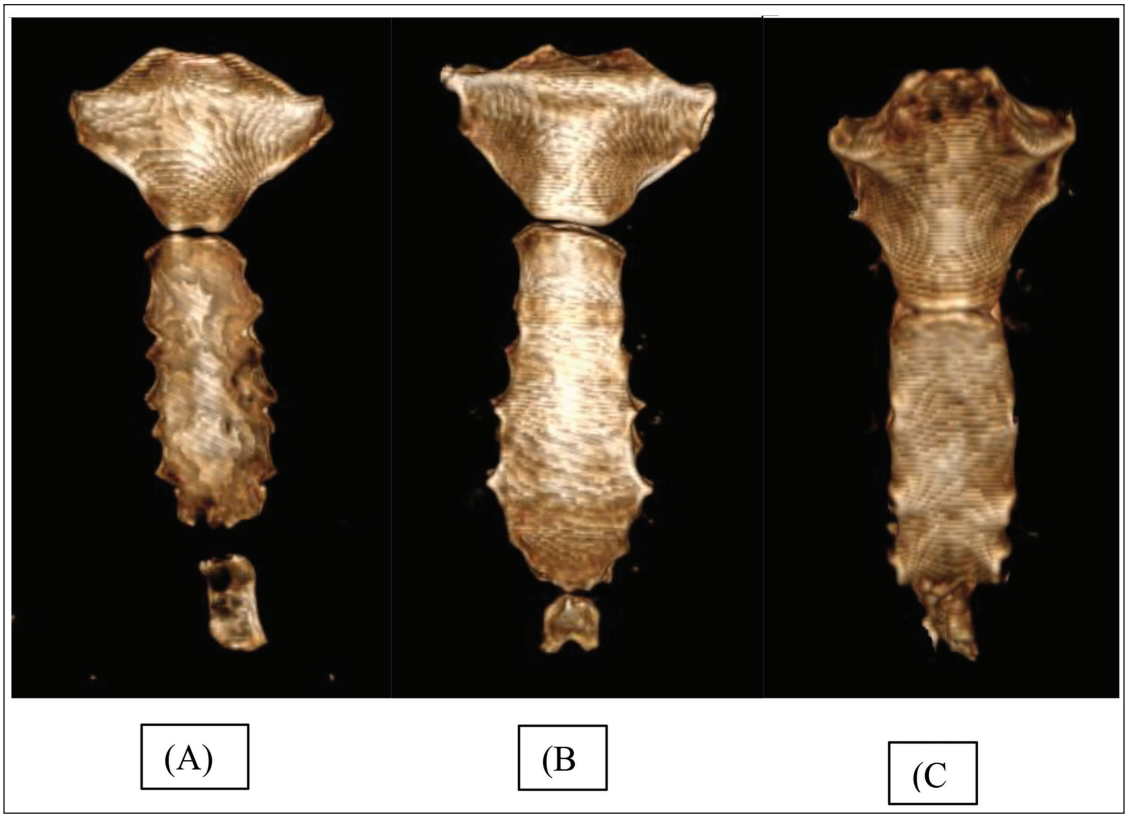

Figure 2. Fusion Between the Different Parts of the Sternum. (A) No Fusion (Type a); (B) Partial Fusion (Type b); (C) Complete Fusion (Type c).

Table 2. Fusion of Sternum, Body and Manubrium in Males.

Age Group	Number of Males	No Fusion (%)	Partial Fusion (%)	Complete Fusion (%)
20–30	15	14	1	0
30–40	15	5	9	1
40–50	15	5	8	2
50–60	15	1	12	2
60–70	15	1	6	8
Total	75	26	36	13

summarized in Tables 4 and 5. Younger individuals typically exhibited no fusion, whereas partial and complete fusion became increasingly common with age. Although both sexes showed similar patterns, males tended to display slightly more advanced fusion changes in older age groups.

Chi-Square analysis indicated a significant association between sex and fusion of the manubrium–body joint Table 6, suggesting that males and females differ in the pattern of fusion at this site. However, no significant relationship was observed between sex and the fusion of the body–xiphoid joint Table 7, indicating that xiphisternal fusion progresses similarly in both sexes.

Regression analysis further confirmed a strong positive relationship between age and M+B fusion, establishing fusion stage as an important predictor of chronological age. The Kruskal–Wallis test supported this finding by demonstrating clear differences in age distribution across the three fusion stages. As detailed in Tables 8 and 9, individuals in more advanced fusion stages consistently belonged to older age groups, reinforcing the biological link between sternal fusion and aging.

Overall, the results confirm that sternal fusion progresses systematically with age and that the manubriosternal joint, in particular, holds significant value for age estimation. These findings support the reliability of sternal fusion as a useful parameter in forensic identification.

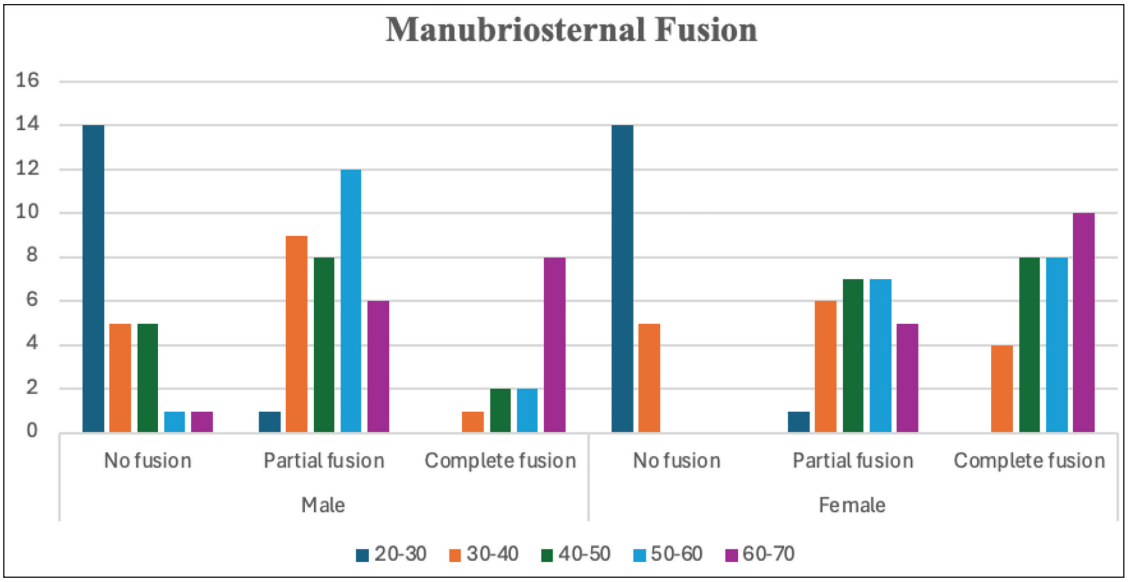

Figure 3. Age-wise Comparison of Manubriosternal Joint Fusion Stages in Both Sexes.

Table 3. Fusion of Sternum, Body and Manubrium in Females.

Age Group	Number of Females	No Fusion	Partial Fusion	Complete Fusion
20–30	15	14	1	0
30–40	15	5	6	4
40–50	15	0	7	8
50–60	15	0	7	8
60–70	15	0	5	10
Total	75	19	26	30

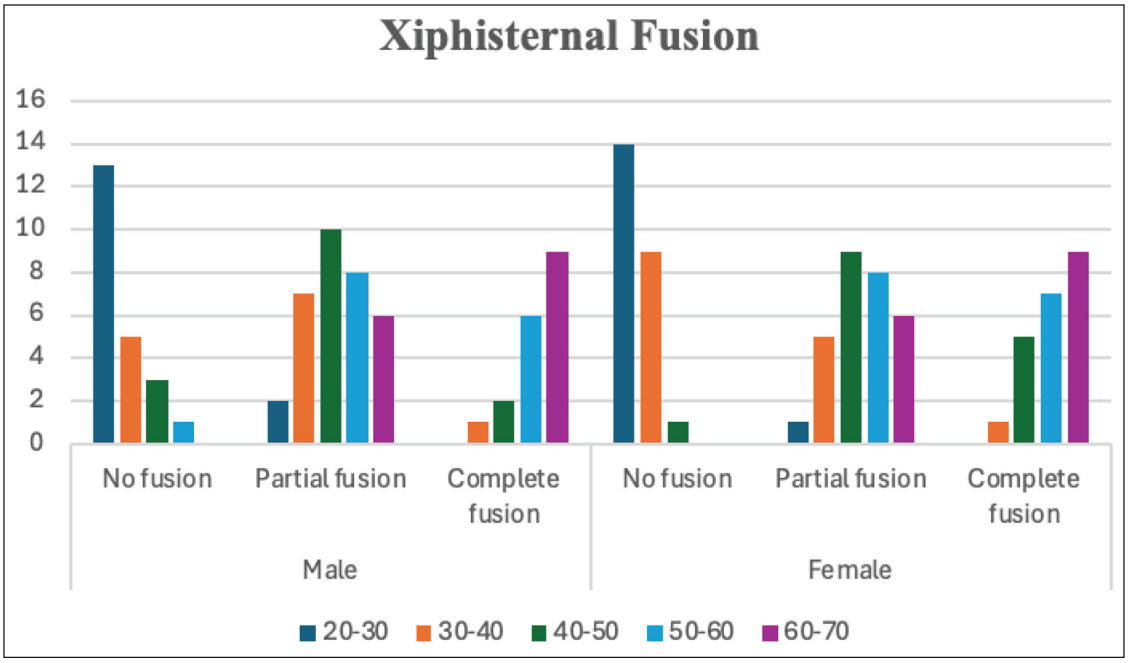

Figure 4. Age-wise Comparison of Xiphisternal Joint Fusion Stages in Both Sexes.

Table 4. Fusion of Sternum, Body and Xiphoid Process in Males.

Age Group	Number of Males	No Fusion (%)	Partial Fusion (%)	Complete Fusion (%)
20–30	15	13	2	0
30–40	15	5	7	1
40–50	15	3	10	2
50–60	15	1	8	6
60–70	15	0	6	9
Total	75	14	30	31

Table 5. Fusion of Sternum Body and Xiphoid Process in Females.

Age Group	Number of Females	No Fusion	Partial Fusion	Complete Fusion
20–30	15	14	1	0
30–40	15	9	5	1
40–50	15	1	9	5
50–60	15	0	8	7
60–70	15	0	6	9
Total	75	24	29	22

Table 6. Showing a Fusion Stage of the Manubriosternal Joint (M+B).

M+B Fusion Type	Female	Male	Total
CF (complete fusion)	30	13	43
NF (no fusion)	19	26	45
PF (partial fusion)	26	36	62
Total	75	75	150

Table 7. Showing Fusion Stages of Xiphisternal Joints (X+B).

B+XP Fusion Type	Female	Male	Total
CF (complete fusion)	22	18	40
NF (no fusion)	24	22	46
PF (partial fusion)	29	35	64
Total	75	75	150

Table 8. Showing Minimum Age, Mean Age and Maximum Age of Fusion of Manubriosternal Joints in Males, Females and Pooled Samples.

Fusion Stage	Gender	Min Age	Mean Age	Max Age
NF	Female	20	34.5	70
	Male	20	35.0	70
	Pooled	20	34.75	70
PF	Female	30	45.5	70
	Male	30	43.0	70
	Pooled	30	44.25	70
CF	Female	33	54.0	70
	Male	39	57.0	70
	Pooled	33	55.5	70

Table 9. Showing Minimum Age, Mean Age and Maximum Age of Fusion of Xiphisternal Joints in Males, Females and Pooled Samples.

Fusion Stage	Gender	Min Age	Mean Age	Max Age
NF	Female	20	28.5	70
	Male	20	31.3	70
	Pooled	20	29.8	70
PF	Female	30	51.2	70
	Male	30	49.1	70
	Pooled	30	44.25	70
CF	Female	33	56.5	70
	Male	39	59.7	70
	Pooled	33	57.9	70

Discussion

The present study on sternal fusion patterns correlates with some previous studies; major variations exist across populations and should be considered for further study. The current investigation also revealed that sternal fusion occurred considerably later in males than in females, with 60% of the male group aged 60–70 years having united Manubrium and Body (M+B). This pattern is similar to that mentioned by some researchers in their study, who state that among South Indians, sternal fusion begins between the ages of 31 and 35 and lasts until the next age range. According to this research, male fusion happens later, especially within specific ethnic populations.[13,15]

There were variations in our findings compared to the current literature on other populations. For example, a study on

the Turkish population, using CT imaging, found that manubriosternal fusion begins much earlier, between the ages of 10–19, in both boys and girls.[16] This difference suggests that environmental factors or genetic predispositions may influence sternal fusion across populations. Another study on a Turkish sample also observed earlier fusion, particularly among female participants. These findings support the idea that the timing and process of sternal fusion are not universal and may be shaped by genetic, nutritional, or environmental factors.[17]

In terms of sex differences, our results showed that females tend to achieve complete sternal fusion earlier than males. Specifically, 66.67% of females in the 60–70 age group exhibited complete Manubrium and Body (M+B) fusion, compared to 53.33% of males in the same age group. This result aligns with one study that reported earlier sternal fusion in females, particularly in northwest Indian populations.[13] Similarly, it was observed that females' complete fusion was noted earlier than males in Turkish populations. These findings suggest a general trend where females reach skeletal maturity earlier than males, though the age at which this occurs can vary across populations.[17]

A key observation with significant implications is that the sternal fusion method for forensic age estimation should be calibrated for specific populations. Studies highlight the considerable variation in sternal fusion patterns across different populations. This is also evident in the current study, where the progression of sternal fusion was slower compared to other research. It suggests that factors such as diet, lifestyle, or genetics may influence these differences.[18,19]

When comparing fusion in the Body and Xiphoid process (B+XP) region, our study did not find a statistically significant relationship between sex and B+XP fusion types, as indicated by the Chi-Square test ($p = .592$). This aligns with the observations from Singh & Pathak and Muller et al., where xiphoid-body (B+X) fusion showed more variability and did not demonstrate consistent sex differences.[13,18] Radiological and fusion studies have shown strong correlations between sternal fusion patterns and chronological age.[20–22] Morphometric analyses reveal significant sexual dimorphism, aiding in accurate sex identification.[23] Additionally, sternal length and curvature strongly correlate with stature, supporting its anthropometric utility.[24,25] This highlights the complexity of using xiphoid fusion as a reliable marker for age estimation and emphasizes the greater utility of manubriosternal fusion in forensic age assessments. Thus. the study, limited to the gross examination, correlates with general trends detected by radiological means and supports sternal fusion as a viable method of estimated age in forensic practice when considering population/sex differential to the same extent, the general trends expressed in various studies underscore the necessity of calibration specific to the given population/sex. From this comparison, it is hoped that future forensic uses of CT scans will incorporate both progress in the field of radiology and a larger-scale database to increase the precision of sternal age assessment even more.

Conclusion

The present study reinforces the significance of sternal fusion, particularly manubriosternal fusion, as a valuable indicator for forensic age estimation. The findings demonstrate that fusion at the manubriosternal joint follows a predictable age-related progression and exhibits meaningful associations with chronological age, emphasizing its utility as a reliable skeletal marker. Although sex-related differences were observed, especially in the pattern of manubriosternal fusion, the xiphisternal joint showed limited predictive relevance, suggesting that not all sternal components contribute equally to age assessment. The study highlights the influence of population-specific variability in sternal fusion patterns. These variations emphasize the need for regionally calibrated standards when interpreting sternal fusion for forensic purposes. Sternal fusion, when analyzed with appropriate consideration of demographic factors, serves as a useful supplementary tool in forensic identification, particularly in cases where conventional skeletal markers are unavailable or compromised. Future research involving larger and more diverse population groups, supported by advanced imaging techniques such as CT, is recommended to further refine and strengthen the applicability of sternal fusion in forensic age estimation.

Abbreviations

CF: Complete fusion
CT: Computed tomography
MDCT: Multidetector computed tomography
MRI: Magnetic resonance imaging
NF: No fusion
PF: Partial fusion
(M+B): Manubriosternal
(X+B): Xiphisternal

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

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.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent

Written informed consent was obtained from the participants.

References

1. Kanchan T and Krishan K. Personal identification in forensic examinations. *Anthropology* 2013; 2(1): 114. DOI: 10.4172/2332-0915.1000114
2. Peng Z, He J, Yang F, et al. An overview and forecast of biometric recognition technology used in forensic science. In: *Chinese conference on biometric recognition*. Cham: Springer Nature Switzerland, 2022: 32–41.
3. Mohamed Y, Mohamed N and Anter AM. A review of methods employed for forensic human identification. *Nature-Inspired Methods for Smart Healthcare Systems and Medical Data* 2023: 1–24.
4. Maranho R, Ferreira MT and Curate F. Sexual dimorphism of the human scapula: A geometric morphometrics study in two Portuguese reference skeletal samples. *Forensic Sci* 2022; 2(4): 780–794. DOI: 10.3390/forensicsci2040056.0
5. Chopra M, Singh H, Kohli K, et al. Age estimation from sternum for age group 25 years onwards. *J Indian Acad Forensic Med* 2014; 36(4): 340–342.
6. De Tobel J, Bauwens J, Parmentier GI, et al. Magnetic resonance imaging for forensic age estimation in living children and young adults: A systematic review. *Pediatr Radiol* 2020; 50: 1691–1708.
7. Peleg S, Pelleg Kallevag R, Dar G, et al. New methods for sex estimation using sternum and rib morphology. *Int J Legal Med* 2020; 134: 1519–1530.
8. Sahu MR, Tripathy PR, Mohanty MK, et al. Age estimation from sternum of eastern Indian population: Autopsy based study. *Indian J Forensic Community Med* 2022; 9(2): 59–64. DOI: 10.18231/j.ijfcm.2022.014
9. Selthofer R, Nikolić V, Mrčela T, et al. Morphometric analysis of the sternum. *Collegium Antropologicum* 2006; 30(1): 43–47.
10. Ghorbanlou M, Moradi F and Asgari HR. Morphometric study of sternum by computed tomography in an Iranian population: A method to discriminate between male and female. *Forensic Imaging* 2022; 28: 200501. DOI: 10.1016/j.fri.2022.200501
11. Ashley GT. The relationship between the pattern of ossification and the definitive shape of the mesosternum in man. *J Anat* 1956; 90(1): 87–105.
12. Gautam RS, Shah GV, Jadav HR, et al. The human sternum–as an index of age and sex. *J Anat Soc India* 2003; 52(1): 20–23.
13. Singh J and Pathak RK. Sex and age related non-metric variation of the human sternum in a northwest Indian postmortem sample: A pilot study. *Forensic Sci Int* 2013; 228(1–3): 181.e1. DOI: 10.1016/j.forsciint.2013.02.002
14. DA S, HT K, SN S, et al. Radiological age estimation from sternum. *Natl J Integr Res Med* 2013; 4(4): 108-114.
15. Chandrakanth HV, Kanchan T, Krishan K, et al. Estimation of age from human sternum: An autopsy study on a sample from South India. *Int J Legal Med* 2012; 126: 863–868.
16. Bolatl G, Dogan NU, Koplay M, et al. Evaluation of sternal morphology according to age and sex in multidetector computerized tomography. *Anatomy* 2020; 14(1): 29–38.
17. Oktay C and Aytaç G. Evaluation of manubriosternal joint fusion and second costal cartilage calcification: Are they useful for estimating advanced age groups? *J Forensic Sci* 2022; 67(2): 450–459. DOI: 10.1111/1556-4029.14951
18. Ali MIM, Mosallam W, Mostafa EM, et al. Sternum as an indicator for sex and age estimation using multidetector computed tomography in an Egyptian population. *Forensic Imaging* 2021; 26: 200457. DOI: 10.1016/j.fri.2021.200457
19. Monum T, Makino Y, Prasitwattanaseree S, et al. Age estimation from ossification of sternum and true ribs using 3D postmortem CT images in a Japanese population. *Legal Med* 2020; 43: 101663. DOI: 10.1016/j.legalmed.2019.101663
20. Vaishnawa NK, Bishnoi A and Vyas PC. Assessment of the fusion of the sternum and the medial clavicular epiphysis for the purpose of age estimation: A conventional radiographic study. *J Indian Acad Forensic Med* 2021; 43(1): 14–17. DOI: 10.5958/0974-0848.2021.00004.X
21. Chopra M, Singh H, Kohli K, et al. Age estimation from sternum for age group 25 years onwards. *J Indian Acad Forensic Med* 2014; 36(3): 270–272. DOI: 10.1177/0971097320140313
22. Zohlupuii LB, Devi TM, Haricharan A, et al. Estimation of stature from the length of the sternum in the ethnic Meitei population: A study in medicolegal autopsies. *J Indian Acad Forensic Med* 2023; 45(2): 137–140. DOI: 10.48165/jiafm.2023.45
23. Mukhopadhyay PP. Determination of sex from adult sternum by discriminant function analysis on autopsy sample of Indian Bengali population: A new approach. *J Indian Acad Forensic Med* 2010; 32(4): 321–324. DOI: 10.1177/0971097320100413
24. Tyagi A, Bhardwaj P and Chawla H. Correlation of cadaveric stature with posterior curve length of sternum in Mewat region of Haryana: A comparative analysis of SPSS with machine learning. *J Indian Acad Forensic Med* 2021; 43(2): 118–121. DOI: 10.5958/0974-0848.2021.00031.2
25. Tyagi A, Atal DK and Naik SK. Estimation of cadaveric stature from sternal measurements: An autopsy-based study. *J Indian Acad Forensic Med* 2021; 43(2): 122–125. DOI: 10.5958/0974-0848.2021.00032.4

Pattern of Injuries in Fatal Road Traffic Accident Cases in a Peripheral Medical College & Hospital of West Bengal: An Autopsy-based Study

Journal of Indian Academy
of Forensic Medicine
47(4) 360–363, 2025

DOI: 10.1177/09710973251413359
journals.sagepub.com/home/iaf
Sage

Bhaskar Jyoti Debnath[1], Joydeep Khan[2], Kallol Roy[3] and Saumabrata Panja[4]

Abstract

With the advancement in the automotive industry throughout the world, presently road traffic injuries have become one of the relevant factors to cause considerable losses to individuals, their families and to nations as a whole in many aspects. A retrospective observational study was conducted at Raiganj Govt. Medical College & Hospital, a tertiary care center of Uttar Dinajpur, a peripheral district of West Bengal, between January 2022 and December 2023, to analyze the injury pattern in a total of 288 autopsy cases with a history of road traffic accident (RTA), and to draw public attention and awareness to encounter it.

The study shows that deaths are more in the age group of 21–30 years (19.44%), Males (73.61%) are more affected than females (26.39%), and two-wheeler riders are the most frequent victims (38.89%). Coexistence of multiple blunt injuries, that is, abrasion, bruise or contusion, laceration, along with fracture of bones commonly noted during the postmortem examination of RTA victims (64.93%). Head injury is the main or associated factor of causing death in 82.64% cases.

Keywords

Road traffic accident (RTA), injury pattern, blunt injuries, head injury

Received 21 June 2025; **accepted** 16 December 2025

Introduction

An accident is an event that occurs suddenly, unexpectedly, and inadvertently under unforeseen circumstances.[1] An accident that takes place on the road involving a vehicle is termed a road traffic accident (RTA).[2] RTAs have emerged as a major public health concern of this century throughout the world and are now recognized as a "veritable neglected pandemic."[3] Eventually, every year, the incidence of RTA suppresses the data of the previous year. Our own country, India, is also not an exception in this case.

The pattern of injuries resulting from RTA depends on several factors. Key contributing factors include human error, driver fatigue, inadequate traffic awareness, mechanical failures, excessive speed and overtaking, violations of traffic regulations, substandard road conditions, traffic congestion, road encroachment, and driving under the influence of alcohol.[4] Victims in RTAs sustain a variety of injuries, external as well as internal. Early detection of the injuries and prompt treatment are necessary to save the lives of many of these victims. A careful and detailed study of injuries helps in the reconstruction of RTAs, especially in hit and run cases, which in turn help the investigating agencies to identify & prosecute the offenders who are responsible for the accident. In addition, the study of injuries associated with fatal outcomes helps in the implementation of measures to prevent fatalities due to RTAs.[5]

[1]Department of Forensic Medicine and Toxicology, Raiganj Government Medical College and Hospital, Raiganj, West Bengal, India
[2]Department of Forensic Medicine and Toxicology, Burdwan Medical College and Hospital, Bardhaman, West Bengal, India
[3]Department of Forensic Medicine and Toxicology, Barasat Government Medical College and Hospital, Barasat, West Bengal, India
[4]Department of Forensic Medicine and Toxicology, R. G. Kar Medical College and Hospital, Kolkata, West Bengal, India
Corresponding author:
Bhaskar Jyoti Debnath, Assistant Professor, Department of Forensic Medicine and Toxicology, Raiganj Government Medical College and Hospital, Raiganj, West Bengal 733134, India.
E-mail: bhaskarjyotidebnath@gmail.com

The present study was therefore conducted to ascertain the incidence of fatal RTAs that occurred in Uttar Dinajpur, a peripheral district of North Bengal, and patterns & distributions of injuries with emphasis on demographic profile from autopsy cases done at the mortuary of Raiganj Govt. Medical College &Hospital, which can be used for the strategical development to prevent fatality due to RTA, and to educate public about road safety.

Materials and Methods

After getting the ethical clearance, a retrospective study was conducted on the dead bodies that died due to RTA and were sent for postmortem examination in the mortuary of Raiganj Govt. Medical College & Hospital, a tertiary care center of Uttar Dinajpur, a peripheral district of North Bengal, from January 2022 to December 2023. Detailed information was based on inquest reports, medical records, and evaluation of postmortem reports. Age, sex, nature of collision, survival period, internal & external injuries, distribution of head injuries, and cause of death were the primary points to analyze & prepare a data sheet. After that, an interpretation of the collected data was done by using appropriate statistical methods.

Results

During the study period, a total of 288 medicolegal autopsies were conducted in connection with RTA. Males outnumbered the females in the total number of deaths due to RTA, 212 (73.61%) male cases compared to 76 (26.39%) female cases (Table 1).

The age group of 21–30 years was commonly affected (19.44%), followed by 31–40 years (17.36%). The deceased aged more than 70 years were the least (3.47%). The youngest victim was a 3-year-old male child, and the oldest was a 93-year-old female (Table 2).

In the present study, two-wheeler riders were the most frequent victims (38.89%), followed by pedestrians (26.39%), four-wheeler riders (21.53%) and three-wheeler riders (11.46%) (Table 3).

Following the accidents, most of the victims (66.67%) declared as "brought dead" at hospital followed by 22.22% of total victims died within 12 hours of accident, 5.55% died within 12–24 hours, 4.17% of total victims survived for varying periods between 1 and 7 days and rest of the victims (1.39%) died after that (Table 4).

Different types of blunt injuries like abrasion, bruise or contusion, laceration & fractures are noted respectively in 94.79%, 96.18%, 85.76% & 76.04% cases. Coexistence of multiple blunt injuries, that is, abrasion, bruise or contusion, laceration, along with fracture of bones commonly noted during the postmortem examination of RTA victims (64.93%), followed by coexistence of abrasion, bruise or contusion and laceration found in 13.89% victims, whereas sharp injuries are noted only in 1.04% cases (Table 5).

Isolated head injury was found to be the leading cause of death in our study (34.72%). Upper or lower limb injuries were found as an associated factor along with head injury to be the cause of death in 17.36% of total cases, whereas isolated abdominal or pelvic injuries were found to be the cause of death in 6.25% cases (Table 6).

Table 1. Frequency Distribution of the Study Population in Different Sex.

Sex	No. of Cases	% of Total Population
Male	212	73.61
Female	76	26.39
Total	288	100

Table 2. Frequency Distribution of Study Population According to Different Age Groups.

Age Range (Years)	No. of Cases	% of Total Population
0–10	12	4.17
11–20	40	13.89
21–30	56	19.44
31–40	50	17.36
41–50	46	15.97
51–60	44	15.28
61–70	30	10.42
>70	10	3.47

Table 3. Frequency Distribution of Study Population According to Type of Road Users.

Type of Victim	No. of Cases	% of Total Population
4-wheeler rider	62	21.53
3-wheeler rider	33	11.46
2-wheeler rider	112	38.89
Pedestrian	76	26.39
Not known	5	1.74

Table 4. Frequency Distribution of Study Population According to Period of Survival After RTA.

Period of Survival	No. of Cases	% of Total Population
Brought in dead condition	192	66.67
0–12 hours	64	22.22
12–24 hours	16	5.55
1–7 days	12	4.17
>1 week	4	1.39

Table 5. Frequency Distribution of Study Population According to Type of Injuries.

Type of Injury	No. of Cases	% of Total Population
Abrasion (A)	273	94.79
Bruise/contusion (B)	277	96.18
Laceration (C)	247	85.76
Fracture (D)	219	76.04
Coexistence of (A) & (B)	10	3.47
Coexistence of (B) & (C)	8	2.78
Coexistence of (A) & (C)	8	2.78
Coexistence of (B) & (C) & (D)	4	1.39
Coexistence of (A) & (B) & (C)	40	13.89
Coexistence of (A) & (B) & (D)	28	9.72
Coexistence of (A) & (B) & (C) & (D)	187	64.93
Sharp injury	3	1.04

Table 6. Frequency Distribution of Study Population According to Cause of Death.

Cause of Death	No. of Cases	% of Total Population
Head injury (A)	100	34.72
Neck or chest injury (B)	4	1.39
Abdominal or pelvic injury (C)	18	6.25
Upper or lower limb injury (D)	8	2.78
Coexistence of (A) & (B)	28	9.72
Coexistence of (A) & (C)	16	5.55
Coexistence of (B) & (C)	8	2.78
Coexistence of (A) & (D)	50	17.36
Coexistence of (B) & (D)	4	1.39
Coexistence of (C) & (D)	4	1.39
Coexistence of (A) & (B) & (C)	12	4.17
Coexistence of (A) & (B) & (D)	4	1.39
Coexistence of (A) & (C) & (D)	12	4.17
Coexistence of (B) & (C) & (D)	4	1.39
Coexistence of (A) & (B) & (C) & (D)	16	5.55

Out of the total 288 medicolegal autopsies, head injury was the main or associated factor of the cause of death in 238 cases. Among these, coexistence of scalp injury & skull bone fracture along with EDH or SDH or SAH was noted in 55.46% cases, followed by coexistence of scalp injury & EDH or SDH or SAH noted in 26.89% cases. Whereas only scalp injury was noted in 6.72% cases (Table 7).

Table 7. Frequency Distribution According to Nature of Head Injury.

Type of Head Injury	No. of Cases	% of Total Head Injury Cases
Separate existence of scalp injury (A)	16	6.72
Separate existence of skull bone fracture (B)	0	0
Separate existence of EDH/SDH/SAH (C)	8	3.36
Separate existence of intra-cerebral hemorrhage (D)	0	0
Coexistence of (B) & (C)	12	5.04
Coexistence of (A) & (C)	64	26.89
Coexistence of (A) & (B) & (C)	132	55.46
Coexistence of (A) & (B) & (C) & (D)	6	2.52

Discussion

In the present study, males outnumbered females in the total number of deaths due to RTA, like many other studies.[6,7] This male predominance is expected because of the socio-economic culture of our country, where most of the outside work is usually done by males, and they tend to violate the traffic rules & regulations, driving under the influence of alcohol, and aggressiveness compared to females.

The most vulnerable age group commonly affected, according to the present study, was 21–30 years, followed by 31–40 years (19.44% & 17.36%, respectively), and the least affected age group was above 70 years (3.47%). The young age group has a tendency to show less attention to traffic rules & regulations, along with non-use of safety devices like helmets, seatbelts, etc. This is a possible explanation for the same. Similar kinds of results have also been found in other studies from different parts of India.[8–10]

Regarding the victims' status, the present study showed that the primary target of fatal RTAs was two-wheeler riders (38.89%), followed by pedestrians (26.39%). This is similar to a study done by Manoranjan B, Somashekhar SP, et al. in Karnataka, India.[11] A modern-day common trend of rash and negligent driving of over-designed motor vehicles by the young generation without wearing helmets might be the main reason behind this type of tragedy.

In the present study, most of the victims died "on the spot" or before being brought to any trauma or medical care center (66.67%), followed by 22.22% of total cases that died within 12 hours of hospitalization. These findings also correspond with other studies.[12,13]

Coexistence of different types of blunt injuries, that is, abrasion, bruise or contusion, laceration & fractures are found in most of the victims (64.93%). Those injuries are produced by forcible impact with hard, blunt objects, which are very common in RTA cases. On the contrary, sharp penetrating

injuries are seen only in three cases (1.04%), which may be produced by different projecting objects, either from vehicles or from the surroundings.

Solely head injury was found to be the most common cause of death in our study (34.72%), followed by the coexistence of head along with upper or lower limb injuries (17.36%). Head injury associated with other regional injuries proved to be fatal in 238 cases (82.64%). Among the total 238 head injury cases, fracture of the skull was noted in 150 cases (63.02%), and intracranial hemorrhages were found in 222 cases (93.28%). Head injury is also noted as a major cause of death in other studies done by Salgado (69.6%) & Biswas G (47.3%).[14,15] In maximum cases head becomes the affected part either due to primary or secondary impact in RTA.

Conclusion

RTA, being a grave concern in public health, is associated with a considerable number of deaths in our country. Contributory factors, from reckless driving to poor road conditions, are already under scrutiny of the appropriate authorities. However, the distribution of primary impact injury and other associated injuries found during this study indicates a huge number of cases contributed by the victims themselves. Most of the cases occurred on the National Highway and near some specific areas, with a lack of vigilance and social awareness.

Appropriate measures need to be taken to reduce the number of accidents, like: frequent check posts, proper signage, construction of overbridges near high-speed zones, etc. Awareness as well as prevention are the keys to reducing RTA-related deaths.

One well-equipped trauma care center with neuro-surgical facilities needs to be established locally to give proper treatment of head injuries due to RTA, as it is found to be the most common cause of death in our study, so that precious lives can be saved within the crucial first few hours after the accidents.

Acknowledgement

No other person has made substantial contributions to this manuscript.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval and Informed Consent

Taken from the Institutional Ethical Committee of Raiganj Government Medical College. The study was conducted over the dead bodies brought for medicolegal postmortem examination & identity of the individual was not revealed. So informed consent from the next of kin was not required.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Bhaskar Jyoti Debnath https://orcid.org/0009-0005-0382-6953

References

1. Singh YN, Bairagi K and Das K. An epidemiological study of road traffic accident victims in medico-legal autopsies. *J Indian Acad Forensic Med* 2005; 27(3): 166–169.
2. Odero W, Garner P and Zwi A. Road traffic injuries in developing countries: A comparative review of epidemiological studies. *Trop Med Int Health* 1997; 2: 445–460.
3. Dandona R and Mishra A. Deaths due to road traffic crashes in Hyderabad city in India: Need for strengthening surveillance. *Natl Med J India* 2004; 17: 74–79.
4. Kaul A, Sinha US, Pathak YK, et al. Fatal road traffic accidents: Study of distribution, nature and type of injury. *J Indian Acad Forensic Med* 2005; 27(2): 71–75.
5. Dileep KR, Raju GM, Vijayanath V, et al. Deaths due to fatal road traffic accidents: A retrospective study. *J Indian Acad Forensic Med* 2013; 35(3): 236–238.
6. Choudhury BL, Singh D, Tripude BH, et al. Profile of road traffic accident cases in Kasturba Hospital of MGIMS, Sevagram, Wardha, Maharashtra, India. *Medico Legal Update* 2005; 5(4): 1–12.
7. Arvind K, Sanjeev L, Deepak A, et al. Fatal road traffic accidents and their relationship with head injuries: An epidemiological survey of five years. *Indian J Neurotrauma* 2008; 5(2): 63–67.
8. Menon A, Pai VK and Rajeev A. Pattern of fatal head injuries due to vehicular accidents in Mangalore. *J Forensic Leg Med* 2008; 5(2): 75–77.
9. Gupta A, Kumar A and Gupta P. Profile of death due to road traffic accidents in urban region of Uttar Pradesh, India. *J Indian Acad Forensic Med* 2017; 39(3): 229–234.
10. Banzal RK, Jain A, Yadav J, et al. Pattern and distribution of head injuries in fatal road traffic accidents in Bhopal region of central India. *J Indian Acad Forensic Med* 2015; 37(3): 242–245.
11. Manoranjan B, Somashekhar SP, Ravindra SH, et al. A study of injury pattern and mode of accident of fatal injuries in RTA cases admitted in a tertiary care centre: A three-year retrospective study. *J Indian Acad Forensic Med* 2023; 45(2): 132–135.
12. Singh H and Dhattarwal SK. Pattern and distribution of injuries in fatal road traffic accidents in Rohtak, Haryana. *J Indian Acad Forensic Med* 2004; 26(1): 20–23.
13. Rajesh DR, Kaur B, Singh A, et al. Pattern of injuries due to fatal road traffic accidents in rural Haryana: An epidemiological survey. *J Indian Acad Forensic Med* 2012; 34(3): 229–232.
14. Salgado MSL and Colombage SM. Analysis of fatalities in road accidents. *Forensic Sci Int* 1998; 36: 91–96.
15. Biswas G. Pattern of road traffic accidents in North-East Delhi. *J Forensic Med Toxicol* 2003; 20(1): 27–32.

Original Research Article

Estimating Stature from Foot and Hand Dimensions: Insights from a Cross-sectional Study of the Yadav Population

Journal of Indian Academy
of Forensic Medicine
47(4) 364–372, 2025

DOI: 10.1177/09710973251410642
journals.sagepub.com/home/iaf
Sage

Neha Kumari[1], Rajeev Ahirwar[1], Mamta[1], Jyoti Verma[1] and Prakash Ranjan Mondal[1]

Abstract

Stature estimation is a crucial step in the identification of dismembered and skeletonized human remains. It indicates the individual experiences of nutritional intake, genetic makeup, and disease history. The adult Yadav population of Firozabad, Uttar Pradesh, was considered in this study for stature estimation on the basis of hand and foot lengths, and the *r* value is determined using a simple linear regression analysis. The sample size includes 380 participants, consisting of 190 male participants and 190 female participants aged between 18 and 64 years. The assessed parameters included age, stature, right hand length (RHL), left hand length (LHL), right foot length (RFL), and left foot length (LFL). As compared to males, females exhibited a higher correlation ($r = 0.665$) between stature and LHL. The derived regression formulas were, stature = 70.632 + 4.799(HL) ± 5.489 cm and stature = 74.860 + 3.291(FL) ± 5.344 cm for females and stature = 108.757 + 3.091(HL) ±10.654 cm and stature = 81.028 + 3.291(FL) ± 11.284 cm for males. The mean age, stature, RHL, LHL, RFL and LFL were 44 ± 11 years, 166.11 ± 6.71 cm, 18.51 ± 1.06 cm, 18.59 ± 1.04 cm, 25.84 ± 1.28 cm and 25.86 ± 1.23 cm in case of males and 36 ± 11 years, 151.93 ± 5.78 cm, 17.03 ± 0.78 cm, 17.03 ± 0.81 cm, 23.41 ± 1.13 cm and 23.41 ± 1.15 cm in case of the females, respectively. In the study population, the stature and LFL showed the highest correlation value ($r = 0.814$). Based on these findings, it is concluded that foot length of individuals is a more dependable variable for precise estimation of stature in the Yadav population.

Keywords

Forensic science, forensic anthropology, stature estimation, regression model, hand and foot dimensions

Received: 15 May 2025; **accepted** 08 December 2025

Introduction

Personal identification is a primary objective in the field of forensic research. The estimation of stature is widely recognized as a critical component of forensic anthropology, contributing significantly to the establishment of an individual's biological profile. Stature refers to a person's natural height when they are standing upright.[1,2] It is considered one of the key criteria, often referred to as the "big four," in forensic anthropology for the purpose of identifying individuals, along with sex, age, and ancestry.[1] Leonardo da Vinci's promotion of Vitruvius' work and his idea that the human body has specific proportions set the stage for the development of stature measurement. His classic painting, "The Vitruvian Man," used illustrations of these proportions.[3]

Researchers have been working to develop the latest techniques for estimating stature over time to assist in personal identification.[1–4] These techniques can be either mathematical or anatomical. The anatomical methods, first proposed by Dwight in 1894, estimate the overall height. Later, in 1956, fully modified the anatomical method for stature estimation.[4] In this method, the height of the vertebral column, skull, tibia, calcaneus, talus, and femur is all added together. The main drawback of this method is that it often cannot provide an accurate estimate of stature because not all of these bones are always available.[4]

The mathematical approach utilizes one or more bones to create regression equations that estimate a person's stature.[5] Due to the extensive use of regression models by forensic scientists, measurements of certain body parts can now be easily employed to predict the anthropometry of another part, such as using measurements of the hand and foot to estimate stature.[6–12]

[1]Department of Anthropology, University of Delhi, India

Corresponding author:
Prakash Ranjan Mondal, Department of Anthropology, University of Delhi, Room no. 36, Delhi 110007, India.
E-mail: prmondal1@rediffmail.com

Interactions between genetic and environmental factors can lead to variations within and between populations. Numerous studies have shown the importance of tailoring regression formulas to specific sex and population characteristics to ensure accuracy and relevance.[13–23]

Most studies conducted on stature estimation in India tend to overlook the significance of sub-ethnic groups, which typically consist of homogeneous populations.[6–11,18,19,21] There is still a lack of information regarding the most accurate model for estimating adult stature using hand and foot measurements within the Yadav population. This study, the first of its kind, focuses on a homogenous population with a shared genetic background and exposure to a single environment, particularly a rural setting. By controlling for environmental and genetic heterogeneity, this study aims to offer insights into the most effective method for estimating stature using hand and foot lengths among the adult Yadav population. This research employed a basic linear regression methodology and correlation coefficients (*R* values) to determine the most effective method for estimating stature based on hand and foot measurements among the adult Yadav population.

Materials and Methods

Study Design and Sample Size

In this cross-sectional study, a population-based assessment was conducted among the Yadav community residing in the rural areas of Firozabad district, Uttar Pradesh, India. The Yadavs, a non-elite, endogamous peasant group, have historically received limited attention in research, with a predominant focus on urban populations. By conducting this study in a rural context, we aim to fill this knowledge gap and provide insights into stature estimates that are particularly relevant to the Yadav population. We included 380 individuals (190 males and 190 females) from the Yadav community in Firozabad, Uttar Pradesh, for this study. The research was carried out following approval from the institutional research and ethics committee, and written informed consent was obtained from all subjects after a comprehensive explanation of the methodology.

Number and Sampling of the Subject

Using G*power 3.1 by Faul et al. (2009), we calculated the required minimum sample size to be 59.[24] Drawing from a similar study conducted previously by Asadujjaman et al. (2019), we set the effect size (f2) at a value of 0.35, the significance level (α) at 0.05, the statistical power (1–β) at 0.80, and the number of predictors at four. Initially, a total of 488 people were selected through simple random sampling to achieve the target of 244 responses. However, due to an expected dropout rate of 50% and the fact that sample collection primarily occurred during morning hours when many individuals were engaged in occupational commitments, rendering them unavailable for sample provision, the sample size was subsequently reduced to 380. The study included 190 male and 190 female Yadav individuals between the ages of 18 and 64 who provided samples for the research.

Selection of Subject

Inclusion Criteria

This study consisted of healthy male and female participants of the age range 18–64 years, belonging to the Yadav community residing in the rural areas of Firozabad district, Uttar Pradesh.

Exclusion Criteria

The study excluded individuals with specific medical conditions and characteristics that could affect stature measurements. This included those with physical deformities, injuries, diseases, fractures, amputations, or a history of surgical procedures that impact stature. Furthermore, participants with neurological conditions that could influence limb measurements, such as cerebrovascular disease, were not included. Additionally, the study excluded individuals with limb abnormalities such as meromelia, polydactyly, or syndactyly. Those of tribal or mixed ancestry who had a previous medical history of genetic disorders such as Marfan's syndrome or achondroplasia, as well as individuals with endocrine disorders such as dwarfism, acromegaly, and diabetes mellitus, were also not part of the study. Final, participants with a history of acquired trauma that could potentially affect stature were excluded from the research.

Procedure for Collection of Anthropometric Measurements

Before conducting any measurements, participants were provided with detailed information regarding the objectives of the study. Each participant willingly participated in the measurement protocol after granting written informed consent, indicating their comprehension of the aims of the study. All measurements were taken during the morning hours to minimize the influence of diurnal variation and obtain reliable data. The standard measuring methods described by Marfell-Jones (2012) were followed, and a standard measuring instrument with a centimeter scale was used to determine stature, hand length, and foot length.[23]

Stature measurements were obtained using an "anthropometer." Stature, in this context, refers to the height achieved when a person stands upright. To measure stature, participants were instructed to stand in an erect position without wearing any footwear or headgear. The measurement involved assessing the distance from the ground to the highest anatomical point on the head.[10]

Hand measurements were taken using an "anthropometric rod compass." To do this, we first identified and marked the styloid processes of both the radius and ulna using a marker pen. Subsequently, we drew an interstyloid line and marked its midpoint. The hand length was measured from the midpoint of the inter-styloid line to the fingertip of the middle finger, and measurements were recorded for both the right and left hands.[7]

Foot measurements were taken using an "anthropometric rod compass." The foot length was determined by measuring the farthest distance between the heel and the tip of the longest toe. Both the left and right feet were assessed for their lengths.[10]

Each participant underwent dual testing, and the mean value was used to reduce potential measurement errors when all readings fell within a 0.4-cm range. In cases where the 0.4-cm criteria were not met, two initial assessments were conducted, and the mean result was utilized.

Following the guidelines of Pederson and Gore (2004),[25] the lead researcher calculated the mean value through dual measurements and conducted intra-observer reliability and validity assessments to evaluate measurement dependability and accuracy. To establish the association between stature and each factor, a regression equation of the form "stature = constant + regression coefficient × variable" was employed.

Statistical Analysis

The SPSS software (version 20.0) and Microsoft Excel 2020 were used for data analysis and to assess the statistical significance. Reliability assessments are vital to ensure that the data and measurements are consistent, dependable, and not significantly affected by random variability or measurement error. The study involved repeated measurements made by the same observer. The intraclass correlation coefficient is well-suited for such scenarios and is designed to assess the consistency among multiple measurements made by the same observer. The reliability of the measurements was evaluated through the intraclass correlation coefficient. The precision, accuracy, and validity of the instruments were determined by calculating the relative and absolute technical errors of measurement, as well as the coefficient of reliability. Simple linear regression was employed to analyze the association between the independent variables, including right- and left hand length and foot length, and the dependent variable, measured stature. The beta coefficients and constants for all variables were computed. An unpaired *t*-test was utilized to calculate the mean differences between the measured and estimated stature. Various models were compared using the standard errors of the estimates and *R* values. Furthermore, a multiple regression analysis was conducted to predict stature based on combined hand and foot somatometric measurements. A two-tailed *p* value of .001 was regarded as statistically significant.

Results

Descriptive statistics were calculated for all 380 studied participants, and the results are presented in Tables 1–4. Table 1 provides an overview of the mean age, stature, right and left hand lengths, as well as right and left foot lengths for all participants, regardless of their gender. The average age across the cohort was 40 years, with mean values for stature, right and left hand length, right and left foot length recorded as 155.47 cm, 17.40 cm, 17.42 cm, 24.02 cm, and 24.02 cm, respectively.

The results of Tables 2 and 3 provide quantitative descriptions of the measured variables, focusing on females and males as separate groups. The study observed that males generally exhibited higher mean values for all measured parameters, including stature, foot length, and foot width, compared to females. The results of Table 4 present correlation coefficients, regression equations, and correlation tests to illustrate the relationships between variables. Overall, the left foot showed a stronger correlation with stature (r = 0.814). However, when examined by gender, stature demonstrated a higher correlation with the left hand in females (r = 0.665) and the left foot in males (r = 0.624).

In essence, the results indicated gender differences in certain parameters, such as stature, foot, and hand measurements. Moreover, the correlation between stature and different body parts was found to vary across genders. These findings may have implications for understanding the relationship between body dimensions and overall physical development, as well as for the development of appropriate measurement tools for use in both sexes.

Discussion

For a significant duration, a close association has been established between an individual's stature and the measurements of different body segments; these findings are commonly used in medico-legal inquiries.[4] Rollet's (1889) pioneering work sheds light on the fascinating interplay between height and long bone length, serving as a testament to his remarkable investigative prowess. With meticulous care, he scrutinized the femur, fibula, tibia, radius, ulna, and humerus of French cadavers, taking precise measurements and compiling a comprehensive report.[57] Human hands and feet have been identified as reliable indicators of stature for forensic identification, particularly in cases of accidents, mass disasters, or situations where only mutilated bodies are encountered.[6–23,27–56] Anthropologists have employed predictive regression models to accurately estimate stature by utilizing somatometric measurements of various body parts, such as hand and foot lengths.[9,12,24]

This (anthropological) population-based study, conducted in India, aimed to predict an individual's stature based on the lengths of their hands and feet and the interrelationships

Table 1. Descriptive Statistics for Age and Anthropometric Measurements of Study Participants.

Parameter	Mean	SEM	*SD*	Min	Max	Var
Age (years)	40	1	12	18	64	135
Stature (cm)	155.47	0.44	8.60	136.40	186.30	74.11
RHL (cm)	17.40	0.05	1.07	14.40	21.80	1.16
LHL (cm)	17.42	0.05	1.10	14.30	21.60	1.22
RFL (cm)	24.02	0.08	1.57	20.30	29.30	2.48
LFL (cm)	24.02	0.08	1.58	20.30	29.20	2.50

Note: SEM = Standard error of mean, *SD* = Standard deviation, Var = Variance, Min = Minimum, Max = Maximum, RHL = Right hand length, LHL = Left hand length, RFL = Right foot length, LFL = Left foot length.

Table 2. Descriptive Statistics for Age and Anthropometric Measurements of Male Participants.

Parameter	Mean	SEM	*SD*	Min	Max	Var
Age (years)	44	1	11	18	64	119
Stature (cm)	166.11	0.68	6.71	150.80	186.30	45.05
RHL (cm)	18.51	0.10	1.06	14.40	21.80	1.14
LHL (cm)	18.59	0.10	1.04	14.30	21.60	1.10
RFL (cm)	23.41	0.13	1.28	22.40	29.30	1.63
LFL (cm)	23.41	0.12	1.23	22.40	29.20	1.52

Note: SEM = Standard error of mean, *SD* = Standard deviation, Var = Variance, Min = Minimum, Max = Maximum, RHL = Right hand length, LHL = Left hand length, RFL = Right foot length, LFL = Left foot length.

Table 3. Descriptive Statistics for Age and Anthropometric Measurements of Female Participants.

Parameter	Mean	SEM	*SD*	Min	Max	Var
Age (years)	38	1	11	18	62	132
Stature (cm)	151.93	0.34	5.78	136.40	174.30	33.51
RHL (cm)	17.03	0.04	0.78	15.30	19.80	0.62
LHL (cm)	17.03	0.04	0.81	15.20	20.10	0.66
RFL (cm)	23.41	0.06	1.13	20.30	27.40	1.28
LFL (cm)	23.41	0.06	1.15	20.30	27.50	1.33

Note: SEM = Standard error of mean, *SD* = Standard deviation, Var = Variance, Min = Minimum, Max = Maximum, RHL = Right hand length, LHL = Left hand length, RFL = Right foot length, LFL = Left foot length.

Table 4. Pearson's Correlation, Significance, and Regression Analysis of Stature Predicted from Hand and Foot Length.

Parameter (Stature vs.)	Correlation Value (*R*)	*p* Value	Inference (Correlation)	Regression Formula
All Subjects				
Right hand length	0.757	.00	High and very significant	Stature = 50.407 + 6.029 × RHL ± 4.393
Left hand length	0.777	.00	High and very significant	Stature = 50.407 + 4.772 × LHL ± 5.383
Right foot length	0.809	.00	High and very significant	Stature = 49.316 + 4.419× RFL ± 3.976
Left foot length	0.814	.00	High and very significant	Stature = 49.178 + 4.425 × LFL ± 3.913
Female				
Right hand length	0.658	.00	High and very significant	Stature = 69.773 + 4.826 × RHL ± 5.595
Left hand length	0.665	.00	High and very significant	Stature = 71.492 + 4.772 × LHL ± 5.383
Right foot length	0.649	.00	High and very significant	Stature = 74.486+ 3.307 × RFL± 5.408
Left foot length	0.654	.00	High and very significant	Stature = 75.235 + 3.276 × LFL ± 5.281
Male				
Right hand length	0.461	.00	Significant	Stature = 112.558 + 2.893 × RHL ± 10.720
Left hand length	0.514	.00	High and significant	Stature = 104.956 + 3.289 × LHL ± 10.589
Right foot length	0.609	.00	High and very significant	Stature = 83.599 + 3.192 × RFL ± 11.164
Left foot length	0.624	.00	High and very significant	Stature = 78.457 + 3.390 × LFL ± 11.405

Note: **The correlation exhibits statistical significance at the 0.01 significance level (two-tailed).

between these measurements. It was determined that this approach can provide valuable and precise data for use in estimation and identification procedures within the field of forensics and other investigative sciences. Several authors[27–56] have documented significant variations in stature among different populations. In the Indian subcontinent, multiple researchers have conducted studies on stature estimation. India, being a vast country with diverse population groups exhibiting numerous interracial and interethnic differences, experiences variations in stature across different regions. Consequently, the formulas used for estimating stature also exhibit variations among these diverse population groups. The population under study demonstrated a significant positive correlation between stature and both hand and foot length, which aligns with findings in related research.[7,8,10,11,27] Furthermore, males exhibited greater somatometric dimensions compared to females (for males: Stature = 166.11 ± 6.71 cm, right hand length (RHL) = 18.51 ± 1.06 cm, left hand length (LHL) = 18.59 ± 1.04 cm, right foot length (RFL) = 23.41 ± 1.28 cm, left foot length (LFL) = 23.41 ± 1.23 cm; for females: Stature = 151.93 ± 5.78 cm, RHL = 17.03 ± 0.78 cm, LHL = 17.03 ± 0.81 cm, RFL = 23.41 ± 1.13 cm, LFL = 23.41 ± 1.15 cm).

The observed somatometric differences between males and females could be attributed to the earlier onset of pubertal development in females compared to males, which leads to limb growth ceasing more quickly in females. In this study, the coefficient of correlation for stature and left hand length was notably stronger in females with an r value of 0.65 ($p < .01$) than in males with an r value of 0.51 ($p < .01$). However, it's important to note that the correlation coefficients observed in this research were comparatively lower for both genders when compared to similar studies. These differences may be attributed to racial and population variations, which could have influenced the outcomes.[7,27]

Female foot length showed a statistically significant correlation with stature ($r = 0.65$, $p < .01$) as compared to the male counterparts. These results align with the similar studies of Krishan (2008) and Khanapurkar et al., 2012.[8,39] The stature predictions obtained from the regression equation utilized in this study are highly appropriate and applicable equations available for the Yadav population of Uttar Pradesh, as they have been tested randomly on individuals of the Yadav population of Uttar Pradesh. The formula for females is S = 4.826(RHL) + 69.773 cm; S = 4.772(LHL) + 71.492 cm; S = 3.307(RFL) + 74.486 cm; and S = 3.276(LFL) + 75.235 cm and while for male it was S = 2.893(RHL) + 112.558 cm; S = 3.289(LHL) + 104.956 cm; S = 3.192(RFL) + 83.599 cm; and S = 3.390(LFL) + 78.457 cm. These regression equations, utilized to estimate the stature from hand and foot measurements, will contrast across different populations due to the inherent differences in human body dimensions from one region to another.

Based on the results obtained from the study, it becomes evident that the regression equation used for stature estimation exhibits distinct variations between male and female cohorts. Furthermore, upon examining findings from various authors, it is clear that no two regression equations are congruent. Tables 5 and 6 present previously reported studies that explore the relationship between hand length and foot length with stature in various geographical regions.

Consequently, it is evident that the use of a regression equation depends on the specific population and gender under study, making it inappropriate to use them interchangeably. This highlights the importance of developing separate regression equations for estimating height within each population group, which contributes to the establishment of a robust foundational database. A key limitation of this study is its modest sample size, which may affect the reliability and interpretability of the analyses. A limited number of participants may reduce statistical power, increase the risk of type II errors, and restrict the ability to generalize findings to broader populations. Additionally, findings from a smaller group may not adequately reflect the variation present in broader populations, as important differences in demographic, genetic, or environmental profiles could be missed. Consequently, these results should be viewed with caution. Future research should prioritize recruiting larger and more diverse cohorts to strengthen the credibility and wider relevance of such findings, enable more precise estimations, and facilitate deeper exploration of subgroup patterns.

The findings of this study have diverse applications, including forensic identification for solving criminal cases and disaster victim identification, aiding in clinical assessments to detect medical conditions, and contributing to anthropological research by understanding variations in hand and foot dimensions among different ethnic or regional groups, thereby enhancing the field of anthropometry.

Limitations

A significant limitation of the present study is the relatively small sample size, which restricts the generalizability of the results. To enhance reliability and reduce the wide standard deviations, future anthropometric investigations are recommended to be conducted with larger sample sizes. Additionally, the age range and region of the participants in this study present limitations. Therefore, it is advisable to conduct similar studies in different age groups and across various geographical regions. It's essential to emphasize that the equations derived in this study are specific to the Yadav population and should not be applied to other populations. The models developed in this study are based on an adult sample and are not applicable to juveniles.

A key limitation of this study is the lack of external validation for the regression equations. Future research will focus on validating the model using independent datasets to assess its generalizability and predictive accuracy in broader contexts.

Table 5. Showing the Relationship of Hand Length with Stature.

S. No.	Author	Region	Population	Gender	*r* value	Linear Regression Equation
1.	Krishan and Sharma, 2007[7]	Himachal Pradesh	Students	Male	0.599	S = 88.243 + 4.39 HL
				Female	0.686	S = 81.314 + 4.42 HL
2.	Rastogi et al., 2008[13]	North India	Students	Male	0.660	H = 74.691 + 4.866 HL
				Female	0.737	H = 73.374 + 4.754 HL
3.	Rastogi et al., 2008[13]	South India	Students	Male	0.734	H = 65.979 + 5.323 HL
				Female	0.701	H = 79.953 + 4.398 HL
4.	Agnihotri et al., 2008[14]	Mauritius	Students	Male	0.594	H = 94.835 + 4.187 HL
				Female	0.739	H = 74.404 + 4.945 HL
5.	Ilayperuma et al., 2009[15]	Sri Lankan	Students	Male	0.58	H=103.732 + 3.493 HL
				Female	0.59	H = 93.689 + 3.625 HL
6.	Habib et al., 2010[16]	Egyptian	Students	Male	0.697	S = 57.70 + 6.06 RHL
				Female	0.495	S = 101.13 + 3.39 RHL
7.	Chikhalkar et al., 2010[17]	Mumbai	Students	Male and female	0.590	H = 116.69 + 2.665 HL
8.	Ahemad and Purkait, 2011[18]	Madhya Pradesh	General	Male	0.558	H = 940.29 + 4.169 HL
9.	Ishak et al., 2012[19]	Western Australia	General	Male	0.73	H = 69.723 + 5.567 RHL
				Female	0.69	H = 57.135 + 6.057 RHL
10.	Vijeta and Kapoor, 2012[20]	Himachal Pradesh	General	Male	0.554	H = 79.23 + 4.91 RHL
				Female	0.570	H = 86.03 + 4.11 RHL
11.	Ozaslan et al., 2012[21]	Turkey	General	Male	0.578	S = 922.01 + 4.15 HL
				Female	0.309	S = 1116.56 + 2.80 HL
12.	Tang et al., 2012[22]	Southern China	General	Male	0.650	S = 105.361 + 3.547 RHL
				Female	0.646	S = 97.280 + 3.661 RHL
13.	Kaur et al., 2013[26]	North India	General	Male	0.589	S = 130.90 + 2.398 HL
				Female	0.550	S = 160.41 + 0.027 HL
14.	Uhrová et al., 2015[27]	Slovakia	Students	Male	0.63	H = 93.11 + 4.63 RHL
				Female	0.58	H = 84.69 + 4.75 RHL
15.	Pal et al., 2016[28]	West Bengal	General	Female	0.688	H = 88.1 + 3.88 HL
16.	Iddalgave et al., 2017[29]	Karnataka	Students	Male	0.513	H = 96.238 + 4.024 RHL
				Female	0.64	H = 87.6 + 4.12 RHL
17.	Kim et al., 2018[30]	South Korea	General	Male	0.620	H = 79.610 + 4.945 HL
				Female	0.502	H = 87.362 + 4.106 HL
18.	Zulkifly et al., 2018[31]	Sarawak	General	Male	0.76	H = 48.653 + 6.030 RHL
				Female	0.68	H = 65.455 + 4.955 RHL
19.	Asadujjaman et al., 2019[32]	Bangladesh	General	Male	0.545	H = 87.498 + 4.431 RHL
				Female	0.644	H = 81.15 + 4.14 RHL
20.	Nanayakkara et al., 2021[33]	Sri Lanka	Students	Male	0.676	H = 75.57 + 5.207 HL
				Female	0.661	H = 79.5 + 4.597 HL
21.	Mohamed et al., 2022[34]	Maldives	General	Male	0.65	H = 3.599 HL + 99.819
				Female	0.69	H = 4.869 HL + 73.301
22.	Madadin and Menezes, 2022[35]	Saudi Arabian	General	Male	0.643	H = 4.622 HL + 851.702
23.	Present study	North Indian	General	Male	0.461	H = 112.558 + 2.893 RHL
				Female	0.658	H = 69.773 + 4.826 RHL

Table 6. Showing the Relationship of Foot Length with Stature.

S. No.	Author	Region	Population	Gender	*r* value	Linear Regression Equation
1.	Agnihotri et al., 2007[6]	Mauritius	Students	Male	0.720	H = 68.586 + 4.036 RFL
				Female	0.608	H = 77.059 + 3.536 RFL
2.	Krishan and Sharma, 2007[7]	Himachal Pradesh	Students	Male	0.732	H = 68.085 + 4.054 FL
				Female	0.739	H = 71.941 + 3.703 FL
3.	Patel et al., 2007[36]	Gujarat	Students	Female	0.80	H = 75.41 + 3.43 FL
4.	Ilayperuma et al., 2008[37]	Sri Lankan	Students	Male	0.724	H = 79.042 + 3.590 FL
				Female	0.719	H = 65.549 + 3.944 FL
5.	Sen and Ghosh, 2008[11]	North Bengal	General	Male	0.626	H = 83.518 + 3.282 FL
				Female	0.692	H = 67.009 + 3.707 FL
6.	Kanchan et al., 2008[9]	Punjab	General	Male	0.759	H = 93.269 + 2.819 RFL
				Female	0.512	H = 103.27 + 2.365 RFL
7.	Chikhalkar et al., 2010[17]	Mumbai	Students	Male and female	0.610	H = 79.723 + 3.650 FL
8.	Rani et al., 2011[38]	Delhi	Students	Male	0.808	H = 98.320 + 3.050 RFL
				Female	0.808	H = 90.207 + 3.374 RFL
9.	Khanapurkar and Radke, 2012[39]	Maharashtra	Students	Male	0.645	H = 90.0 + 3.2 FL
				Female	0.702	H = 72.8 + 3.7 FL
10.	Mansur et al., 2012[40]	Nepal	Students	Male	0.688	H = 100.1 + 2.74 RFL
				Female	0.587	H = 96.31 + 2.66 RFL
11.	Ozaslan et al., 2012[21]	Turkey	General	Female	0.496	H = 941.95 + 2.96 FL
				Male	0.696	H = 840.88 + 3.52 FL
12.	Babu et al., 2013[41]	Secunderabad	General	Male	0.583	H = 82.830 + 3.468 RFL
				Female	0.66	H = 73.523 + 3.615 RFL
13.	Kautilya et al., 2013[42]	Chennai	General	Female	0.657	H = 83.24 + 0.337 RFL
14.	Khairulmazidah et al., 2013[43]	Malaysia	Students	Male	0.697	H = 84.663 + 3.321 RFL
15.	Ozoko, 2013[44]	Nigeria	Students	Male	0.779	H = 84.45 + 3.559 FL
16.	Dayananda et al., 2014[45]	Kolar Tamil Nadu	Students	Male	0.636	H = 69.3663 × 3.663 FL
17.	Parekh et al., 2014[46]	Ahmadabad Gujarat	Students	Male	0.989	H = 74.75 + 3.42 FL
				Female	0.988	H = 63.62 + 3.61 FL
18.	Sutay et al., 2014[47]	Madhya Pradesh	Students	Male	0.688	H = 140.59 + 1.35 FL
				Female	0.587	H = 121.50 + 1.604 FL
19.	Tobias et al., 2014[48]	Western Nigeria	Students	Male	0.7	H = 71.19 + 3.858 FL
				Female	0.8	H = 73.15 + 3.578 FL
20.	Malik et al., 2015[49]	Lahore	Students	Female	0.63	H = 88.210 + 2.93 FL
21.	Rajesh et al., 2015[50]	Puducherry	Students	Male	0.821	H = 98.159 + 3.746 RFL
22.	Saharan & Arun, 2015[51]	Mysore	Students	Male	0.720	H = 101.95 + 2.6 LFL
23.	Agarwal et al., 2015[52]	TMU residents	Students	Male	0.702	H = 69.99 + 3.93 RFL
				Female	0.484	H = 89.82 + 2.95 RFL
24.	Taneja et al., 2016[53]	Udaipur	General	Male	0.184	H = 145.71 + 0.692 × FL
25.	Kanwar et al., 2016[54]	Mahakaushal	General	Male	0.958	H = 6.52 × FL − 1.30
				Female	0.936	H = 6.82 × FL − 6.45
26.	Iddalgave et al., 2017[55]	Karnataka	Students	Male	0.616	H = 89.9 + 3.23 RFL
				Female	0.424	H = 130.97 + 1.20 RFL
27.	Saleem et al., 2018[56]	GMC Jammu	Students	Male	0.761	H = 58.4 + 4.41 FL
				Female	0.690	H = 69.7 + 3.83 FL
28.	Present study	North India	General	Male	0.609	S = 83.599 + 3.192 RFL
				Female	0.649	S = 74.486 + 3.307 RFL

Conclusions

This study explores the correlation between measured stature, hand length, and foot length in the Yadav population of Uttar Pradesh, aiming to establish the feasibility of using these anthropometric parameters to estimate one another. Notably, hand length showed a stronger association with stature in females, while foot length exhibited a more pronounced association with stature in male participants. Consequently, it can be concluded that hand length in females and foot length in males can be more accurately utilized to estimate the stature of the Yadav population.

The regression model employed in this study carries practical implications for estimating the stature of the Yadav population and provides valuable insights for researchers and practitioners in the field of anthropometry. These findings underscore the importance of conducting population-specific studies with larger sample sizes in various geographical regions.

Moreover, it would be beneficial to consider conducting longitudinal studies to assess the stability and applicability of these regression models over time. A longitudinal approach can provide insights into how well these models perform and whether their effectiveness remains consistent or evolves as populations and demographics change.

Acknowledgements

We sincerely appreciate the support of all the participants who participated in the study and provided the data for the study.

Authors' Contribution

Neha Kumari, Rajeev Ahirwar, Prakash Ranjan Mondal–Design study.
Neha Kumari–Practical performance.
Neha Kumari, Rajeev Ahirwar, Mamta, and Jyoti Verma–Data analysis.
Neha Kumari, Mamta, and Jyoti Verma–Preparation manuscript.
Prakash Ranjan Mondal, Rajeev Ahirwar, Mamta, and Jyoti Verma–Critical review manuscript.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics Approval

The study was approved by the Ethical Committee of the Department of Anthropology, University of Delhi (Ref. No. Anth/2022-23/639).

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was funded by UGC-NFSC Fellowship (2020-2021).

Informed Consent

Each participant gave their written informed consent for the various physical measurements to be taken.

ORCID iD

Prakash Ranjan Mondal https://orcid.org/0000-0002-9720-2076

References

1. Iscan MY and Steyn M. *The human skeleton in forensic medicine*. Charles C Thomas Publisher, 2013.
2. Ebite LE, Ozoko TC, Eweka AO, et al. Height: Ulna ratio: A method of stature estimation in a rural community in Edo state, Nigeria. *Internet J Forensic Sci* 2008; 3(1): 12–18.
3. Polio MV. deArchitectura Book III [Internet] 2020. Available from: https://penelope.uchicago.edu/Thayer/E/Roman/Texts/Vitruvius/3*.html
4. Fully G. New method of determination of the height. *Ann Méd Lég Criminol Police Sci Toxicol* 1956; 36(5): 266–273.
5. Pearson K. Mathematical contributions to the theory of evolution. V. On the reconstruction of the stature of prehistoric races. *Proc R Soc Lond* 1898; 63(389–400): 417–420.
6. Agnihotri AK, Purwar B, Googoolye K, et al. Estimation of stature by foot length. *J Forensic Leg Med* 2007; 14(5): 279–283.
7. Krishan K and Sharma A. Estimation of stature from dimensions of hands and feet in a North Indian population. *J Forensic Leg Med* 2007; 14(6): 327–332.
8. Krishan K. Determination of stature from foot and its segments in a north Indian population. *Am J Forensic Med Pathol* 2008; 29(4): 297–303.
9. Kanchan T, Menezes RG, Moudgil R, et al. Stature estimation from foot dimensions. *Forensic Sci Int* 2008; 179(2–3): 241-e1.
10. Krishan K, Kanchan T and Passi N. Estimation of stature from the foot and its segments in a sub-adult female population of North India. *J Foot Ankle Res* 2011; 4(1): 1–8.
11. Sen J and Ghosh S. Estimation of stature from foot length and foot breadth among the Rajbanshi: An indigenous population of North Bengal. *Forensic Sci Int* 2008; 181(1–3): 55-e1.
12. Dupertuis CW and Hadden Jr JA. On the reconstruction of stature from long bones. *Am J Phys Anthropol* 1951; 9(1): 15–54.
13. Rastogi P, Nagesh KR and Yoganarasimha K. Estimation of stature from hand dimensions of north and south Indians. *Legal Med* 2008; 10(4): 185–189.
14. Agnihotri AK, Agnihotri S, Jeebun N, et al. Prediction of stature using hand dimensions. *J Forensic Legal Med* 2008; 15(8): 479–482.
15. Ilayperuma I, Nanayakkara G and Palahepitiya N. Prediction of personal stature based on the hand length. *Galle Med J* 2009; 14(1): 15–18.
16. Habib SR and Kamal NN. Stature estimation from hand and phalanges lengths of Egyptians. *J Forensic Leg Med* 2010; 17(3): 156–160.
17. Chikhalkar BG, Mangaonkar AA, Nanandkar SD, et al. Estimation of stature from measurements of long bones, hand and foot dimensions. *J Indian Acad Forensic Med* 2010; 32(4): 329–331.

18. Ahemad N and Purkait R. Estimation of stature from hand impression: A nonconventional approach. *J Forensic Sci* 2011; 56(3): 706–709.
19. Ishak NI, Hemy N and Franklin D. Estimation of stature from hand and handprint dimensions in a Western Australian population. *Forensic Sci Int* 2012; 216(1–3): 199-e1.
20. Vijeta and Kapoor AK. Estimation of stature from hand length and hand breadth among population groups of Himachal Pradesh. *Asian J Sci Appl Technol* 2012; 1(1): 50–54.
21. Ozaslan A, Karadayi B, Kolusayin M, et al. Predictive role of hand and foot dimensions in stature estimation. *Rom J Leg Med* 2012; 20(1): 41–46.
22. Tang J, Chen R and Lai X. Stature estimation from hand dimensions in a Han population of Southern China. *J Forensic Sci* 2012; 57(6): 1541–1544.
23. International Society for Advancement of Kinanthropometry Stewart A, Marfell-Jones M et al. *International standards for anthropometric assessment.* International Society for the Advancement of Kinanthropometry; 2011.
24. Faul F, Erdfelder E, Buchner A, et al. Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behav Res Methods* 2009; 41(4): 1149–1160.
25. Pederson D, & Gore C. Anthropometry measurement error. *Anthropometrica: A Textbook of Body Measurement for Sports and Health Courses* 1996; 77: 96.
26. Kaur M, Singh B, Mahajan A, et al. Anthropometric measurements of hand length for estimation of stature in North Indians. *Int J Appl Biol Pharm Technol* 2013; 4: 251–255.
27. Uhrová P, Beňuš R, Masnicová S, et al. Estimation of stature using hand and foot dimensions in Slovak adults. *Leg Med* 2015; 17(2): 92–97.
28. Pal A, De S, Sengupta P, et al. Estimation of stature from hand dimensions in Bengalee population, West Bengal, India. *Egypt J Forensic Sci* 2016; 6(2): 90–98.
29. Iddalgave S, Kuppast N, Dhanwadkar SS, et al. Role of hand length in prediction of stature. *Int J Anat Res* 2017; 5(2.2): 3805–3808.
30. Kim W, Kim YM and Yun MH. Estimation of stature from hand and foot dimensions in a Korean population. *J Forensic Leg Med* 2018; 55: 87–92.
31. Zulkifly NR, Abd Wahab R, Layang E, et al. Estimation of stature from hand and handprint measurements in Iban population in Sarawak, Malaysia and its applications in forensic investigation. *J Forensic Leg Med* 2018; 53: 35–45.
32. Asadujjaman M, Molla MB and Al Noman SN. Stature estimation from hand anthropometric measurements in Bangladeshi population. *J Forensic Leg Med* 2019; 65: 86–91.
33. Nanayakkara D, Nawarathna LS, Nandasena T, et al. Hand and handprint measurements in the estimation of stature in a Sri Lankan population. *Int J Morphol* 2021; 39(1): 222–230.
34. Mohamed I, Saleem M, Zulkifly NR, et al. Estimation of stature from hand and handprint measurements in a monoethnic Maldivian population. *Aust J Forensic Sci* 2022; 54(1): 42–60.
35. Madadin M and Menezes RG. Stature estimation from the hand dimensions in the Eastern Saudi Arabian adult male population. *Acta Biomed* 2022; 93(2): e2022063.
36. Patel SM, Shah GV and Patel SV. Estimation of height from measurements of foot length in Gujarat region. *J Anat Soc India* 2007; 56(1): 25–27.
37. Ilayperuma I, Nanayakkara BG and Palahepitiya KN. A model for reconstruction of personal stature based on the measurements of foot length. *Galle Med J* 2008; 13(1): 6–9.
38. Rani M, Tyagi AK, Ranga VK, et al. Stature estimates from foot dimensions. *J Punjab Acad Forensic Med Toxicol* 2011; 11(1): 26–30.
39. Khanapurkar S and Radke A. Estimation of stature from the measurement of foot length, hand length and head length in Maharashtra region. *Indian J Basic Appl Med Res* 2012; 1(2): 77–85.
40. Mansur DI, Haque MK, Sharma K, et al. Estimation of stature from foot length in adult Nepalese population and its clinical relevance. *Kathmandu Univ Med J* 2012; 10(1): 11–15.
41. Babu RS, Deepika V and Potturi BR. Estimation of stature from foot length. *Int J Pharm Biol Sci* 2013; 3(3): 266–270.
42. Kautilya DV, Bodkha P and Poothanathan P. Determination of stature and sex from anthropometry of the foot among south Indians. *Int J Rev Life Sci* 2013; 3(2): 22–26.
43. Khairulmazidah M, Nadiah AN and Rumiza AR. Stature estimation using foot and shoeprint length of Malaysian population. *Int J Med Health Sci* 2013; 7(7): 365–368.
44. Chris-ozoko LE. Foot length ratios compared to stature in a mixed gender, non-pathological sample. *J Biol Sci Bioconserv* 2013; 5(25): e32.
45. Dayananda R, Umesh B and Kiran J. Estimation of stature from dimensions of foot. *Med Leg Update* 2014; 14(1): 6.
46. Parekh U, Patel R and Patel P. A study of relation of stature with foot length in natives of Gujarat State. *NHL J Med Sci* 2014; 3(1): 22–26.
47. Sutay S, Surwade V, Tiwari UK, et al. Study of stature by foot length measurement in Madhya Pradesh. *Int J Bioassays* 2014; 3(11): 3441–3444.
48. Tobias KE, George MD, Vitalis ME, et al. Sexual dimorphism of correlations of feet anthropometric parameters and Height (stature) among undergraduate students of a University, Western Nigeria. *IOSR J Dent Med Sci* 2014; 13(4): 46–53.
49. Malik AR, Akhter N, Ali R, et al. A study on estimation of stature from foot length: A study on estimation of stature from foot length. *Prof Med J* 2015; 22(05): 632–639.
50. Rajesh DR, Chikkara P, Chokker VK, et al. Estimation of stature from foot dimensions and stature among South Indian medical students using regression models. *J Krishna Inst Med Sci Univ* 2015; 4(1): 95–99.
51. Saharan RA and Arun M. Stature estimation from foot anthropometry in individuals above 18 years belonging to Indian demography. *J Med Sci Health* 2015; 1(2): 25–29.
52. Agarwal S, Zaidi SH and Agarwal SK. Correlation of body height by foot length and knee height measurements in population of North India. *Int J Anat Res* 2015; 3(3): 1225–1229.
53. Taneja C, Babel H and Jain LK. An anthropometric study of stature estimation among males from the measurements of feet in Udaipur District of Rajasthan. *Int J Curr Res Rev* 2016; 8(17): 41.
54. Kanwar R, Lakhanpal AV and Shrivastava SK. Estimation of height from foot dimensions. *Int J Anat Res* 2016; 4(3): 2833–2837.
55. Iddalgave S, Kuppast N, Dhanwadkhar SS, et al. Reliability of foot length in prediction of stature. *Indian J Anat* 2017; 6(2): 214–217.
56. Saleem A, Magotra R, Rashid S, et al. Anthropometric measurement of foot length and its relation to stature in Jammu and Kashmir population. *Int J Adv Res* 2018; 6(Mar): 909–913.
57. Rollet E. De la mensuration des os longs des membres dans ses rapports avec l'anthropologie. *La Clin et la Med. Judi, Lyon* 1889: 128.

Deaths Due to Choking: An Autopsy-Based Study

Journal of Indian Academy
of Forensic Medicine
47(4) 373–377, 2025

DOI: 10.1177/09710973251405931
journals.sagepub.com/home/iaf
Sage

Harish S[1] and Nithin Mathew Sam[1]

Abstract

Choking is a form of asphyxia caused by an obstruction within the air passages. A record-based cross-sectional study involving 30 cases of choking deaths brought for autopsy to the Department of Forensic Medicine, Government T.D. Medical College, Alappuzha, Kerala, India, from 1 January 2013 to 31 December 2022. The commonest age group affected was 0–10 years (26.7%), and there was a male preponderance (73.3%). Time of occurrence aligned with the postprandial phases after the day's major meals, especially dinner. 46.7% of the victims had pre-existing illnesses like coronary artery disease, seizure disorder, chronic liver disease, inguinal hernia, diabetes mellitus and hypertension. Out of the 20 cases where the choking event was witnessed, only four survived long enough to receive medical assistance prior to death. In 50% of the subjects, the level of obstruction was bronchioles, followed by the laryngeal inlet (33.3%). Choking material was food in 70% of the cases, and the non-food materials included denture, sand, rambutan seed, bottle cap, baby coconut and handkerchief. Lungs showed congestion and oedema in 31.3%, haemorrhages in 14.1%, emphysema in 9.4% and atelectasis in 6.3%. Cerebral oedema was noted in 26.6% of cases. The manner of death was mostly accidental.

Keywords

Choking, autopsy, level of obstruction, choking material

Received 24 February 2025; **accepted** 20 November 2025

Introduction

Choking is the obstruction of the upper aerodigestive tract by food.[1] The internal airways are blocked between the pharynx and the tracheal bifurcation.[2] Obstruction can lead to respiratory distress. Bolus death, also known as Café coronary, is a fatal condition caused by obstruction of the larynx by a bolus of food, leading to reflex cardiac arrest.[3,4] Choking can occur in any age group.[2] It may be seen in children who may have the habit of chewing a variety of non-food materials. Absent or rudimentary dentition and limited chewing skills predispose to choking in infants and toddlers.[5] The peak age is between 2 and 3 years, and most cases occur under 5 years.[6] It is common in elderly people with neurodegenerative diseases like Parkinson's disease and Alzheimer's disease. Poor or absent dentition and loosely fitted dentures can predispose to a choking episode.[5] Mental illnesses and false teeth, especially partial dental plates, may also predispose to choking.[2] Choking material could be anything, varying from food materials like a chunk of meat, candy, carrots, nuts, grapes, seeds, plastic or metal parts of toys, the lid of bottles, balloons, coins, dentures, teeth, etc. A soft food bolus can get impacted and result in the death of elderly individuals. Sand, soil, cornmeal or sawdust may be aspirated in rare instances.[4,7] Irrespective of the cause of death, 20%–25% of cases aspirate food. Choking in adults usually involves a food bolus and may be commonly associated with alcohol intoxication.[7] This is due to the activating effect of alcohol on the parasympathetic nervous system and inhibitory effect on the sympathetic system.[4] Blood alcohol level above 150 mg/100 ml and blockage of airways with gastric contents in an individual who are found dead may be assumed to have died due to regurgitation, and evidence such as external vomit on the clothing and surroundings must be looked for in such cases.[2]

[1]Department of Forensic Medicine, Govt T.D. Medical College, Alappuzha, Kerala, India

Corresponding author:
Nithin Mathew Sam, Department of Forensic Medicine, Govt T.D. Medical College, Alappuzha, Kerala 688005, India.
E-mail: drnithinmathewsam@gmail.com

The rationale of this study on choking fatalities is to explore the underlying causes, associated risk factors, and situational aspects of such deaths to enhance preventive measures and response strategies.

Materials and Methods

This record-based cross-sectional study was conducted in the mortuary wing of the Government T. D. Medical College Hospital, under the Department of Forensic Medicine. The study population comprised all cases of death due to choking that were brought for medicolegal autopsy. The inclusion criteria comprised all documented deaths due to choking which underwent medicolegal autopsy at the Department of Forensic Medicine, Government T.D. Medical College, Alappuzha, between 1st January 2013 and 31st December 2022. Cases with incomplete or missing documentation were excluded. The final sample size consisted of all documented deaths due to choking, brought for autopsy during the specified period.

Data Collection Tools & Procedure

Cases were selected from the postmortem register. The required data were collected from the records kept in the records library, police requisition forms, postmortem detailed notes and postmortem certificates. A proforma was used for recording the necessary data.

Data Analysis

Data were collected and stored as hard copies and later entered into Microsoft Excel. Analysis was done using the Statistical Package for Social Sciences (SPSS) software trial version. During the analysis, qualitative variables were expressed as frequency and percentage, quantitative variables as mean and standard deviation.

Results

Out of the total, 22 cases (73.3%) were males, while 8 cases (26.7%) were females. Among 30 autopsy cases, thick mucus was found in 17 cases (56.7%), blood-stained mucoid fluid in 4 cases (13.3%), and no content in 9 cases (30%). In the oesophagus, regurgitated gastric contents were present in 8 cases (26.6%), while food particles were identified in 4 cases (13.3%). Sand was found in 1 case (3.3%), and in 17 cases (56.8%), no content was observed. Mucosal changes in the air passages revealed congestion in 17 cases (56.7%), haemorrhages in 2 cases (6.6%), and a normal mucosal appearance in 11 cases (36.7%), out of a total of 30 cases examined. Indicators of alcohol presence were noted in 6 cases (20%), which exhibited a detectable smell of alcohol in the stomach contents, and chemical analysis confirmed the presence of ethyl alcohol in 2 cases. No traces of other poisons or drugs were identified in any of the cases. Out of the total of 30 cases, suspected foul play was identified in 5 cases (cases where the manner of death was recorded as 'suspicious' in the police requisition), accounting for 16.7%. In contrast, 25 cases (53.3%) showed no indication of foul play. Other results of this study have been elaborated in Tables 1–6 and Figures 1 and 2.

Table 1. Age Group.

Age (in Years)	No.	%
0–10	8	26.7
11–20	1	3.3
21–30	5	16.7
31–40	1	3.3
41–50	7	23.3
51–60	1	3.3
61–70	3	10.0
71–80	2	6.7
81–90	1	3.3
91–100	1	3.3
Total	30	100.0
Mean age = 36.54 years, standard deviation = 27.39.		

Table 2. Clinical Presentation (as Documented in the Police Requisition).

	No.	%
Acute onset of illness	3	10.0
While having food	7	23.3
Witnessed swallowing of a foreign body	4	13.3
Following fall	3	10.0
Following a seizure episode	1	3.3
Found unconscious	3	10.0
Found dead	8	26.7
Buried after the assault	1	3.3
	30	100.0

Table 3. Time of Occurrence (as Documented in the Police Requisition).

	No.	%
12 AM–6 AM	3	10.0
6 AM–12 PM	6	20.0
12 PM–6 PM	9	30.0
6 PM–12 AM	11	36.7
Data not available	1	3.3
	30	100.0

Table 4. Activity Prior to Choking (as Documented in the Police Requisition).

	No.	%
Having food	9	30.0
Playing	2	6.7
Sleeping	2	6.7
Seizure	1	3.3
Riding motorcycle	1	3.3
Fall from a step	2	6.7
Walking	1	3.3
Not known	12	40.0
	30	100

Table 5. Stomach Contents.

	No.	%
Rice	13	41.9
Vegetables	2	6.5
Meat & vegetables	4	12.9
Soft, well-masticated particles & vegetables	3	9.7
Mucoid fluid	2	6.5
Soft, well-masticated particles & curry leaves	1	3.2
Pomegranate seed & thermocol piece	1	3.2
Altered blood	1	3.2
No content	4	12.9
	31	

Table 6. Findings in the Internal Organs.

	No.	%
Congestion & oedema of lungs	20	31.3
Emphysematous lung changes	6	9.4
Atelectasis of the lungs	4	6.3
Pulmonary haemorrhages	9	14.1
Congestion of the heart	2	3.1
Pallor of heart	3	4.6
Myocardial haemorrhages	3	4.6
Petechial haemorrhages of the scalp	0	0
Cerebral oedema	17	26.6

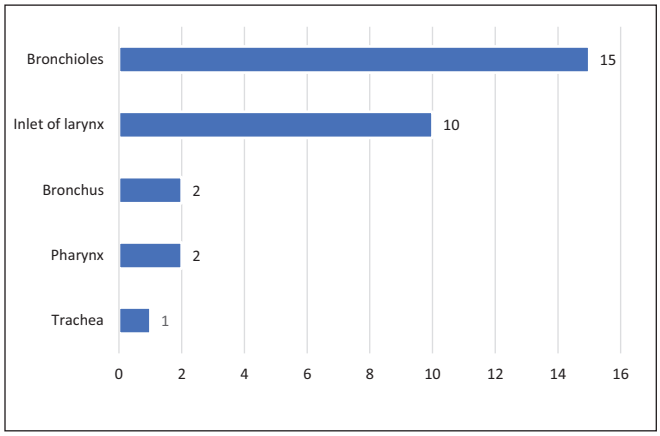

Figure 1. Level of Obstruction.

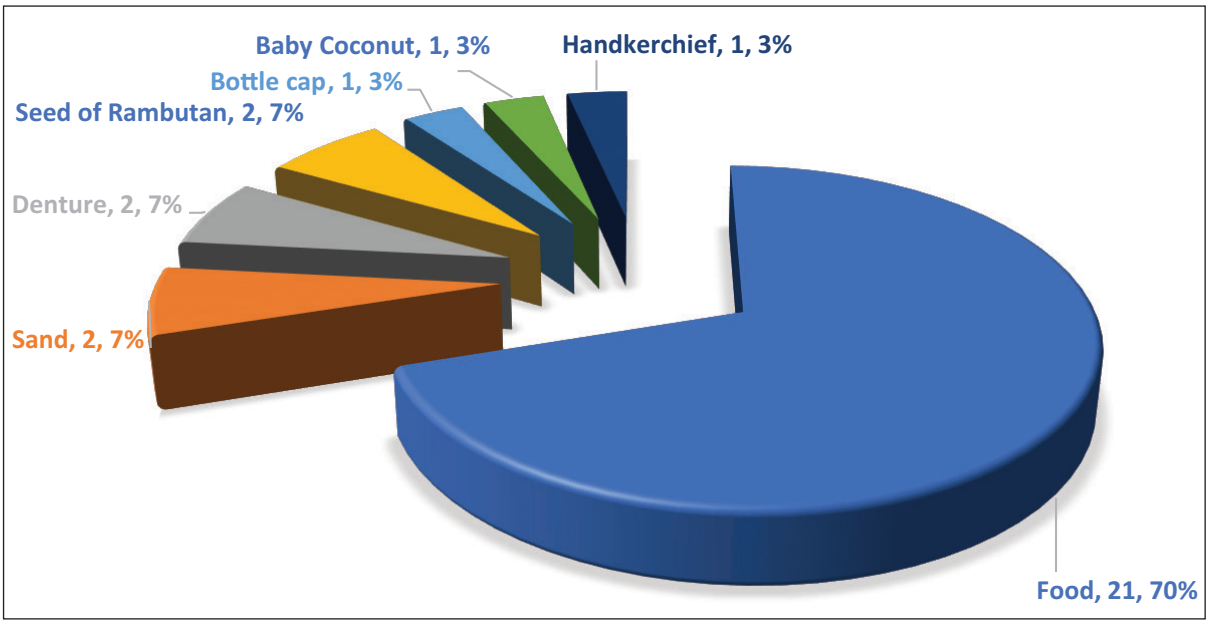

Figure 2. Choking Material.

Discussion

Out of the 9006 consequent autopsies conducted from 1st January 2013 to 31st December 2022, there were 30 cases (0.33%) of deaths due to choking. Other studies had a study population ranging from 3 to 200, and the study period extended up to 17 years.[8–15] The affected age ranged from 5 days to 91 years in the other studies.[8–14] Infants and young children may attempt to bite and chew a variety of non-food materials. In one of our cases, a piece of thermocol was found among the stomach contents, even though the choking material was a fruit seed. Young children develop their incisor teeth well before their molars and so can bite off pieces of firm food before being able to masticate them adequately.[5,6] Their dentition being rudimentary and their chewing skills limited make them more susceptible. Poor or absent natural dentition, ill-fitting dentures and neurodegenerative diseases predispose the elderly to choking.[5,16] In our study, there was a male preponderance, which agrees with available studies,[8–10,14] except for one hospital-based study done at Pennsylvania.[12]

The time of occurrence of choking incidents aligned with the postprandial period of the day's major meals.

In other hospital-based studies, pre-existing illnesses like psychiatric and neurodegenerative diseases, such as Parkinson's disease and Alzheimer's disease, were seen to be associated with deaths due to choking.[10,12,15] Ours being an autopsy-based study, non-detection of the above-mentioned diseases may be due to the absence of medicolegal autopsy in most such deaths.

Unlike other studies where the survival period of the victims is not documented, our study found that 66.7% of choking events were witnessed, but only 13.3% of those victims survived long enough to receive medical assistance before death.

Ethyl alcohol was detected in chemical analysis in 2 cases, who had blood alcohol concentrations of 199 and 352 mg per 100 ml, respectively. The presence of alcohol in blood has been reported in 75% of the study subjects by Phanjoubam M. et al.[9]

In our study subjects, foreign bodies were seen obstructing the air passage at the level of bronchioles in 50% cases. In contrast to our observation, other studies have recorded the common site as the inlet of larynx,[1,4] bronchi,[9] larynx[11] and trachea.[13] Both food and non-food materials causing choking were encountered in this study. But the case involving the handkerchief was a challenging one, where the manner of death remained undetermined. Other authors have mentioned non-food choking materials like denture, grain, cornmeal, sawdust, coin, candy, carrot, nuts, grapes, toys, balloons, screw and plastic pen components.[2–7] Rare cases of aspiration of sand and soil have been documented[4]; two such cases were encountered in our study. If the victim had an occluded airway and the object or food was removed during resuscitation, the only way to make the diagnosis would be by history;[16] we came across one such case where the plastic cap of a 'VICKS VapoRub' bottle was the choking material.

Di Maio has noted agonal aspiration of food in 20%–25% of individuals irrespective of their cause of death.[7,16] Agonal and postmortem redistribution of stomach contents to the upper airway has also been documented.[2,5] Other than the choking material, thick mucus was noted in the air passages in 56.7% of cases. A similar observation has been mentioned in the literature.[17]

According to Madea B., in about two-thirds of cases, undigested food particles were found in the stomach and corresponded with the bolus material. This indicates that food ingestion occurred immediately prior to the choking event. The stomach was empty in the other third, where the first mouthful proved fatal.[4]

Among our findings in the internal organs—cerebral oedema, pulmonary atelectasis and pallor—congestion and haemorrhages in the myocardium have not been documented in other studies. Duchania and Garg noted petechial haemorrhages on the surface of cerebrum.[13] None of the victims involved in the study showed petechial haemorrhages in the conjunctiva and sclera, which agrees with other authors.[4,7] The internal organ changes noted by other researchers, as well as in our study, included pulmonary congestion & oedema[11] and acute pulmonary emphysema.[4]

Foul play was alleged in only 16.7% of cases in our study, whereas a study conducted in Imphal reported suspicion of foul play in every case under consideration.[9]

Conclusion

Choking-related fatalities represent a distinct subset of asphyxial deaths, typically resulting from intraluminal airway obstruction, with the bronchioles frequently implicated. While most cases are accidental, the diversity of obstructive materials and the vulnerability of certain populations—such as infants, edentulous elderly individuals, and individuals under the influence of alcohol—highlight the multifactorial nature of this phenomenon. The medicolegal significance of choking is particularly evident in unwitnessed deaths, where the absence of clear external indicators may raise suspicion of foul play, necessitating a thorough and systematic autopsy. Preventive strategies, including appropriate feeding practices, prosthetic management, and public education on emergency interventions such as the Heimlich manoeuvre, are essential to mitigate risk. These findings underscore the need for heightened clinical awareness and forensic diligence in the evaluation and management of suspected choking deaths.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Ethical Approval

The study spanned a period of six months following ethical clearance, which was granted by the Institutional Ethics Committee (Approval No. EC 46/2023, dated 13 March 2023).

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

Informed Consent

Not applicable.

ORCID iD

Nithin Mathew Sam https://orcid.org/0009-0007-5469-2558

References

1. Jamieson A and Moenssens A. *Wiley Encyclopedia of forensic science*. 1st ed. Chichester: John Wiley and Sons Ltd, 2009, p.227.
2. Saukko P and Knight B. *Knight's forensic pathology*. 4th ed. Boca Raton: CRC Press, Taylor & Francis Group, 2016, pp.362–364.
3. Payne James J and Jones R. *Simpson's forensic medicine*. 14th ed. Boca Raton: CRC Press, Taylor & Francis Group, 2020, pp.172–173.
4. Madea B. *Handbook of forensic medicine*. 1st ed. Chichester: John Wiley and Sons Ltd, 2014, pp.406–407.
5. Dolinak D, Matshes EW and Lew EO. *Forensic pathology principles and practice*. Amsterdam: Elsevier Academic Press, 2005, pp.206–207.
6. Payne James J and Byard RW. *Encyclopedia of forensic and legal medicine*. 2nd ed. Amsterdam: Elsevier Ltd, 2016, p.495.
7. DiMaio VJM and Dana SE. *Handbook of forensic pathology*. 2nd ed. Boca Raton: CRC Press, 2006, pp.156–157.
8. Sasi Kanth Z and Ramarao B. A Study of asphyxial deaths. *Medico-legal Update* 2019; 19(2): 286–288.
9. Phanjoubam M, Keisham S, Devi M, et al. A 10-year post-mortem study of choking cases brought to the mortuary of a tertiary care hospital in Imphal. *Medico-legal Update* 2020; 20(4): 338–342.
10. Ruschena D, Mullen PE, Palmer S, et al. Choking deaths: The role of antipsychotic medication. *Br J Psychiatry* 2003; 183: 446–450.
11. Tingne CV, Kumar NB, Ghormade PS, et al. Deaths due to choking among psychiatric patients: A report of three cases. *J Forensic Med Sci Law* 2014; 23(1).
12. Kukielka E. Accidental choking among hospitalized patients in Pennsylvania: A 15-year retrospective review. *Patient Saf* 2020; 2(3): 42–53.
13. Duchania SK and Garg S. A series of fatal choking deaths in elderly. *J Forensic Med* 2022; 7: 173.
14. Berzlanovich AM, Fazeny-Dorner B, Waldhoer T, et al. Foreign body asphyxiation: A preventable cause of death in elderly. *Am J Prev Med* 2005; 28(1): 65–69.
15. Wu W-S, Sung K-C, Cheng T-J, et al. Associations between chronic diseases and choking deaths among older adults in the USA: A cross-sectional study using multiple cause mortality data from 2009 to 2013. *BMJ Open* 2015; 5: e009464.
16. Reddy KSN and Murty OP. *The essentials of forensic medicine and toxicology*. 35th ed. New Delhi: Jaypee Brothers Medical Publishers, 2022, p.281.
17. DiMaio VJM and Molina DK. *DiMaio's forensic pathology*. 3rd ed. Boca Raton: CRC Press, 2022, pp.239–242.

Evaluation of Diagnostic Discrepancies in Nasal Bone Fractures at Public Hospitals in East Tehran According to Forensic Experts' Opinions (2018–2019)

Journal of Indian Academy
of Forensic Medicine
47(4) 378–383, 2025

DOI: 10.1177/09710973251406686
journals.sagepub.com/home/iaf
Sage

Shayesteh Ashrafi Isfahani[1], Masoud Ghadipasha[1], Bashir Nazparvar[1], Nahid Dadashzadeh Asl[1], Ali Mohammad Alimohammadi[1], Parviz Gholipoor[2], Katayon Sayari Nejad[3] and Esmaiel Parsa[3]

Abstract

Nasal bone fractures are among the most prevalent indications for referral to forensic medicine centers for examination and certification. The objective of this study was to ascertain the frequency of diagnostic discrepancies in nasal bone fractures between public hospitals and forensic medicine experts in East Tehran zfrom 2018 to 2019. In this prospective quantitative study, 200 patients referred to the East Tehran Forensic Medicine Center in 2018 were selected based on available files. A survey was conducted to assess the frequency of unconfirmed nasal fracture diagnoses from public hospitals. These diagnoses were then analyzed in conjunction with the opinions of forensic experts. The results indicated that fractures were not confirmed in 59 patients (29.5%), suggesting a substantial discrepancy ($p < .05$). The underlying causes for non-confirmation included an initial diagnosis that was either incorrect or missing (55.9%), the presence of old fractures (35.6%), and post-rhinoplasty conditions (8.5%). The study's findings indicate that approximately one-third of nasal bone fracture diagnoses from public hospitals were not in accordance with the evaluations of forensic experts. The primary etiologies of these discrepancies were identified as diagnostic errors, pre-existing fractures, and post-surgical alterations. To address these concerns, it is advisable to place greater emphasis on the following: (a) the utilization of early and precise radiographic imaging, (b) comprehensive clinical documentation, and (c) the prompt referral of patients to forensic centers for expert evaluation.

Keywords

Nasal fractures, forensic medicine, causes, diagnostic inaccuracy, forensic experts' opinion

Received 30 April 2025; **accepted** 20 November 2025

Introduction

Nasal bone fractures represent the most prevalent type of facial fracture, often resulting from sports-related accidents, physical altercations, and other forms of trauma.[1] Although often regarded as inconsequential, an accurate diagnosis is imperative for two primary reasons. First, it serves as a crucial guide for determining the most suitable clinical management approach. Second, it plays a pivotal role in medico-legal contexts, ensuring the appropriate handling of medical cases in legal proceedings.[2,3] In numerous legal jurisdictions, the corroboration of a fracture by a forensic expert is a prerequisite for legal claims, compensation, and criminal prosecution.

The forensic significance of the nasal and midfacial anatomy is well-established, as structures such as the nasal septum and frontal sinus exhibit unique morphological patterns that can aid in human identification in forensic investigations, a fact highlighted in studies published in the *Journal of Indian Academy of Forensic Medicine*. Furthermore, the resilience of structures like the maxillary sinus, which often remains intact despite severe trauma to the skull, underscores

[1]Legal Medicine Research Center, Iranian Legal Medicine Organization, Tehran, Iran
[2]East Tehran Forensic Medicine Center, Iranian Legal Medicine Organization, Tehran, Iran
[3]Independent Researcher, Tehran, Iran

Corresponding author:
Shayesteh Ashrafi Isfahani, Legal Medicine Research Center, Iranian Legal Medicine Organization, District 12, Behesht St, MCJ8+C75 Park e Shahr, Tehran, Iran.
E-mail: sh.ashrafi.es@gmail.com

their critical value as stable anthropological markers for identity verification in complex cases.[4,5]

However, a significant challenge arises from discrepancies between initial diagnoses made in emergency departments or public hospitals and the subsequent evaluations conducted by forensic medicine specialists.[6,7] These diagnostic inconsistencies can lead to serious consequences, including unjust legal outcomes, loss of public trust in the healthcare system, and the financial burden of unwarranted claims on insurance and judicial systems. This phenomenon has garnered significant attention within the domain of medico-legal systems on a global scale, extending to regions such as India and the Middle East.

Despite the global recognition of this problem, there is a paucity of robust data quantifying the frequency and causes of these discrepancies, particularly in the Iranian context. A review of the extant literature reveals a prevalence of two notable limitations. First, the sample sizes of existing studies are often inadequate, and second, the majority of these studies are designed in a manner that is limited to a single center. Therefore, the specific research gap pertains to the absence of concrete, evidence-based analyses of mismatch rates and their etiologies in our region.[1,3,6,7]

The present study aims to address this gap by investigating the frequency of non-confirmation of nasal bone fracture diagnoses initially made in public hospitals by forensic experts in East Tehran. In addition, a thorough analysis of the underlying causes of these discrepancies is conducted. The results of this prospective study will provide valuable insights to help minimize misdiagnosis, improve referral practices, and enhance the reliability of medico-legal certifications.

Materials and Methods

This prospective quantitative study was conducted at the East Tehran Forensic Medicine Center from 2018 to 2019.

The study population comprised all individuals who were referred to the center for medico-legal assessment of suspected nasal bone fractures during the study period.

The inclusion criteria for the study were as follows: The patient must have been referred from a public hospital in East Tehran with an initial diagnosis of acute nasal bone fracture. The patient must be at least 18 years of age and must have complete medical and forensic records. The following criteria were used to determine exclusion from the study: The presence of other major facial fractures that could complicate the assessment is the first consideration.

Second, referral from private clinics or other cities is to be taken into account.

Finally, the availability or completeness of radiographic images must be ascertained. Due to the specific and consecutive nature of the referrals during the study period, a convenience sampling method was employed. The annual caseload was used to calculate the sample size, which was determined to be 200 participants, with a margin of error of approximately 7% and a 95% confidence level. This size was deemed sufficient for the study's objectives.

Data Collection and Diagnostic Confirmation

The data were collected using a structured form to record demographic information, mechanism of injury, medical history (including previous fractures, rhinoplasty, or nasal deviation), time intervals between trauma and assessments, and clinical findings.

Diagnostic Confirmation Protocol

The definitive diagnosis (confirmation or non-confirmation of an acute nasal bone fracture) was made by two senior forensic medicine specialists. The diagnosis was based on a standardized protocol:

Physical Examination: The specialists assessed the patient for objective signs of acute trauma, including crepitation, deformity, swelling, and bruising over the nasal bridge, as well as periorbital ecchymosis (raccoon eyes).

Imaging Review: All available imaging (nasal bone radiographs and, if available, computed tomography (CT) scans) was reviewed. The experts looked for definitive radiographic evidence of an acute fracture, carefully distinguishing it from signs of old healed fractures or post-surgical changes (e.g., from previous rhinoplasty).

A case was categorized as "confirmed" only if both specialists agreed on the presence of an acute fracture based on a combination of positive clinical and radiographic findings. Cases where the initial diagnosis could not be verified based on these objective criteria were categorized as "unconfirmed."

Data Analysis

Data analysis was performed using SPSS software version 24. Descriptive statistics are presented as mean ± standard deviation for quantitative variables and frequency (percentage) for qualitative variables. The Chi-square test was used to compare categorical variables. A p value of less than .05 was considered statistically significant.

Results

A total of 200 cases with an initial diagnosis of nasal bone fracture from public hospitals were referred for forensic evaluation. As demonstrated in Table 1, the forensic experts corroborated the diagnosis in 141 cases (70.5%), yet did not substantiate it in 59 cases (29.5%), thereby unveiling a substantial discrepancy rate of 29.5%.

The demographic factors examined (see Table 2) demonstrated that age, gender, and education level were not significantly associated with fracture confirmation ($p > .05$). However,

Table 1. Outcome of Initial Hospital Diagnosis After Forensic Expert Evaluation.

Initial Hospital Diagnosis	Final Forensic Expert Assessment	Number of Cases	%
Nasal bone fracture (*n* = 200)	Confirmed	141	70.5
	Unconfirmed	59	29.5
Reasons for unconfirmed diagnosis (*n* = 59)	Incorrect initial diagnosis	33	55.9
	Old healed fracture	21	35.6
	Post-rhinoplasty changes	5	8.5

Note: Data sourced from original hospital and forensic medicine records.

Table 2. Association Between Demographic Characteristics and Fracture Confirmation by Forensic Experts.

Variable		Confirmed Fracture	Unconfirmed Fracture	*p* Value
Age (year)	Under 30	60 (42.6%)	24 (40.7%)	>.05
	30–50	69 (48.9%)	29 (49.2%)	
	Over 50	12 (8.5%)	6 (10.2%)	
Gender	Male	112 (79.4%)	44 (74.6%)	>.05
	Female	29 (20.6%)	15 (25.4%)	
Occupation	Self-employed	94 (66.7%)	29 (49.2%)	.019
	Retired; unemployed; housewife	31 (21.9%)	22 (37.3%)	
	Employee	16 (11.3%)	8 (13.6%)	
Education	No diploma	58 (41.1%)	22 (37.2%)	>.05
	Diploma	55 (39%)	19 (32.2%)	
	University degree	24 (17%)	18 (30.5%)	

Notes: Data are presented as n (%).
p value calculated by Chi-square test.

Table 3. Clinical History Factors and Fracture Confirmation.

Variable		Confirmed Fracture	Unconfirmed Fracture
History of fracture	Present	9 (6.4%)	5 (8.5%)
	Absent	132 (93.6%)	54 (91.5%)
History of rhinoplasty	Present	5 (3.5%)	5 (8.5%)
	Absent	136 (96.5%)	54 (91.5%)
Symptoms status	Asymptomatic	12 (8.5%)	13 (22%)
	Swelling/bruising	56 (39.7%)	20 (33.9%)
	Nosebleeds	14 (9.9%)	8 (13.6%)
	Bruising around eyes	59 (41.8%)	18 (30.5%)

Note: Data are presented as *n* (%).

a significant association was identified with occupation ($p = .019$). The largest group with unconfirmed fractures was the self-employed individuals, which may be related to specific work-related risks or motivations for seeking certification.

Analysis of clinical history factors showed that a prior history of nasal fracture or rhinoplasty was not significantly associated with the current fracture confirmation status ($p > .05$ for both). A clear difference was observed in symptom presentation: 22.0% of unconfirmed cases were asymptomatic, compared to only 8.5% of confirmed cases. The distribution of reported symptoms (swelling, nosebleeds, bruising) is presented descriptively in Table 3; however, as patients could present with more than one symptom, formal statistical comparison for individual symptoms is not appropriate."

As demonstrated in Table 4, neither the mechanism of injury nor the primary method used for the initial diagnosis exhibited a significant relationship with the final confirmation outcome ($p > .05$).

Table 4. Association of Injury Mechanism and Diagnostic Method with Fracture Confirmation.

Variable		Confirmed Fracture	Unconfirmed Fracture	*p* Value
Mechanism of injury	Conflict	96 (68.1%)	40 (67.8%)	>.05
	Accident	38 (27%)	18 (30.5%)	
	Other events	7 (5%)	1 (1.7%)	
Diagnostic method applied	Clinical symptoms	47 (33.3%)	23 (39%)	>.05
	Radiographic findings	34 (24.1%)	14 (23.7%)	
	Combined methods	60 (42.6%)	22 (37.3%)	

Notes: Data are presented as n (%).
p value calculated by Chi-square test.

The predominant reasons for forensic non-confirmation included incorrect interpretation of imaging or symptoms (55.9%) and the failure to distinguish acute trauma from pre-existing conditions such as old fractures (35.6%) or post-surgical changes (8.5%).

This synthesis delineates a clear target for intervention, namely the enhancement of diagnostic accuracy. This enhancement is contingent upon the implementation of heightened scrutiny for specific patient profiles and a more critical evaluation of imaging to rule out old injuries.

Discussion

The primary objective of this study was to investigate the critical issue of diagnostic discrepancies in nasal bone fractures between public hospitals and forensic medicine experts. This is a problem with profound medico-legal consequences. The findings indicate that 29.5% of initial diagnoses were not corroborated by forensic experts, thereby underscoring a substantial gap in the accuracy of injury documentation. This documentation is fundamental to legal claims, compensation awards, and criminal justice outcomes.

The underlying causes of non-confirmation, namely an inaccurate diagnosis (55.9%), the presence of old fractures (35.6%), and post-rhinoplasty alterations (8.5%), underscore specific domains that necessitate intervention. The high rate of incorrect diagnoses indicates a necessity for enhanced training in acute fracture recognition for emergency physicians. This issue has also been identified in studies focusing on initial clinical assessments.[8,9] The prevalence of old fractures being misclassified as acute cases is a well-documented pitfall in forensic practice. This phenomenon underscores the indispensable role of a detailed patient history and the forensic expert's ability to distinguish radiographic signs of healing. This is an area where specialized training is crucial.[9,10] A thorough understanding of the normal morphological variations of the nasal bone, including differences related to sex, is fundamental for accurately identifying pathological fractures. For instance, a study in the *Journal of Indian Academy of Forensic Medicine* highlighted significant differences in pyramidal angle and linear distance of the nasal bone between genders using CT imaging, underscoring the detailed anatomical knowledge required for precise forensic assessment.[11] These discrepancies are not merely clinical errors; they directly impact the judicial process. Unconfirmed claims may signify either honest diagnostic errors or, in a subset of cases, potential attempts to seek unwarranted compensation. This is a challenge that medico-legal systems face globally.[12,13]

A particularly intriguing finding of our study is the significant association between occupation and fracture confirmation status (**p** = .019), with self-employed individuals showing a higher rate of unconfirmed fractures. The present socio-demographic variable has the potential to be associated with the motivations individuals have for seeking certification. One such motivation may be the necessity of documentation to support claims for financial compensation. This factor has the capacity to influence the manner in which patients present themselves and the information they provide in their histories.[12,13] This finding moves the discussion beyond pure diagnostic accuracy and into the complex interplay between socio-economic factors and the medico-legal system.

Furthermore, the markedly elevated incidence of unconfirmed fractures in asymptomatic patients (**p** = .044) offers a compelling clinical-forensic correlation. The absence of acute signs, such as swelling or bruising, upon physical examination serves as a significant indication that the initial diagnosis may be inaccurate or that the alleged acute injury is not recent. This finding is consistent with established forensic principles that prioritize objective clinical findings, a standard practice in expert evaluation.[8,9,14]

Our results strongly resonate with the work of Sener et al.,[15] who found that overdiagnosis of nasal fractures (24.5%) was far more common than missed diagnoses (1.9%). This pattern suggests that a major component of the discrepancy problem is not a failure to detect fractures, but a tendency to label soft tissue injuries or old changes as acute fractures, particularly when examinations are conducted without specialist consultation and rely solely on plain radiography.

While the overall discrepancy rate in our setting appears higher than that reported in some studies,[9] it is consistent with

the known variability in diagnostic accuracy across different contexts.[12,14] This variation can be attributed to differences in study settings, the experience level of the initial diagnosticians, and the specific protocols used by forensic centers. For instance, the diagnostic accuracy can be influenced by the imaging modality used. In our study, a majority of initial assessments included CT scans, yet discrepancies persisted. This underscores that while advanced imaging is crucial, as seen in the study by Hosukler et al.[16] where 76.5% of cases had CT scans, its interpretation by non-specialists remains a vulnerability. The consistent theme across all studies, including ours, is that a reliance solely on the initial hospital diagnosis without expert forensic verification is prone to error, potentially leading to significant legal and financial repercussions.[13]

The practical implications of our findings are threefold. First, the high rate of misdiagnosis underscores the necessity for advanced training in the interpretation of nasal radiographs for emergency physicians, particularly to differentiate acute fractures from old or post-rhinoplasty changes. This is critically important as general practitioners and emergency physicians have been shown to have a significantly higher tendency to overdiagnose non-depressed fractures. Second, it is imperative to exercise caution when diagnosing fractures in asymptomatic patients, and to promptly refer them for forensic evaluation when necessary. Third, clinicians should consider socio-demographic factors, such as occupation, which may influence motivations for filing claims. They should maintain objective and meticulous documentation in doing so. Ultimately, as concluded by Hosukler et al., the most reliable solution may be for the final forensic report in cases of nasal trauma to be issued by a Forensic Medicine Specialist, who can integrate clinical, radiological, and contextual findings into a holistic and objective assessment. The implementation of these measures has the potential to mitigate diagnostic discrepancies.

A limitation concerns the analysis of symptoms. As clinical signs were recorded as non-exclusive categories, it was not statistically valid to compare them directly using a single Chi-square test. Unfortunately, the original dataset is no longer available to permit a re-analysis using mutually exclusive categories or individual binary variables. Therefore, the symptom analysis is presented descriptively, and the primary robust finding is the significant difference in confirmation rates between asymptomatic and symptomatic patients.

Recommendations and Conclusion

To address these discrepancies, a multifaceted approach is proposed:

1. Enhanced Training: It is imperative that emergency physicians partake in obligatory workshops that focus on the acute and chronic radiographic characteristics of nasal fractures.
2. Standardized Protocols: The development of clear guidelines for when to suspect an old injury or a post-surgical state and when referral to a forensic specialist is warranted or is essential.
3. Forensic Vigilance: The present study offers evidence to assist forensic practitioners in recognizing the potential impact of socio-demographic factors, including occupation, on the legitimacy of claims.

In summary, the present study advances beyond the mere quantification of diagnostic error to underscore its substantial medico-legal ramifications. A discrepancy rate of nearly one-third calls into question the reliability of initial diagnoses for legal purposes. By identifying incorrect diagnoses as the primary cause and examining the roles of asymptomatic presentations and occupational status, a roadmap is provided for improving diagnostic accuracy and safeguarding the integrity of the medico-legal process. This roadmap is based on evidence.

Data Availability Statement

Data will be available upon request from the corresponding author.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

This study will be conducted in accordance with the ethical principles of the Declaration of Helsinki. The study protocol was reviewed by the Ethics Committee of the Forensic Medicine Organization and approved with the code (IR.LMO.REC.1398.002). Patient information will remain confidential and will only be accessible to the research tea.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent

Written informed consent was obtained from all individual participants included in the study.

ORCID iD

Shayesteh Ashrafi Isfahani https://orcid.org/0000-0002-6919-5155

References

1. Tasman AJ. Rhinoplasty - indications and techniques. *GMS Curr Top Otorhinolaryngol Head Neck Surg* 2007; 6: Doc09.
2. Immerman S, Alexander A and White WM. Nasal and Sinus Trauma. In: Kountakis SE (ed) *Encyclopedia of otolaryngology,*

head and neck surgery. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013. pp.1729–1742.
3. Kelley BP, Downey CR and Stal S. Evaluation and reduction of nasal trauma. *Semin Plast Surg* 2010; 24(4): 339–3347.
4. Shetty KM, Rao K and KP. Application of maxillary sinus and nasal aperture morphology for forensic identification with the aid of CBCT imaging: A review. *J Indian Acad Forensic Med* 2021; 43(2): 173–176.
5. Verma P, Verma KG, Khosa R, et al. Combined use of frontal sinus and nasal septum patterns as an aid in forensics: A digital radiographic study. *North Am J Med Sci* 2015; 7(2): 47.
6. Manninen IK, Klockars T, Mäkinen LK, et al. Epidemiology and aetiology of sport-related nasal fractures: Analysis of 599 finnish patients. *Clin Otolaryngol*. 2023; 48(1): 70–74.
7. Xiao CC, Kshirsagar RS, Hoerter JE, et al. Sport and recreational causes of nasal bone fractures. *Ann Otol Rhinol Laryngol* 2022; 131(7): 760–766.
8. Daniel M and Raghavan U. Relation between epistaxis, external nasal deformity, and septal deviation following nasal trauma. *Emerg Med J* 2005; 22(11): 778–779.
9. Gharedaghi J, Samadi B, Ghatre SV, et al. The comparison of physical and radiologic finding in referral cases of nasal bone trauma to East Azarbabaijan Legal Medicine Center and epidemiologic finding between 2007 and 2008. *Iran J Forensic Med* 2010; 16(1): 28–32.
10. Stranc M and Robertson G. A classification of injuries of the nasal skeleton. *Ann Plast Surg* 1979; 2(6): 468–474.
11. Hasham SA, Kotian RP and Madhavan T. Comparison of morphological measures of nasal bone between genders using computed tomography. *J Indian Acad Forensic Med* 2020; 42(1): 40–42.
12. Bajwa SJS, Kaur J, Singh A, et al. Clinical and critical care concerns of cranio-facial trauma: A retrospective study in a tertiary care institute. *Natl J Maxillofac Surg* 2012; 3(2): 133–138.
13. Higuera S, Lee EI, Cole P, et al. Nasal trauma and the deviated nose. *Plast Reconstr Surg* 2007; 120(7): 64S–75S.
14. Gilyoma JM and Chalya PL. Ear, nose and throat injuries at Bugando Medical Centre in northwestern Tanzania: A five-year prospective review of 456 cases. *BMC Ear Nose Throat Disord* 2013; 13: 1–7.
15. Sener M, Kok A, Kara C, et al. Diagnosing isolated nasal fractures in the emergency department: Are they missed or overdiagnosed? Ten years experience of 535 forensic cases. *Eur J Trauma Emerg Surg* 2014; 40(6): 715–719.
16. Hosukler E, Erkol ZZ and Dincer G. Forensic medical evaluation of nasal trauma cases. *Ann Med Res* 2022; 29(6): 639–643.

Original Research Article

Quality of the Death Certificates of Hospitals in Addis Ababa, Ethiopia: A Time to Adopt the Internationally Recommended Form

Journal of Indian Academy of Forensic Medicine
47(4) 384–390, 2025

DOI: 10.1177/09710973251412499
journals.sagepub.com/home/iaf
Sage

Natnael Getu Bekele[1], Belayneh Lulseged[2], Yoseph Worku[3], Sara Assefa Beyene[4] and Alemayehu Shiferaw Lema[5]

Abstract

The quality of death certificates (DCs) in many countries, including Ethiopia, is often inadequate, leading to significant implications for medical, legal, and administrative processes. This study evaluated the quality of DCs issued at St. Paul's Hospital Millennium Medical College and Ras Desta Damtew Memorial Hospital in Addis Ababa. A retrospective review of 595 randomly selected DCs from September 11, 2020 to September 10, 2021, was conducted using a standardized evaluation tool developed by the University of Melbourne. All reviewed DCs contained errors, with the most prevalent being the omission of the time interval between symptom onset and death (100%) and ill-defined underlying causes of death (72.8%). Both hospitals in this study used paper-based DCs, but neither had implemented the internationally recommended format for DCs. The high frequency of errors underscores the need for targeted training for certifiers, implementation of quality assurance mechanisms, and adoption of standardized formats to enhance the consistency and accuracy of DCs.

Keywords

Medical certification of cause of death, death certificates, causes of death, mortality statistics, Ethiopia

Received 07 August 2025; **accepted** 16 December 2025

Introduction

Medical Certification of Cause of Death (MCCD) is a document of utmost importance in the medical, legal, and social realms.[1] It serves as a means of documenting and registering the facts and causes surrounding an individual's death.[1,2] The MCCD holds significant value for various purposes, including legal, administrative, and health-related matters. Death certificates (DCs) provide important information for government officials, public health authorities, health studies, and families.[1–3] However, concerns regarding the quality of DCs and their application in vital statistics often arise.[1–5]

Death certification is essential to furnish legal evidence regarding the cause of death (COD), to establish whether criminal activity was involved, and to resolve matters related to inheritance, insurance claims, and other legal affairs. Death certification is helpful not only to provide health-related data regarding COD and preceding illnesses but also to identify the leading COD, trends and patterns of mortality, risk factors, and determinants of health outcomes. They also guide health policy decisions and assist in setting priorities.[1–5]

[1]Department of Forensic Medicine and Toxicology, Menelik II Comprehensive Specialized Hospital, Addis Ababa, Ethiopia
[2]Department of Reproductive Health and Health Service Management, School of Public Health, St. Paul's Hospital Millennium Medical College, Addis Ababa, Ethiopia
[3]Department of Epidemiology, School of Public Health, St. Paul's Hospital Millennium Medical College, Addis Ababa, Ethiopia
[4]St. Peter Specialized Hospital, Addis Ababa, Ethiopia
[5]Department of Forensic Medicine and Toxicology, St. Paul's Hospital Millennium Medical College, Addis Ababa, Ethiopia

Corresponding author:
Alemayehu Shiferaw Lema, Department of Forensic Medicine and Toxicology, St. Paul's Hospital Millennium Medical College, Addis Ababa, Ethiopia.
E-mail: alemayehu.shiferaw@sphmmc.edu.et

The quality of DC and its applicability to mortality statistics depend on several factors, including data availability, completeness, accuracy, consistency, and timeliness. These factors are influenced by the format and process of death certification, as well as the knowledge and skills of the certifier. The accuracy of DCs relies on various factors, such as the certifiers' proficiency in accurately identifying the sequence of events that led to death and their understanding of the concept and significance of the underlying cause of death (UCOD).[3] To ensure a standardized format for death certification, the World Health Organization (WHO) has recommended the use of MCCD. This certificate consists of two parts: (a) the UCOD and (b) other significant conditions contributing to the death. The information from the MCCD is then coded using the latest International Classification of Diseases (ICD) codes, which classify and aggregate COD for statistical purposes.[6,7]

Several studies have reported common problems and issues with the quality of MCCD and its use for mortality statistics. Some of these problems include vague descriptions of conditions, such as modes of dying (e.g., cardiac arrest or respiratory failure) or mechanisms, rather than specifying the UCOD, like listing hemorrhage without detailing the specific injury. Other concerns involve clinically implausible sequences of COD, listing multiple CODs on a single line, incomplete or omitted information (e.g., failing to include relevant comorbidities or the duration of illness), and the use of abbreviations and illegible handwriting.[1–5] These problems can affect the validity and comparability of mortality data and statistics, thereby compromising their usefulness for mortality studies.

In Ethiopia, the official and functioning outline of vital event registration was established by adopting a widespread rule. This rule was made obligatory by National Proclamation No. 760/2012. Vital events registration was implemented nationwide starting on August 6, 2016 and was reinforced by Proclamation No. 1049/2017.[8,9] However, the internationally recommended DC format prescribed by the WHO has never been used in Ethiopia.[10]

In Ethiopia, there is limited information regarding the quality of MCCD and its common problems. Identifying common errors and concerns associated with death certification will be beneficial for improving hospital-based data and national statistics. It will also guide how to enhance the quality of certification and records in healthcare institutions. Therefore, we assessed the quality of DC in selected public health facilities in Addis Ababa, Ethiopia.

Materials and Methods

Study Setting, Design and Period

This study was conducted in Addis Ababa, the capital of Ethiopia, with a population of 3,774,000 as of the July 2021 Ethiopian Statistical Service projection report. Among the 12 public hospitals in Addis Ababa, St. Paul's Hospital Millennium Medical College (SPHMMC) and Ras Desta Damtew Memorial Hospital (RDDMH) were randomly selected for this hospital-based cross-sectional study. DCs issued over a year from September 11, 2020 to September 10, 2021, were reviewed retrospectively. The data were collected from May to June 2022.

Population

Records of all deaths that occurred at SPHMMC and RDDMH during the study period were the source population. The sampled records of deaths in both hospitals were the study population. Cases referred for autopsy were excluded from the study.

Sample Size and Sampling Procedure

The sample size was calculated using a single population proportion formula considering a 95% confidence level ($Z\alpha/2 = 1.96$), a 5% margin of error, and a 48.5% estimated prevalence of a major error on DCs, based on a previous study conducted at Tikur Anbessa Specialized Hospital.[10] After adjusting for 10% of non-response for the unreadable or lost records and a design effect of 1.5, the final estimated sample size was 634.

The lists of medical record numbers of deaths registered at the facilities were separately obtained from Health Management Information System logbooks and used as a sampling frame. Over the study period, SPHMMC and RDDMH recorded 1,892 and 769 deaths, respectively. To ensure representativeness, the samples were allocated proportionally to each hospital based on the total number of DCs during the study period. Participant records were selected using a simple random sampling technique using computer-generated numbers.

Data Collection

The quality of the DCs was assessed by a structured data abstraction template designed using a rapid assessment tool adopted from the University of Melbourne.[5] The data collection tool comprised patients' information on the socio-demographic data of the deceased, duration of stay, time and place of death, qualification of the certifier and treating physicians, manner of death, DC format, and a rapid assessment checklist. The data collection form was pretested on 50 cases, and the necessary amendments were made. Data were collected by well-trained medical residents and supervised by the principal investigators. All collected data were examined for completeness and consistency. Incomplete or incorrect entries were corrected daily by reviewing the original record using the assigned code.

Assessment Tool

The data collection tool served as a checklist to identify common errors in MCCDs. The assessment criteria classified errors as either major or minor, based on their impact on determining the UCOD. Major errors were defined as errors that directly affect the determination of UCOD, such as listing multiple causes per line, incorrect sequencing of events leading to death, entering ill-defined conditions as the UCOD, and illegible handwriting. Minor errors were defined as errors that did not directly affect the determination of UCOD, such as the presence of blank spaces within the sequence of events, the absence of disease time intervals, and the use of abbreviations.[5]

Data Analysis

Data were analyzed using IBM SPSS Statistics for Windows (version 26). Descriptive statistics were utilized to summarize categorical variables with proportions and frequency tables. Continuous variables were summarized using the mean and standard deviation.

Results

After excluding the lost records, we reviewed 620 sampled DCs and corresponding medical records; 441 were obtained from SPHMMC, and 179 were obtained from RDDMH. Among these, (25 DCs, 4.03%) had illegible handwriting and were omitted from further review. The study included 595 DCs with a 94% retrieval rate: 71.6% (n = 426) from SPHMMC and 28.4% (n = 169) from RDDMH. The mean age at death was 46 ± 17.06 years, with males representing 58.2% (n = 346) of the cases. Most deaths (65.7%) occurred in the 25–65 age group, followed by individuals older than 65 years, accounting for 21.7% of the deaths (Table 1).

Medical residents issued about two-thirds (66.7%) of DC, while general practitioners issued the remaining third (33.3%). A substantial number of deaths (56.1%) occurred after hospital stays lasting between 1 and 7 days. Most DCs (98.5%) indicated a natural manner of death, with only 1.5% classified as undetermined. The majority of deaths occurred in the emergency department, accounting for 43.5% of the cases (Table 1).

Table 1. Demographic and Health Facility-related Characteristics of the Deceased for Whom Death Certificates Were Issued at the SPHMMC and RDDH From September 11, 2020 to September 10, 2021.

Variables		Frequency	%
Sex	Male	346	58.2
	Female	249	41.8
Age	0–14	22	3.7
	15–24	53	8.9
	25–65	391	65.7
	>65	129	21.7
Hospital name	SPHMMC*	426	71.6
	RDDMH**	169	28.4
Qualification of death certifiers	General practitioner	198	33.3
	Resident physicians	397	66.7
Place of death	Emergency department	259	43.5
	Intensive care unit	191	32.1
	Ward	145	24.4
Duration of hospital stay before death	<1 day	110	18.5
	1–7 days	334	56.1
	8–30 days	140	23.5
	>30 days	11	1.9
Time of death	Night time	340	57.1
	Daytime	255	42.9
Manner of death	Natural	586	98.5
	Undetermined	9	1.5

Notes: *SPHMMC: St. Paul's Hospital Millennium Medical College.

**RDDMH: Ras Desta Damtew Memorial Hospital.

Errors in Death Certificates

Both hospitals in this study used paper-based DCs, but neither adhered to the standardized format recommended by the WHO. The DC form used in both hospitals did not include the standard part one and part two formats, making it impossible to evaluate errors such as listing multiple CODs on a single line or leaving blank spaces.

All the issued DCs (100%) contained errors. The most common error was the omission of the time interval between the onset of symptoms and death (100%), followed by an ill-defined UCOD. Major errors included ill-defined UCOD (72.8%; 95% CI: 69.1%, 76.2%), clinically improbable sequences of COD (46.8%; 95% CI: 42.8%, 50.8%), and unspecified neoplasms (6.4%; 95% CI: 4.7%, 8.6%). Among these ill-defined conditions, the mode of death was the most frequently listed at 60.9%, followed by the mechanism of death at 33.9%. Furthermore, ill-defined conditions such as laboratory values, signs, and symptoms were mentioned in 4.7% and 0.5% of the certificates, respectively. Table 2 summarizes the frequency of major and minor errors identified on DCs.

Overall, all the DCs reviewed contained errors. Among these, approximately 3.7% of the DCs had one, 25.9% had two, 40% had three, and 30.4% had four or more errors. When considering the severity of these errors, 11.9% of the DCs had no major errors, while 50.9% had one major error. In addition, 36.3% of the DCs contained two major errors, and only 0.8% had three major errors. Regarding minor errors, 34.1% of the DCs had a single minor error, 57.5% had two minor errors, and 8.4% had three minor errors.

Table 2. Types of Errors in Death Certificates Issued at SPHMMC and RDDMH From September 11, 2020 to September 10, 2021.

Errors in Death Certificates	Frequency	%
Major errors		
Clinically improbable sequence of COD	279	46.80
Ill-defined UCOD	433	72.80
Unspecified neoplasm	38	6.40
Minor errors		
Abbreviations used	350	58.80
Time interval omitted	595	100
Additional errors		
Not recording age	21	3.53
Not recording sex	22	3.70
Not recording the date of admission	33	5.55
Not recording the time of death	28	4.70
Not recording the place of death	42	7.06
Additional errors (all)	146	24.53

Discussion

This study evaluated the quality of and challenges related to the certification of deaths in selected public health institutions in Addis Ababa, Ethiopia. It was observed that healthcare facilities in Ethiopia have not yet adopted the internationally recommended DC format provided by the WHO. A systematic review conducted to evaluate common errors in DCs revealed that the use of non-standard DC forms was a key factor leading to inaccuracies in the completion of DCs.[2] Adhering to these guidelines and forms is crucial for guaranteeing the precision and excellence of medical death certification, as well as for producing mortality data that can be compared across countries, national and subnational populations, specific population groups, and different periods. Consequently, we urge immediate adoption of the standard DC format recommended by the WHO in Ethiopia.

The most significant finding of this study is that all the DCs examined had errors. This finding is consistent with previous research conducted in Addis Ababa and other countries, indicating that errors in death certification are a universal problem. A review of studies from various countries revealed that the percentage of DC errors ranged from 20% to 100%, with most studies reporting error rates above 90%.[1] Additionally, several studies from Egypt, Saudi Arabia, India, and Korea reported that none of the DCs examined were error-free.[11–17] According to a recent systematic review, the main causes of DC errors are a lack of training or poor training for certifiers, a lack of understanding among physicians about the significance of DCs, and the absence of quality control mechanisms.[2] This finding is strongly supported by studies from India, which identify a lack of formal training and knowledge, as well as work overload, as the primary causes of errors. These studies recommend formal training and the implementation of audit systems for quality control.[16–21] To improve the quality of DCs, ongoing and targeted training for certifiers should be provided, quality assurance or control mechanisms should be established, and tracking mechanisms should be implemented to ensure the completion of accurate DCs. Moreover, standardizing DC forms to comply with WHO requirements and potentially using electronic DC forms are also suggested as feasible solutions.

In this study, the most common error was the omission of the time interval between symptom onset and death, followed by listing ill-defined UCODs. The study revealed that omission of the time interval between symptom onset and death was observed in 100% of the DCs. Similar findings have also been reported in studies conducted at Tikur Anbesa Specialized Hospital in Addis Ababa, Ethiopia, as well as in other countries, including Iran, India, and Egypt.[10,12,22,23] The potential reason for the exclusion of the time between the onset of symptoms and death may be attributed to the absence of a designated space for recording the time interval in the

outdated DC format employed by healthcare facilities. Additionally, this could also be due to a lack of awareness regarding the importance of documenting this information. Although missing time intervals were considered minor errors in these studies, recording accurate time intervals is crucial for identifying UCOD and preventing sequencing errors.

Another prevalent error observed in this study was the documentation of ill-defined conditions as a COD. The mode and mechanism of death were frequently listed as ill-defined conditions in this study. The study also revealed that an incorrect sequence of events was present in 46.8% of the DCs. This error was also observed in previous studies conducted in India, Egypt, Iran, and Palestine.[12,20,24,25] Incorrect diagnosis, sequence, or incorrect completion of DC can lead to errors in mortality statistics, directly impacting the formulation of national health policy. Likewise, ill-defined conditions have limited value from a public health perspective.[3,5,26] Hence, it is strongly advised to refrain from documenting ill-defined conditions in DCs and strive to offer more precise information whenever possible.

However, there are challenges in accurately certifying COD in medical practice.[1–5] The accuracy of the MCCD can be influenced by factors such as certifiers' knowledge and expertise in recognizing the series of events leading to death and their understanding of the concept of the UCOD. Nevertheless, medical students are rarely taught about the public health significance of accurate COD information, the concept of the UCOD, the sequence of events leading to death, and how to correctly complete the MCCD. Previous research and experiences from the Bloomberg Data for Health initiatives have suggested that the training provided to medical students on death certification is insufficient.[2,3,5] It is imperative to introduce or enhance training on COD certification for medical students. Additionally, implementing measures such as continuous training and quality assurance can help improve the quality and reliability of DCs. Further research is needed to assess the quality of the MCCD in other health facilities and regions of Ethiopia and to evaluate the impact of interventions aimed at reducing errors in death certification.

The study showed that the use of abbreviations was the third most prevalent error in DCs, with 58.8% of the certificates containing this error. This finding is consistent with previous studies conducted in Ethiopia, India, and Bangladesh, which also reported high error rates related to the use of abbreviations.[10,23,26] Abbreviations should not be used in DCs as they could result in misinterpretation of COD, incorrect coding, and erroneous statistics.[2] The error of illegible handwriting was found in 4.03% of the DCs in this study. This rate was lower than that of similar studies conducted in other countries.[17,22,24,25] To reduce errors such as the use of abbreviations, illegible handwriting, and omissions of information, digitalizing DC forms is an effective solution. In addition, the implementation of quality assurance and tracking systems that ensure the timely completion of incomplete DCs can be helpful.[2]

In this study, most of the deceased individuals (66.7%) were treated by senior physicians, medical residents, and medical interns at different times during their hospital stay. Medical residents issued DCs for these individuals. Conversely, the remaining 33.3% of the deceased individuals received treatment from senior physicians, general practitioners, and interns, and their DCs were issued by general practitioners. Inaccuracies in death certification may arise from work overload because only residents or general practitioners are responsible for certification in the study facilities.[2] To address this issue, we recommend that DCs be completed by a physician who is familiar with the patient, even if this may lead to delayed completion of the DC. Additionally, medical certifiers are strongly encouraged to discuss DCs with the clinical care team. Countersigning DCs by senior medical staff, who are likely to possess greater knowledge and experience, is also crucial. Furthermore, our finding of an undetermined manner of death in 1.5% of the reviewed documents, which were not referred for autopsy, is concerning. When certifying a death, if the manner is classified as undetermined based on the information available, it is crucial to recognize that these cases may involve unnatural causes and should be referred for a postmortem examination. This practice is essential for accurately determining both the cause and manner of death, and all physicians should be made aware of this protocol.

Our study revealed a significant occurrence of DC errors in selected public hospitals in Addis Ababa, Ethiopia. The omission of the time interval between onset and death and the listing of ill-defined UCODs were the most common errors identified. To improve the accuracy of DCs, we recommend implementing ongoing targeted training for certifiers, establishing quality assurance mechanisms, and introducing tracking systems to ensure accurate completion of DCs. Additionally, healthcare institutions should adopt the internationally recommended DC format endorsed by the WHO to improve data consistency and reliability. Further research is needed to assess the quality of DC in other health facilities and regions of Ethiopia and to evaluate the impact of interventions aimed at reducing errors in death certification.

Abbreviations

DC: Death certificate
MCCD: Medical Certification of Cause of Death
COD: Cause of death
ICOD: Immediate cause of death
UCOD: Underlying cause of death
ICD: International Classification of Diseases
WHO: World Health Organization
SPSS: Statistical Package for Social Sciences
SPHMMC: St. Paul's Hospital Millennium Medical College
RDDMH: Ras Desta Damtew Memorial Hospital.

Acknowledgements

The authors would like to express their sincere gratitude to St. Paul's Millennium Medical College and Ras Desta Damtew Memorial Hospital for their support in the accomplishment of this study. We would also like to thank the data collectors (medical residents) for taking their precious time to collect the data.

Authors' Contribution

NGB contributed to the conceptualization, data curation, methodology, formal analysis, investigation, resources, software, validation, visualization, and writing both the original draft and review and editing of the manuscript. BL and YW were involved in the conceptualization, data curation, methodology, formal analysis, investigation, supervision, validation, visualization, as well as review and editing of the manuscript. SAB participated in the conceptualization, data curation, methodology, formal analysis, investigation, validation, visualization, as well as writing both the original draft and review and editing of the manuscript. ASL contributed to the conceptualization, data curation, methodology, formal analysis, investigation, supervision, validation, visualization, and writing both the original draft and review and editing of the manuscript.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval and Informed Consent

Ethical approval for the conduct of the study was obtained from the institutional review board (IRB) of Saint Paul's Hospital Millennium Medical College (Reference number of PM 23/7). All methods were performed in accordance with relevant guidelines and regulations. All the information was treated anonymously and confidentially using unique identification codes rather than individual identifiers. This study received ethical approval from the Saint Paul's Hospital Millennium Medical College IRB (Reference number of PM 23/7) on July 07, 2022. This is an IRB-approved retrospective study; all patient information was de-identified, and patient consent was not required. Patient data will not be shared with third parties.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Yoseph Worku https://orcid.org/0000-0002-6885-0437
Alemayehu Shiferaw Lema https://orcid.org/0000-0002-2884-5609

References

1. Zaki MK and Sobh ZK. Optimum standardization of cause-of-death certification procedures in healthcare facilities: A medicolegal initiative. *Forensic Sci Int Rep* 2023; *8*: 100329.
2. Alipour J and Payandeh A. Common errors in reporting cause-of-death statement on death certificates: A systematic review and meta-analysis. *J Forensic Leg Med* 2021; *82*: 102220.
3. Hart JD, Sorchik R, Bo KS, et al. Improving medical certification of cause of death: Effective strategies and approaches based on experiences from the Data for Health Initiative. *BMC Med* 2020; *18*: 1.
4. Hobson P and Meara J. Mortality and quality of death certification in a cohort of patients with Parkinson's disease and matched controls in North Wales, UK at 18 years: A community-based cohort study. *BMJ Open* 2018; *8*: e018969.
5. Rampatige R, Gamage S, Richards N, et al. Assessing the quality of death certificates: Guidance for the rapid tool. Melbourne: *Civil Registration and Vital Statistics Improvement*, *The University of Melbourne, Bloomberg Philanthropies Data for Health Initiative*. 2019. Available from: https://crvsgateway.info/file/9587/62 (2016, accessed 7 September 2024).
6. World Health Organization. *Medical certification: International form of medical certificate of cause of death*. 2016. https://www.who.int/standards/classifications/classification-of-diseases/cause-of-death (2016, accessed 7 September 2024).
7. World Health Organization. *Medical certification: International form of medical certificate of cause of death*. 2023. https://www.who.int/standards/classifications/classification-of-diseases/cause-of-death (2023, accessed 7 September 2024).
8. UNICEF. *CRVS: Birth, marriage and death registration in Ethiopia*. 2021. https://data.unicef.org/crvs/ethiopia/ (2021, accessed 28 May 2025).
9. United Nations Ethiopia. *Vital events registration kicks off in Ethiopia*. 2021. https://ethiopia.un.org/en/14847-vital-events-registration-kicks-ethiopia (2021, accessed 28 May 2025).
10. Abebe H. Quality assessment of facility-based medical certification of cause of death in the Department of Pediatrics and Child Health at Tikur Anbesa Specialized Hospital between July–August 2021, Addis Ababa, Ethiopia. Unpublished.
11. Madboly AG and Metwally ES. Accuracy of medical certification of cause of death at Benha University Hospitals, Egypt: A one-year retrospective descriptive study (2014). *Egypt J Forensic Sci Appl Toxicol* 2015; *15*: 129–146.
12. Aly EA, Anwar WA, Abdelhafez AM, et al. Trend of ill-defined causes of death in Egypt (2000–2013) in comparison to selected Eastern Mediterranean countries, and an intervention study to improve the accuracy of death certification in one district in Cairo, Egypt. *Egypt J Community Med 2017*; 35: 35–48.
13. Aljerian K. Death certificate errors in one Saudi Arabian hospital. *Death Stud* 2019; *43*: 311–315.
14. Uplap P, Wani D and Sankhe L. Assessment of medical certificate of cause of death at a tertiary care centre in Mumbai, India. *Indian J Forensic Community Med* 2019; *6*: 70–74.
15. Park BJ and Kim SH. Errors in pediatric death certificates issued in an emergency department. *Pediatr Emerg Med J* 2022; *9*: 17–22.
16. Bamboria BL, Surwade VB and Gupta, BD. Pattern of filling up of medical certification of cause of death (MCCD) at a tertiary care hospital: Pitfalls and suggestions. *J Indian Acad Forensic Med* 2017; *39*(3): 283–286. DOI: 10.5958/0974-0848.2017.00055.0.
17. Patil A, Chaudhari VA, Raskar K, et al. Audit of medical certificate of cause of death at a tertiary care teaching hospital. *J Indian Acad Forensic Med* 2019; *41*(3): 197–200. DOI: 10.5958/0974-0848.2019.00057.5.

18. Raje MG. Evaluation of errors and its etiological relevance with variables associated with death certificate. *J Indian Acad Forensic Med* 2011; *33*(1): 50–56. DOI: 10.1177/0971097320110115.
19. Gupta BD, Trangadia MM, Mehta RA, et al. Death certificate: Ignorance and facts. *J Indian Acad Forensic Med* 2013; *35*(3): 259–261. DOI: 10.1177/0971097320130322.
20. Prakash AK, K S, Charanya S, et al. Analysis of the case records for the accuracy on medical certification of cause of death in a tertiary care hospital. *J Indian Acad Forensic Med* 2023; *45*(4): 361–363. DOI: 10.48165/jiafm.2023.45.4.11.
21. Agarwal SS, Kumar L, Gouda HS, et al. Medical certification of cause of death. *J Indian Acad Forensic Med* 2008; *30*(4): 249–254. DOI: 10.1177/0971097320080419.
22. Keyvanara M, Zardoeigolanbar, S, Karimi S, et al. The quality of death certificates record in the educational and non-educational hospitals in Kermanshah, Iran. *Health Inf Manag 2011*; 8: 23–32.
23. Azim A, Singh P, Bhatia P, et al. Impact of an educational intervention on errors in death certification: An observational study from the intensive care unit of a tertiary care teaching hospital. *J Anaesthesiol Clin Pharmacol* 2014; *30*: 78.
24. Alipour J, Karimi A, Hayavi Haghighi, MH, et al. Death certificate errors in three teaching hospitals of Zahedan, southeast of Iran. *Death Stud* 2022; *46*: 1157–1165.
25. Qaddumi JA, Nazzal Z, Yacoub, A, et al. Physicians' knowledge and practice on death certification in the North West Bank, Palestine: A cross-sectional study. *BMC Health Serv Res* 2018; *18*: 1.
26. Hazard RH, Chowdhury HR, Adair T, et al. The quality of medical death certification of cause of death in hospitals in rural Bangladesh: Impact of introducing the international form of medical certificate of cause of death. *BMC Health Serv Res* 2017; *17*: 1.

Original Research Article

Incidental Finding in Histopathology Report of Unnatural Deaths: A Six-year Retrospective Study

Journal of Indian Academy of Forensic Medicine
47(4) 391–395, 2025

DOI: 10.1177/09710973251409876
journals.sagepub.com/home/iaf
Sage

Mayanglambam Bidyarani Devi[1], Soreingam Ragui A[2], Romen Shinglai[1], Gangmei Angam[1], M Bapin Kumar[1] and Konsam Suken Singh[1]

Abstract

Incidental histopathological findings during medicolegal autopsies provide valuable insights into the underlying health status of individuals who appear clinically healthy during life. Such findings contribute to understanding silent disease burdens in the community. A six-year retrospective study (2016–2021) was conducted at a tertiary care institute in Northeast India, analyzing medicolegal autopsy cases of apparently healthy individuals with no documented chronic illness who died due to unnatural causes. A total of 199 cases with significant incidental histopathological findings were included. Atherosclerosis was the most prevalent incidental finding (41%), followed by pulmonary edema (12%), diffuse alveolar damage (7%), interstitial pneumonitis (6%), and viral hepatitis (5%). The highest frequency of incidental lesions was observed in the 40–60-year age group. Notably, early atherosclerotic changes were identified even in individuals as young as 22 years. Although incidental findings did not contribute to the cause of death, they revealed a substantial burden of asymptomatic pathology in the population. These observations highlight the relevance of autopsy-based surveillance in understanding the epidemiology of silent diseases and their potential public health implications.

Keywords

Histopathological findings, atherosclerosis, incidental findings, unnatural death

Received 10 March 2025; **accepted** 08 December 2025

Introduction

Medicolegal autopsy remains one of the most powerful tools in forensic medicine, enabling the accurate determination of the cause and manner of death while simultaneously providing essential insights into the health profile of the deceased. Although the primary objective of a post-mortem examination is to investigate unnatural or suspicious deaths, it often reveals unsuspected pathological conditions that were clinically silent during life.[1] Individuals who die suddenly due to road traffic accidents, poisoning, falls, electrocution, or other unnatural events are generally presumed to be healthy prior to death. However, post-mortem examination frequently uncovers significant incidental findings that carry substantial epidemiological and clinical relevance.

The collaborative involvement of the Department of Forensic Medicine and the Department of Pathology is critical in this regard. Gross autopsy findings, when correlated with histopathological examination, help differentiate between lesions directly contributing to death and those that represent underlying but unrelated disease processes. Histopathology, therefore, enhances the precision of medicolegal interpretation, supports accurate certification, and prevents misattribution of cause of death.[2] Moreover, these incidental findings shed light on early, asymptomatic, or undiagnosed disease states that may otherwise remain undetected in the living population.

[1]Jawaharlal Nehru Institute of Medical Sciences, Manipur University, Imphal, Manipur, India
[2]Department of Forensic Medicine and Toxicology, Churachandpur Medical College, Churachandpur, Manipur, India

Corresponding author:
Soreingam Ragui A, Department of Forensic Medicine and Toxicology, Churachandpur Medical College, Churachandpur, Manipur 795128, India.
E-mail: raguisoreingam@gmail.com

Understanding such silent pathological changes is important for multiple reasons. First, they provide valuable epidemiological data on the prevalence and age distribution of chronic or progressive diseases such as atherosclerosis, hepatitis, pneumonitis, and cardiomyopathies. Second, they demonstrate the natural progression of diseases that may not have produced symptoms significant enough to seek medical attention. Third, they highlight potential risk factors in specific age groups, especially when early degenerative or inflammatory changes are observed in young individuals. Finally, incidental findings identified during medicolegal autopsies can offer indirect insights into lifestyle, environmental exposures, and public health challenges within a region.[3]

The aim of this six-year retrospective study is to analyze the spectrum and frequency of incidental histopathological findings in individuals with no documented chronic illness who died due to unnatural causes. By systematically reviewing these cases, the study aims to identify patterns of asymptomatic pathology, assess their distribution across demographic groups, and explore their broader implications for public health and preventive medicine.

This study highlights the continued importance of post-mortem examination and histopathology in medicolegal practice, not only for resolving medicolegal questions but also for revealing the hidden burden of disease in the community and contributing meaningfully to population-level health understanding.

Materials and Method

Study Design

This retrospective, descriptive cross-sectional study was conducted from January 2016 to December 2021 in the Department of Forensic Medicine and Toxicology, Jawaharlal Nehru Institute of Medical Sciences, a tertiary care institute in Imphal, Manipur, India. The study analyzed incidental histopathological findings observed during medicolegal autopsies performed within the study period.

Sampling and Selection Criteria

All medicolegal autopsies of unnatural deaths brought to the mortuary during the study period were screened. Cases were included or excluded based on the following criteria:

Inclusion Criteria

Autopsy cases demonstrating significant incidental histopathological findings.

Exclusion Criteria

Cases with documented history of non-communicable diseases (NCDs).

Bodies received in advanced decomposition, where histological interpretation was not feasible.

Sample Size

The sample size for this retrospective descriptive cross-sectional study was calculated using the single proportion formula: $n = Z^2p(1 - p)/d^2$, where Z is the standard normal deviate at 95% confidence (1.96), p is the anticipated proportion of incidental histopathological findings, and d is the absolute precision. In the absence of prior regional data, p was taken as .5 to obtain the maximum sample size, with d set at 0.07. This yielded a minimum required sample size of: $n = (1.96)^2 \times 0.5 \times 0.5 / (0.07)^2 \approx 196$.

During the study period, 199 medicolegal autopsy cases met the inclusion criteria and were available in the records. All eligible cases were included, thereby satisfying and slightl exceeding the minimum required sample size.

Data Analysis

Histopathological findings from the 199 cases were systematically classified into three major organ systems: cardiovascular, respiratory, and hepatobiliary. Each system was further subcategorized into specific pathological entities. A descriptive approach was used to analyze the data.

Statistical Analysis

- Descriptive statistics: Frequency distributions and percentages were calculated to determine the prevalence of each incidental finding.
- Trend analysis: Patterns across the six-year study duration were examined.
- Software: Statistical analysis and data visualization were performed using SPSS (Statistical Package for the Social Sciences), version 25.0, and Microsoft Excel 2019.

Ethical Considerations

The study was based exclusively on secondary data, with no direct human participation and no use of identifiable personal information. The Institutional Ethics Committee approved the study and granted exemption from full review (IEC No. Ac/03/IEC/JNIMS/2018, dated 09/09/2024), as the research utilized anonymized histopathological records from medicolegal autopsies. All ethical principles, data protection measures, and confidentiality standards were strictly adhered to throughout the study.

Results

Between 2016 and 2021, a total of 217 medicolegal autopsies were submitted for histopathological examination. The majority of the study population belonged to the 41–60 years

age group, representing the most prominent demographic segment in the dataset (Table 1). Of the total cases examined, incidental findings were identified in 199 cases, indicating a substantial prevalence of unanticipated pathological conditions detected during post-mortem evaluation.

Among the various histopathological observations, the cardiovascular system emerged as the most frequently affected organ system (Table 2). Within this group, atheromatous changes constituted the predominant incidental microscopic finding, reflecting the widespread presence of atherosclerotic pathology in the study population (Tables 3 and 4A). This highlights the significance of silent cardiovascular disease as a major underlying condition in individuals undergoing medicolegal autopsies.

The respiratory system accounted for the next highest frequency of incidental findings (Table 4B). Key observations included pulmonary edema, diffuse alveolar damage, and interstitial pneumonia, conditions that may be associated with underlying systemic illness, acute physiological stress, or respiratory compromise preceding death.

The hepatobiliary system also revealed notable histopathological alterations (Table 4C). These included early cirrhotic changes and viral hepatitis, suggesting the presence of chronic liver disease and infectious processes that, while not directly responsible for death, may have contributed to overall health deterioration.

Overall, this study provides important insights into the prevalence and spectrum of incidental histopathological findings detected during medicolegal autopsies. The results emphasize the presence of silent or subclinical diseases across major organ systems and underscore the value of post-mortem histopathology in unveiling hidden contributors to morbidity and mortality.

Table 1. Age-wise Distribution.

Age Group	Frequency	%
1–20	18	9
21–40	60	30
41–60	90	45
61–80	31	16
Total	199	100

Table 2. System-wise Distribution of Cases.

System	Frequency	%
Cardiovascular	111	56
Respiratory	65	32
Hepatobiliary	23	12
Total	199	100

Table 3. Top Incidental Histopathological Findings.

Histopathological Findings	Frequency (*n*)	%
Atheromatous changes	81	41
Pulmonary edema	24	12
Diffuse alveolar damage	14	7
Interstitial pneumonitis	12	6
Viral hepatitis	10	5
Others	58	29
Total	199	100

Discussion

This retrospective study was conducted to evaluate histopathological findings in medicolegal autopsies, with a specific focus on identifying previously undiagnosed medical conditions. While similar case-based studies have been reported in India by authors such as Patel SH et al.[4] and Vivek K et al.,[5] the larger sample size and broader scope of the present study offer valuable insight into the silent burden of disease across diverse populations.

Age and Demographic Analysis

Individuals in the 41–60 years age group constituted the most affected demographic, consistent with observations by Arunlatha P et al.[6] (2017) and Jhaji et al.[7] (2013). This age range represents a transitional phase wherein cumulative exposure to lifestyle, environmental, and occupational risk factors begins to manifest clinically. The predominance of incidental findings in this group underscores the need for targeted preventive strategies and early screening programs to mitigate undiagnosed health conditions in middle-aged individuals.

Cardiovascular System Findings

The cardiovascular system was the most commonly affected organ system, with atherosclerosis emerging as the predominant incidental finding. Similar findings have been documented by Arunalatha P et al.,[6] Sulegaon R et al.,[8] Patel S et al.,[9] and Puri A et al.,[10] reflecting the widespread prevalence of subclinical cardiovascular disease. Globally, cardiovascular diseases account for 17.9 million deaths annually, representing 32% of all deaths, with 85% attributed to heart-related conditions.[11] Particularly concerning is the detection of atherosclerotic changes in individuals as young as 22 years, indicating an emerging trend of early onset vascular pathology. These findings call for further investigation to determine the potential link between early atherosclerotic lesions and catastrophic events such as sudden cardiac death in younger age groups, and highlight the pressing need for preventive screening and lifestyle interventions.

Table 4. System-wise Incidental Findings.

A. Cardiovascular System Finding		
Finding	**Frequency (*n*)**	%
Atheromatous Changes	81	72.97
• Aortic atheromatous changes	23	20.7
• Mild atheromatous plaque	17	15.3
• Bilateral atheromatous changes	15	13.5
• Right coronary artery atheromatous plaque	10	9.0
• Left anterior descending (LAD) plaque rupture	8	7.2
• Occlusion of coronary lumen	6	5.4
• Narrowing of coronary lumen	2	1.8
Non-atheromatous Pathologies	30	27.02
• Signs of inflammation	7	6.3
• Features of acute myocardial infarction	7	6.3
• Left and right ventricular hypertrophy	6	5.4
• Old healed myocardial infarct	6	5.4
• Mönckeberg medial sclerosis	1	0.9
• Restrictive cardiomyopathy	1	0.9
• Left ventricular wall rupture	1	0.9
• Atrial fibrosis	1	0.9
Total	111	100
B. Respiratory System Findings		
Finding	**Frequency (*n*)**	%
Pulmonary edema	24	37
Interstitial pneumonitis	12	19
Tubercular lung	4	6
Acute pneumonia	8	12
Lobar pneumonia	3	4
Diffuse alveolar damage	14	22
Total	65	100
C. Hepatobiliary System Findings		
Finding	**Frequency (*n*)**	%
Viral hepatitis	10	43
Early cirrhosis	8	35
Steatosis	4	17
Epithelioid granuloma	1	5
Total	23	100

Respiratory System Findings

Within the respiratory system, pulmonary edema was the most common incidental finding, with a prevalence of 36.9%, significantly higher than the 12.37% to 17% reported by Arunalatha P et al.,[6] Patel S et al.,[9] and Puri A et al.[10] This marked increase may reflect evolving environmental influences, particularly rising air pollution levels, which have become a major public health concern. Interstitial pneumonitis, the second-most prevalent incidental finding at 18.4%, may similarly be associated with deteriorating environmental conditions in the region.[11] Singh et al.[12] and Selvam et al.[13] also highlighted the relationship between respiratory pathology and environmental factors. These observations reinforce the need for stronger public health measures to address air quality, including policy enforcement and community-level awareness initiatives.

Hepatobiliary System Findings

In the hepatobiliary system, viral hepatitis was the most frequent incidental finding, accounting for 43.4% of cases. This high prevalence may be related to silent hepatic infections,

particularly among intravenous drug users (IDUs) in the state.[14] Given the asymptomatic nature of chronic hepatitis and its potential progression to cirrhosis and hepatocellular carcinoma, these findings highlight the importance of rigorous screening and early detection. Public health interventions must also address social vulnerabilities and healthcare gaps that contribute to the spread of viral hepatitis among high-risk populations.

Implications and Way Forward

The findings of this study emphasize the considerable burden of silent disease that often remains undetected during life. The incidental lesions identified in this study highlight the need for proactive, preventive health strategies, including routine screening, lifestyle modification, and early intervention. Moreover, the results draw attention to broader environmental, societal, and systemic determinants of health, calling for coordinated, multisectoral approaches to improving population health.

By correlating incidental findings with existing literature, this study strengthens the link between forensic pathology and public health, underscoring the importance of histopathological evaluation in revealing hidden disease patterns. Future large-scale studies and interdisciplinary collaboration will be essential to further explore these findings and develop effective strategies to address the health challenges identified.

Conclusion

This autopsy-based study demonstrates that, although incidental findings may not contribute directly to the cause of death, they provide valuable insight into the epidemiology of various diseases, including asymptomatic conditions prevalent in the region. Such information is crucial for health policy-makers in planning effective screening and prevention programs. The study also highlights several unexpected and rare incidental findings encountered during medicolegal autopsies.

Histopathological examination of autopsy specimens plays an essential role in refining diagnostic strategies and guiding appropriate clinical management to reduce morbidity and mortality in tertiary care settings. These findings reinforce the importance of regular health check-ups and the adoption of healthy lifestyle practices for all individuals, regardless of their perceived health status.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

The study was based exclusively on secondary data, with no direct human participation and no use of identifiable personal information. The Institutional Ethics Committee approved the study and granted exemption from full review (IEC No. Ac/03/IEC/JNIMS/2018, dated 09/09/2024), as the research utilized anonymized histopathological records from medico-legal autopsies. All ethical principles, data protection measures, and confidentiality standards were strictly adhered to throughout the study.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent

As this is a retrospective, record based study, and all the identifiable information have been de-linked from the study data, we requested and obtained a wavier of informed consent for this study.

ORCID iD

Soreingam Ragui https://orcid.org/0000-0002-4762-5409

References

1. Reddy KSN and Murty OP. *The essentials of forensic medicine and toxicology*. 35th ed. New Delhi: Jaypee Brothers Medical Publishers, 2017, pp. 142–143.
2. Mukherjee JB. *Textbook of forensic medicine toxicology*. 4th ed. Kolkata: Academic Publishers, 2011, p.78.
3. Manjula K, Srinivas Reddy P and Kalyani R. Study of incidental histopathological findings in medico-legal autopsies. *Indian J Forensic Med Pathol* 2019; 12(1): 5–8.
4. Patel SH, Shah MH, Rathod KM, et al. Incidental finding of systemic granulomatous disease in a case of sudden cardiac death: A rare autopsy case report. *J Indian Acad Forensic Med* 2022; 44(2): 92–94.
5. Vivek K, Guatam K, Rajib P, et al. Situs inversus totalis: An incidental finding in a fatal case of road traffic accident. *J Indian Acad Forensic Med* 2020; 42(1): 70–72.
6. Arunalatha P, Sangeetha A and Sumitra Devi NR. Spectrum of histopathological findings in autopsies: Highlighting the interesting and incidental findings. *Int J Curr Med Appl Sci* 2017; 5(2): 61–66.
7. Kaur Jhaji K, Nibhoria S, Sandhu SK, et al. A study of histopathological examination in medico-legal autopsies in Faridkot, Punjab. *Indian J Forensic Med Toxicol* 2013; 7(1): 76–80.
8. Sulegaon R, Kulkarni D and Chuulki S. Medico-legal autopsies: Interesting and incidental findings. *Int J Forensic Sci Pathol* 2013; 3: 156–160.
9. Patel S, Rajalakshmi BR and Manjunath GV. Histopathological findings in autopsies with emphasis on interesting and incidental findings: A pathologist's perspective. *J Clin Diagn Res* 2016; 10(11): 8–12.
10. Puri A, Garg P, Tayal I, et al. Uncommon and fluke pathological discoveries during examination of viscera in postmortem cases: A retrospective study. *J Adv Med Dent Sci Res* 2017; 5(2): 121–123.
11. World Health Organization. *Cardiovascular diseases (CVDs)*. Geneva: World Health Organization, 2021 [cited 2025 Apr 30]. Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-%28cvds%29.
12. Singh N and Singh S. Interstitial lung diseases and air pollution: Narrative review of literature. *J Pulm Ther* 2021; 7(1): 89–100.
13. Selvam V, Thamil Selvi R, Subramaniam PM, et al. Prevalence of common diseases in lungs and liver: A histopathological study. *J Pharm Biomed Sci* 2011; 12(9): 13–15.
14. Biswas S, Ghosh P, Chakraborty D, et al. Variation in injecting drug use behavior across different northeastern states in India. *Indian J Public Health* 2020; 64(5): 71–75.

Original Research Article

Investigating the Impact of Hand Sanitizers on Latent Fingerprints When Used with Metronic Poly Mailers

Journal of Indian Academy of Forensic Medicine
47(4) 396–404, 2025

DOI: 10.1177/09710973251411013
journals.sagepub.com/home/iaf
Sage

Sunisa Aobaom[1], Punika Kongkraisin[2] and Pratthana Phanthong[3]

Abstract

Latent fingerprint analysis remains a cornerstone of forensic identification. With the rise in hand sanitizer use and the growth of online delivery services during the COVID-19 pandemic, concerns have emerged regarding the potential impact of these substances on fingerprint recovery. This study evaluates the effect of four common hand sanitizers (water-based alcohol, gel-based alcohol, Dettol Instant Hand Sanitizer, and a benzalkonium chloride (BAC) non-alcoholic solution) on latent fingerprints deposited on Metronic poly mailers. Additionally, the efficiency of three development techniques—magnetic powder, cyanoacrylate fuming, and a sequential combination of cyanoacrylate fuming followed by magnetic powder—was assessed. Fingerprints from 10 donors were analyzed using the Center for Applied Science and Technology (CAST) grading scale and an Automated Fingerprint Identification System (AFIS). Results revealed that alcohol-based sanitizers significantly diminished fingerprint quality, while the Dettol and BAC formulations paradoxically appeared to enhance ridge clarity. The combined technique (cyanoacrylate fuming and magnetic powder) yielded the highest clarity across most conditions. These findings provide valuable data for forensic protocols when sanitizer contamination is suspected.

Keywords

Latent fingerprint, hand sanitizer, Metronic poly mailer, magnetic powder, cyanoacrylate fuming

Received 27 June 2025; **accepted** 11 December 2025

Introduction

Fingerprint analysis is a fundamental aspect of forensic science, crucial for identifying suspects and exonerating the innocent.[1] Similar to other biological patterns utilized in forensic identification, such as lip prints,[2–3] fingerprints serve as a primary means of establishing identity in criminal investigations. Latent fingerprints, formed from sweat pore secretions, deposit unique chemical residues on surfaces. These secretions consist of a complex mixture of proteins, amino acids, lipids, and other organic compounds.[4]

The COVID-19 pandemic has profoundly impacted daily life, leading to widespread use of hand sanitizers and increased reliance on online delivery services. While alcohol-based sanitizers (60%–95% alcohol) are effective in inactivating viruses,[5–8] concerns have emerged regarding their potential impact on fingerprint recovery. Furthermore, the integrity of latent prints is crucial not only for pattern analysis but also because they can serve as potential sources for touch deoxyribonucleic acid (DNA) profiling, a capability increasingly highlighted in forensic investigations.[9] Recently, benzalkonium chloride (BAC) has emerged as a prominent non-alcoholic substitute, favored for being less irritating than traditional alcohol-based options and serving as an alternative active ingredient during supply shortages.[5,10,11]

In the context of delivery services, Metronic poly mailers have emerged as a popular packaging choice due to their lightweight and cost-effectiveness. These mailers present a non-porous surface, which is generally well-suited for fingerprint detection.[4] However, as they do not absorb residues, latent prints are susceptible to degradation, necessitating

[1]Division of Forensic Science, Department of Medical Technology, Faculty of Allied Health Sciences, Thammasat University, Pathum Thani, Thailand
[2]Microbiology Department, Queen Sirikit National Institute of Child Health, Bangkok, Thailand
[3]Nakhon Sawan Provincial Police Forensic Science, Nakhon Sawan, Thailand

Corresponding author:
Sunisa Aobaom, Division of Forensic Science, Department of Medical Technology, Faculty of Allied Health Sciences, Thammasat University, Rangsit Campus, 99 Moo 18 Phahonyothin Road, Khlong Nueng, Khlong Luang, Pathum Thani 12121, Thailand.
E-mail: Sunisa.aobaom@gmail.com

appropriate detection methods. Two common techniques are magnetic powder and cyanoacrylate fuming. Magnetic powder adheres to moisture and oily components, using a magnetic applicator to minimize ridge damage.[12–14] While various herbal and non-conventional powder formulations have been explored for latent print development on different surfaces,[15] standard magnetic powder remains particularly effective on non-porous surfaces.

Cyanoacrylate fuming utilizes ethyl cyanoacrylate vapor, which polymerizes on fingerprint residues to form a white deposit. While effective on non-porous surfaces, it often requires post-treatment (e.g., magnetic powder or fluorescent dye) to enhance contrast on light-colored backgrounds.[16–18] Previous studies indicate that alcohol-based sanitizers may not significantly affect print clarity, whereas non-alcoholic variants might enhance visibility with certain chemical treatments.[19] Additionally, sanitizers have shown varied effects on digital fingerprint scanners.[20]

Building upon this research, the present study investigates the impact of four hand sanitizers (water-based alcohol, gel alcohol, Dettol Instant, and a BAC solution) on latent fingerprints deposited on Metronic poly mailers. The aim is to assess the effectiveness of enhancement techniques and identify the optimal approach for detecting latent fingerprints on this packaging material when exposed to sanitizer residues.

Materials and Methods

Sample Preparation

Types of Hand Sanitizers and Materials

Four types of hand sanitizers were chosen for this research: Water-based alcohol hand sanitizer (W), gel-based alcohol hand sanitizer (G), BAC non-alcohol hand sanitizer (B) (Besuto Twelve, Thailand), and Dettol Instant Hand Sanitizer (D) (Dettol, Thailand) (Table 1). These were selected for their ease of purchase and common availability. A white Metronic poly mailer (two layers of LDPE, inside matte black and outside glossy white, thickness 100 microns) was chosen to represent a typical non-porous delivery service package.

Preparation of Latent Fingerprints on Metronic Poly Mailers

Ten donors (five males, five females; aged >18 years; no dermatitis or scars) participated in the study. A standardized protocol was established for all groups. First, each donor washed their hands with soap, air-dried them, and subsequently "loaded" their right index fingers by touching them to their necks (a sebaceous-rich area) for 10 seconds. Following this baseline preparation, donors in the experimental groups applied one squirt (approximately 1 mL) of one of four hand sanitizer types: Water-based alcohol, gel-based alcohol, BAC (non-alcohol), and Dettol Instant. The sanitizer was rubbed thoroughly over the entire hand, including fingertips, until fully evaporated (approximately 15–30 seconds). In contrast, donors in the control group (C) omitted this application step and proceeded directly from the baseline protocol to the deposition phase.

Immediately following their assigned procedure (with or without sanitizer), all donors deposited triplicate fingerprints onto designated 5 × 5 cm squares of a white Metronic poly mailer. The deposition process was performed in triplicate (three repetitions) for each donor to ensure consistency. A medium deposition pressure (300–700 g) was applied, as verified by a digital scale. All samples were then stored in darkness at room temperature for a minimum of 24 hours before development to simulate real-world conditions.

Preparation of Reference Minutiae from Donors by Black Ink

After depositing all fingerprints treated with hand sanitizer, the donors washed their hands with soap and allowed them to air dry completely. Subsequently, each donor impressed their right index finger on a black ink pad (Policemate, Japan) until the entire fingerprint area was evenly coated with ink. The inked fingertips were then impressed onto 80-g white paper to create a reference print set for the PrintQuest® Automated Fingerprint Identification System (AFIS) (Edison, USA) (Table 2).

Latent Fingerprint Enhancement, Photography, and AFIS Analysis

Samples were analyzed using three fingerprint enhancement techniques: Magnetic powder (dust), cyanoacrylate fuming (cyano), and a combination of cyanoacrylate fuming followed

Table 1. Composition of Four Hand Sanitizer Products According to Their Package Inserts.

Water-based Alcohol Hand Sanitizer (W)	Gel-based Alcohol Hand Sanitizer	Benzalkonium Chloride Non-alcohol Hand Sanitizer (B)	Dettol Instant Hand Sanitizer (D)
• Water • Ethyl Alcohol 70% v/v	• Alcohol 95% • Propylene glycol • Purified water • Carbopol • Triethanolamine	• Benzalkonium chloride • Green tea extract • Grape seed extract • Cucumber extract • Menthol • Hydroxyethyl cellulose • Polyvinylpyrrolidone • Water	• Alcohol denatured • Water • Propylene glycol • Tetrahydroxypropyl Ethylenediamine • Aloe barbadensis • Leaf juice • Fragrance

Table 2. Reference Minutiae from 10 Donors (F = Female and M = Male).

Doner	Minutiae (Points)
F1	29
F2	53
F3	46
F4	41
F5	47
M1	48
M2	37
M3	41
M4	40
M5	54

by magnetic powder (CD). For both the cyanoacrylate fuming (cyano) and the combined technique (CD), samples were treated with 1 g of superglue (Diago, Thailand), which contains 99.5% ethyl cyanoacrylate, comparable to commercial fingerprint fuming glue.[21] The samples were placed in a cyanoacrylate fuming chamber (Sirchie: CA48T) for a fuming process that lasted 40 minutes. For the combined technique (CD), after the samples were fumed, magnetic powder (Hangzhou, China) was applied to the prints to further enhance the visualization of the latent fingerprints.

All fingerprints were photographed in a laboratory using a Canon PowerShot G7X Mark II camera with a 20.1-megapixel resolution, f/4 aperture, 1/125 s shutter speed, and ISO 400. The photographs were taken under ambient laboratory lighting and subsequently analyzed using AFIS to detect the minutiae.

Quality Assessment

The visual quality of developed fingerprints was evaluated using the Center for Applied Science and Technology (CAST) grading scale (Table 3).[22]

Statistical Analysis

The percentage of minutiae was calculated using the formula: (Minutiae of each factor × 100) /Reference minutiae from each donor. Before analysis, the assumptions for parametric testing were evaluated. Data normality was assessed using histograms and frequency curves. Due to non-normal distribution, the non-parametric Kruskal–Wallis H test was used to compare differences across groups. All analyses were performed using GraphPad Prism 8.3.0.

Result

The Effect of Hand Sanitizers

The fingerprint enhancement results for the four different hand sanitizers using the magnetic powder (dust) technique

Table 3. The CAST Grading Scale.[18]

Grade	Detail Visualized
0	No development
1	Signs of contact but <1/3 of mark with continuous ridges
2	1/3–2/3 of mark with continuous ridges
3	>2/3 of mark with continuous ridges, but not quite a perfect mark
4	Full development–whole mark clear with continuous ridges

are illustrated in Figure 1. Beginning with the control sample (C-dust), which was not treated with any alcohol-based sanitizer, it displays clear ridge details with minimal background interference, indicating effective enhancement. In contrast, the water alcohol hand sanitizer (W-dust) reveals partial ridge clarity, although it presents some background noise and granulation. This suggests that water-based sanitizers may cause slight interference when magnetic powder is applied. Similarly, the gel alcohol hand sanitizer (G-dust) produces moderate ridge definition; however, gaps in ridge detail and background granulation indicate that gel-based sanitizers may leave residues that hinder the effectiveness of the magnetic powder. On the other hand, the BAC non-alcohol hand sanitizer (B-dust) exhibits good ridge detail with relatively minimal background interference, implying that this type of sanitizer may be less disruptive to the enhancement process compared to alcohol-based sanitizers. Furthermore, the fingerprint treated with Dettol Instant Hand Sanitizer (D-dust) shows clear ridge details comparable to the control sample, exhibiting sharp and well-defined ridges with minimal background noise.

The fingerprint enhancement results using two different techniques, cyanoacrylate fuming (cyano) on the left side of each fingerprint and a combination of cyanoacrylate fuming followed by magnetic powder (CD) on the right side, are compared across all samples (Figure 2). In the control sample (C), the cyanoacrylate fuming technique produces faint ridge details with some background noise, offering limited clarity, whereas the combined technique (CD) significantly improves ridge definition and minimizes background interference, demonstrating the effectiveness of using both techniques together. Similarly, for the water alcohol hand sanitizer sample (W), cyanoacrylate fuming yields moderately visible ridges with some blurring, while the CD technique provides sharper ridge details and reduces background noise, suggesting enhanced visibility even with alcohol-based sanitizers. This trend continues with the gel alcohol hand sanitizer sample (G), where cyanoacrylate fuming resulted in largely non-visible ridge patterns, but the CD technique still generated clearer, more defined ridges, indicating that the combined approach mitigates interference from gel-based sanitizers. In the BAC non-alcohol hand sanitizer sample (B), the cyanoacrylate fuming

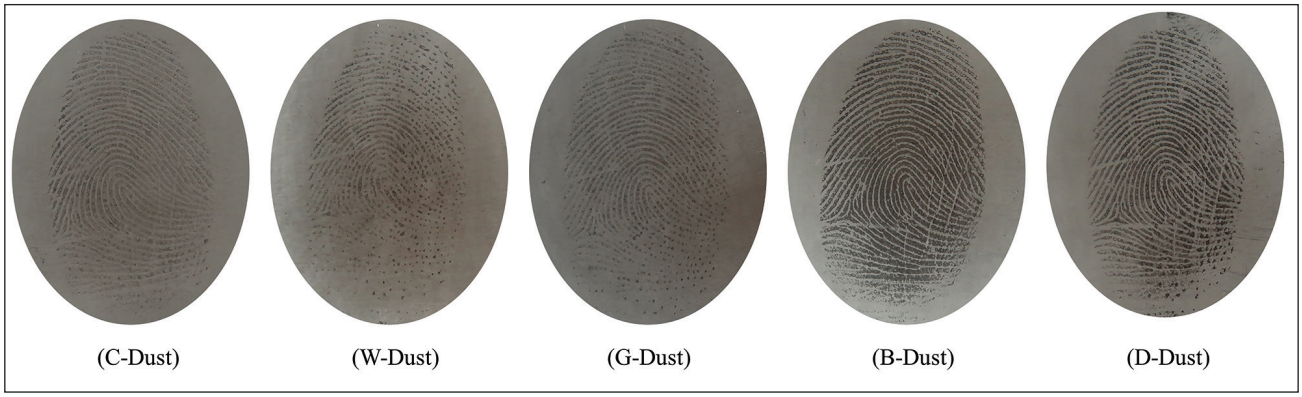

Figure 1. Fingerprint Enhancement Results Using Magnetic Powder (Dust) Following Treatment with Various Hand Sanitizers (C: Control, W: Water Alcohol Hand Sanitizer, G: Gel Alcohol Hand Sanitizer, B: Benzalkonium Chloride Non-alcohol Hand Sanitizer, and D: Dettol Instant Hand Sanitizer).

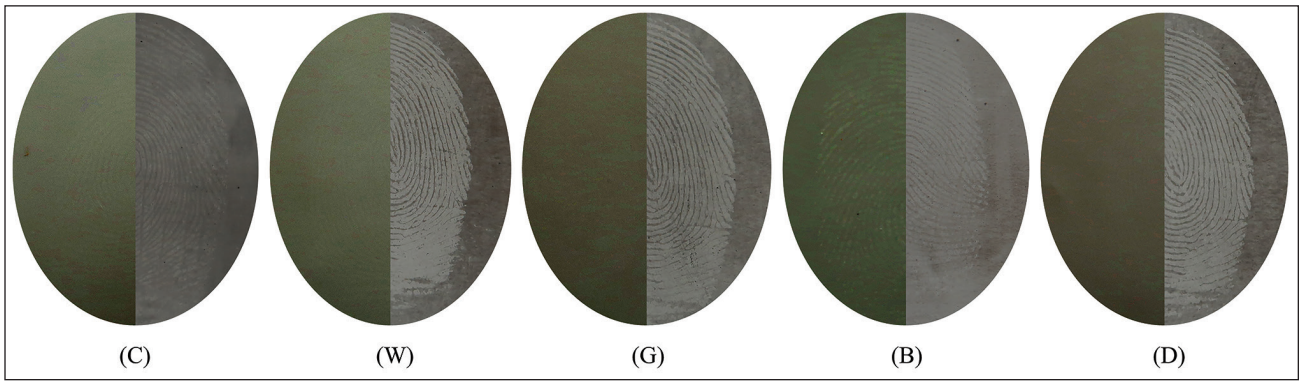

Figure 2. Fingerprint Enhancement Results Using Two Different Techniques—Cyanoacrylate Fuming (Cyano) on the Left Side and a Combination of Cyanoacrylate Fuming Followed by Magnetic Powder (CD) on the Right Side (C: Control, W: Water-based Alcohol Hand Sanitizer, G: Gel-based Alcohol Hand Sanitizer, B: Benzalkonium Chloride Non-alcohol Hand Sanitizer, D: Dettol Instant Hand Sanitizer).

method delivers reasonably clear ridge details, although some background noise is present, while the CD technique further refines the clarity and reduces interference, offering a more defined fingerprint pattern. Final, in the Dettol Instant Hand Sanitizer sample (D), while cyanoacrylate fuming produces moderate clarity, the CD technique leads to a substantial improvement in ridge sharpness and detail.

Latent fingerprints developed using different techniques (Figure 3)—cyanoacrylate fuming (A) and the combination of cyanoacrylate fuming with magnetic powder (CD) (B)—were subsequently analyzed by the AFIS. While the raw photographs of the developed prints (A1 and B1) contained background noise and unclear details, processing through AFIS (A2 and B2) automatically enhanced image clarity and emphasized minutiae points. AFIS processing reduced noise and sharpened the ridge patterns, which allowed for better identification of the latent fingerprints. For the latent fingerprint developed with cyanoacrylate fuming (A2), although some background noise remained, AFIS effectively enhanced the image, making several minutiae points visible. In comparison, the fingerprint developed using the CD technique (B2) exhibited even greater clarity after AFIS processing, with significantly reduced noise and more clearly defined minutiae points.

The Quality of Latent Fingerprints

The quality of the developed fingerprints was evaluated using the CAST grading scale (Table 3), with the results for each hand sanitizer presented in Figures 4 and 5. The CAST grading scale evaluates fingerprint quality by assigning grades from zero (poor quality, unsuitable for identification) to four (excellent quality, suitable for identification). The results (Figure 5) demonstrate the varying effectiveness of fingerprint development techniques across different hand sanitizers compared to the control (C). The analysis focuses on latent fingerprint quality, highlighting the differences in outcomes when using magnetic powder (dust), cyanoacrylate fuming (cyano), and a combination of cyanoacrylate fuming followed by magnetic powder (CD).

For fingerprints enhanced with magnetic powder (Dust) (Figure 5A), the control sample (C-dust) showed a reasonably even distribution across the quality spectrum, with 30% of latent fingerprints achieving grade two and another 30% in grade three. However, only 16.67% reached the highest quality (grade 4), reflecting moderate effectiveness. When hand sanitizers were introduced, significant differences arose. For instance, fingerprints treated with water alcohol (W-dust) and gel alcohol (G-dust) showed a substantial reduction in quality. For both sanitizers, the majority of fingerprints clustered around grades two and three, with minimal representation in grade four (13.33%). These results suggest that alcohol-based hand sanitizers hinder the magnetic powder's ability to develop latent fingerprints effectively. Conversely, BAC (B-dust) resulted in a higher proportion of high-quality fingerprints, with 56.67% of latent prints achieving grade four. This indicates that non-alcohol-based sanitizers have less detrimental impact on the magnetic powder technique.

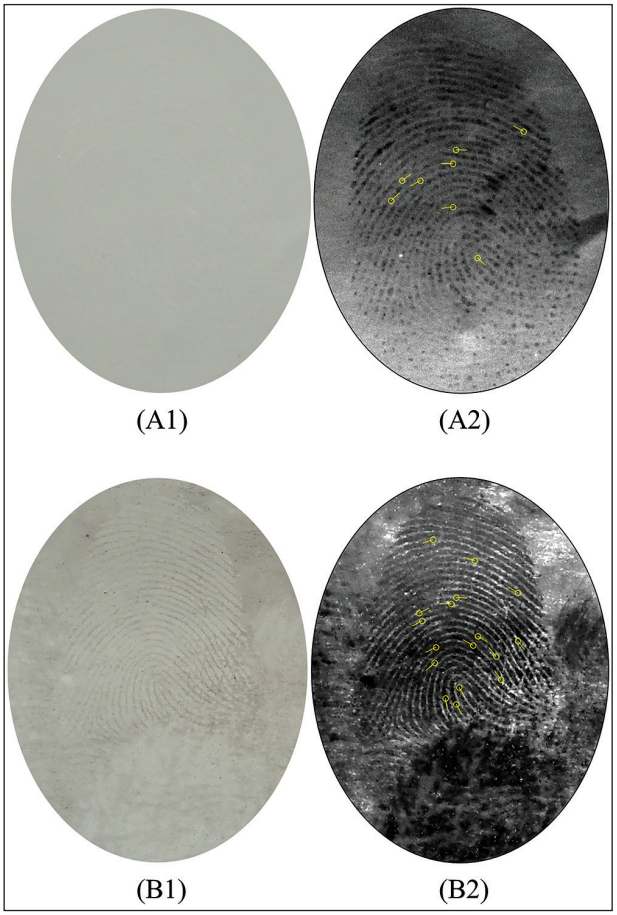

Figure 3. Latent Fingerprints After Being Analyzed by AFIS. Legend: A = Latent Fingerprint Developed by Cyano; B = Latent Fingerprint Developed by CD, 1 = Raw Photograph Before Processing, 2 = Image After Analysis by AFIS.

Enhancement with cyanoacrylate fuming (Figure 5B) demonstrated moderate effectiveness for the control sample (C-cyano), with a significant portion of the fingerprints (56.67%) achieving grade two, but only 10% reaching grade four. When sanitizers were introduced, water alcohol (W-cyano) drastically reduced fingerprint quality, with 70% of prints falling into grade two and only 6.67% in grade four. Gel alcohol (G-cyano) showed similar results but with a slightly higher distribution of prints in grades three and four (23.33% and 10%, respectively). The use of BAC (B-cyano), however, allowed better results, with 66.67% fingerprints in grade three and a small portion (3.33%) in grade four. This indicates that while cyanoacrylate fuming is moderately effective, its performance is notably impacted by alcohol-based sanitizers, although less so with non-alcohol-based alternatives.

However, the combination technique (CD) (Figure 5C) proved to be the most effective across all samples, consistently producing higher quality fingerprints. For the control sample (C-CD), the combined technique significantly improved fingerprint quality, with 43.33% of fingerprints in grade three and 10% in grade four. When alcohol-based sanitizers were used, such as water alcohol (W-CD) and gel alcohol (G-CD), the CD technique still demonstrated superior performance compared to the individual dust or cyano methods. In the W-CD sample, 53.33% of fingerprints were in grade three, and 13.33% reached grade four. Similarly, G-CD results showed a strong distribution of prints in grades three

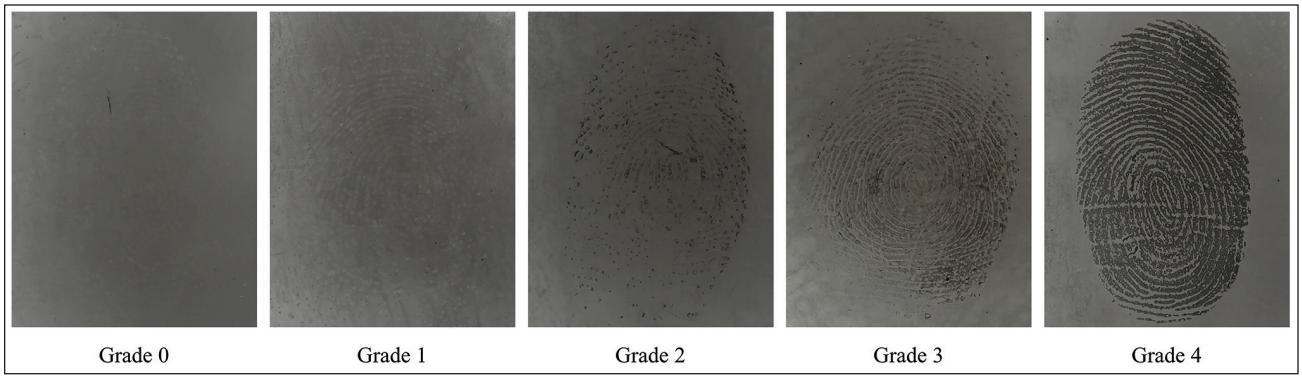

Figure 4. Quality Distribution of Latent Fingerprints According to the CAST Grading Scale.

Figure 5. Summary of CAST Grading Scale Results for Each Hand Sanitizer, Broken Down by Development Technique: (A) = Latent Fingerprints Developed by Magnetic Powder (Dust); (B) = Latent Fingerprints Developed by Cyanoacrylate Fuming (Cyano); (C) = Latent Fingerprints Developed by a Combination of Cyanoacrylate Fuming Followed by Magnetic Powder (CD). (Abbreviations: C = Control, W = Water-based Alcohol Hand Sanitizer, G = Gel-based Alcohol Hand Sanitizer, B = Benzalkonium Chloride Non-alcohol Hand Sanitizer, D = Dettol Instant Hand Sanitizer).

and four, with 46.67% and 10%, respectively. The results for BAC (B-CD) further emphasized the effectiveness of the CD technique, with 43.33% fingerprints in grade three and 36.67% in grade four, marking this combination technique as the most reliable and least affected by sanitizers.

Ranking of Alcohol-based Fingerprint Detection Techniques

A Kruskal–Wallis test comparing the minutiae counts for each technique across all sanitizer types (Table 4) revealed statistically significant differences.

Specifically, the cyanoacrylate fuming (cyano) technique showed a significant negative impact from most sanitizers ($p < .05$) when compared to the control. The mean minutiae counts for the sanitizer-treated samples (W, G, B, D) when developed with cyano were exceptionally low (ranging from 0.00 to 0.58), in stark contrast to the control (C-Cyano), which had a mean count of approximately 12.67.

Conversely, statistically significant differences ($p < .05$) were also found for the magnetic powder (dust) technique, but these indicated an improvement. Fingerprints treated with BAC (B-dust) and Dettol (D-dust) yielded mean minutiae counts (27.67 and 62.89, respectively) that were significantly higher than the control (C-Dust).

Ranking the most suitable techniques for use with each hand sanitizer, it was found that for water alcohol (W) and gel alcohol (G), the best technique was cyanoacrylate fuming combined with magnetic powder (CD), followed by magnetic powder (dust). For BAC (B) and Dettol (D), the best technique was magnetic powder (dust), followed by cyanoacrylate fuming combined with magnetic powder (CD). However, when these top two techniques were compared directly for these samples, no statistically significant differences ($p > .05$) were found. These two techniques were therefore selected for use in the mockup study phase.

Discussion

This study investigated the effects of four hand sanitizers on latent fingerprint quality on Metronic poly mailers using three visualization techniques. As described by Yamashita and French, the adhesion of magnetic powder primarily depends on moisture from skin oils, sweat, and sanitizer residues.[4] While various herbal and non-conventional powder formulations have been explored for latent print development on different surfaces,[15] our study confirms that standard magnetic powder remains highly efficient on white Metronic poly mailers due to the excellent contrast provided by the background.

Cyanoacrylate fuming alone (cyano) showed limitations on the white substrate due to the lack of contrast from the white polymer. However, the sequential CD technique (fuming followed by magnetic powder) effectively compensated for this, significantly enhancing ridge definition.[16] Consequently, techniques utilizing magnetic powder (dust and CD) demonstrated superior performance for fingerprint recovery in this experiment.

Table 4. Descriptive Statistical Results and Mean Rank Comparison of Development Techniques. Alues Represent the Percentage of Minutiae Recovered from Hand Sanitizer-treated Samples, Calculated Relative to the Reference Minutiae from Each Donor. C = Control Group (Samples not Treated with Hand Sanitizer) (*$p \le .05$, **$p \le .01$, ***$p \le .001$).

Hand Sanitizer	Techniques	*N*	Min(%)	Max(%)	Mean(%)	Mean Rank	Ranking	*p* Value	*p* Value Control-techniques	*p* Value Dust-CD
W	Control	90	0.00	95.65	12.67	97.16		.003**		.999
	Dust	30	0.00	28.26	6.90	92.92	2		.999	
	Cyano	30	0.00	4.35	0.36	63.22	3		.002**	
	CD	30	0.00	66.04	19.51	95.40	1		.999	
G	Control	90	0.00	95.65	12.67	93.66		.000***		.999
	Dust	30	0.00	53.66	13.50	103.7	2		.999	
	Cyano	30	0.00	0.00	0.00	54.50	3		.001***	
	CD	30	0.00	69.81	12.34	103.9	1		.999	
B	Control	90	0.00	95.65	12.67	78.99		.000***		.002**
	Dust	30	2.13	100.00	62.89	151.7	1		.000***	
	Cyano	30	0.00	17.39	0.58	47.98	3		.015*	
	CD	30	0.00	83.02	27.38	106.3	2		.047*	
D	Control	90	0.00	95.65	12.67	88.78		.000***		.999
	Dust	30	0.00	82.61	27.67	114.1	1		.064	
	Cyano	30	0.00	0.00	0.00	52.00	3		.001**	
	CD	30	0.00	73.58	19.01	110.6	2		.165	

Analyzing the chemical effects, alcohol-based sanitizers (W and G) resulted in latent prints with fewer visible minutiae compared to non-alcohol or control groups. The cleansing properties of alcohol likely contribute to this by stripping the skin of natural moisture and oils, which are critical for latent fingerprint formation and development.[5,23] The presence of propylene glycol in the gel sanitizer (G) acted as a humectant, retaining some moisture and mitigating the adverse effects of alcohol.[5]

Conversely, the non-alcohol-based sanitizer (B) and the alcohol-based Dettol Instant (D) enhanced fingerprint clarity. This suggests that moisturizing additives influence quality more than the alcohol base itself. The cucumber extract in sanitizer (B)[24] and aloe vera in sanitizer (D)[10] help regulate sebum and hydrate the skin. These properties facilitate better residue deposition, allowing for effective recovery using dust and CD techniques.

Alcohol-based sanitizers degraded fingerprint quality when using the dust technique by removing the moisture necessary for powder adhesion.[5] Similarly, the cyano technique was severely affected by the moisture-stripping effect. However, the sequential CD technique proved robust, yielding high-quality prints even when the initial polymerization was weak. This aligns with prior research indicating that alcohol-based sanitizers reduce latent print clarity on digital scanners.[20] Overall, formulations containing moisturizing additives (B and D) performed best, underscoring the critical impact of skin hydration on latent print visibility.

Conclusion

This study highlights the importance of selecting appropriate fingerprint development techniques based on the type of hand sanitizer present. Magnetic powder and cyanoacrylate fuming combined with magnetic powder (CD method) proved most effective on white Metronic poly mailers, especially when moisturizing additives were present in the sanitizer formulation. Formulations containing moisturizing agents, such as the cucumber extract in the BAC solution and the aloe vera in the Dettol sanitizer, helped preserve latent prints by maintaining moisture and mimicking natural skin secretions. These findings offer practical guidance for forensic professionals in adapting effective development methods to potential hand sanitizer residues at crime scenes.

Limitations

It is important to acknowledge some limitations of this study. The sample size of donors was relatively small, and the materials used (Metronic poly mailers) might not represent the diversity of surfaces encountered in real-world forensic scenarios. Furthermore, it must be acknowledged that real-world conditions introduce significant variability from uncontrolled environmental factors, such as temperature and humidity, which can influence the persistence and subsequent development of latent prints. Additionally, this study focused on fingerprint development techniques and did not explore the impact of hand sanitizers on fingerprint identification accuracy using AFISs.

Future research could address these limitations by expanding the study to include a larger and more diverse sample population and testing fingerprint recovery on various surfaces commonly found at crime scenes. This should also include investigations into the effects of diverse environmental stressors (e.g., temperature cycles, UV exposure, and varying humidity) on the efficacy of the development techniques. Furthermore, investigating the compatibility of different hand sanitizers with AFIS technology would provide valuable insights for forensic practitioners.

Acknowledgements

The authors would like to thank Nakhon Sawan Provincial Police Forensic Science for their support in fingerprint analysis.

Data Availability Statement

Data available on request from the authors

Declarations

We certify that the information given is true and complete to the best of our knowledge. We confirmed that the manuscript has been read and approved by all named authors. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval and Informed Consent

Study protocols were approved by the Human Research Ethics Committee of Thammasat University (Science), Thailand, in accordance with the compliance with the Declaration of Helsinki, the Belmont Report, the council for international organizations of medical sciences (CIOMS) guidelines, and the international practice (ICH-GCP) (COA No. 135/2564).

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Sunisa Aobaom https://orcid.org/0000-0001-5660-3407
Punika Kongkraisin https://orcid.org/0009-0004-5937-2041
Pratthana Phanthong https://orcid.org/0009-0008-1750-827X

References

1. Yamini R, Barman D and Ganesh R. A study on the pattern of fingerprint ridges for determination of gender in an ethnic Tamil population in Thiruporur Taluk of Tamilnadu. *J Indian Acad Forensic Med* 2023; 45(2): 171–174.
2. Murkey PN, Sutay S, Khandekar IL, et al. Cheiloscopy-everything in nature is unique. *J Indian Acad Forensic Med* 2008; 30(3): 194–197.
3. Srilekha N, Anuradha A, Vijay Srinivas G, et al. A study of efficacy of lip prints as an identification tool among the people of Karnataka in India. *J Indian Acad Forensic Med* 2011; 33(3): 200–202.
4. Yamashita B and French M. Chapter 7: Latent print development. In: *The fingerprint sourcebook*. Washington, DC: National Institute of Justice, 2010. pp.155–222.
5. Jing JLJ, Pei Yi T, Bose RJC, et al. Hand sanitizers: A review on formulation aspects, adverse effects, and regulations. *Int J Environ Res Public Health* 2020; 17(9): 3326.
6. Munoz-Figueroa GP and Ojo O. The effectiveness of alcohol-based gel for hand sanitising in infection control. *Br J Nurs* 2018; 27(7): 382–388.
7. Mal DK and Mukherjee B. Educational motivation and legislative approaches for safe and effective hand washes and hand rubs in hand health care during COVID-19 pandemic. *Asia Pac J Public Health* 2020; 32(8): 495–496.
8. Neufeld M, Lachenmeier DW, Ferreira-Borges C, et al. Is alcohol an "Essential Good" during COVID-19? Yes, but only as a disinfectant! *Alcohol Clin Exp Res* 2020; 44(9): 1906–1909.
9. Sinha S, Yadav B and Singh Bumbrah G. Potential utility of touch DNA in forensic investigations. *J Indian Acad Forensic Med* 2021; 43(2): 180–184.
10. Bondurant S, McKinney T, Bondurant L, et al. Evaluation of a benzalkonium chloride hand sanitizer in reducing transient staphylococcus aureus bacterial skin contamination in health care workers. *Am J Infect Control* 2020; 48(5): 522–526.
11. Moadab A, Rupley KF and Wadhams P. Effectiveness of a non-rinse, alcohol-free antiseptic hand wash. *J Am Podiatr Med Assoc* 2001; 91(6): 288–293.
12. Sodhi GS and Kaur J. Powder method for detecting latent fingerprints: A review. *Forensic Sci Int* 2001; 120(3): 172–176.
13. Wilshire B. Advances in fingerprint detection. *Endeavour* 1996; 20(1): 12–15.
14. Thonglon T and Chaikum N. Magnetic fingerprint powder from a mineral indigenous to Thailand. *J Forensic Sci* 2010; 55(5): 1343–1346.
15. Kaur R and Kaur H. Ashtagandha powder: A herbal formulation for deciphering latent fingerprints. *J Indian Acad Forensic Med* 2017; 39(2): 136–140.
16. Bumbrah GS. Cyanoacrylate fuming method for detection of latent fingermarks: A review. *Egypt J Forensic Sci* 2017; 7(1): 4.
17. Wargacki SP, Lewis LA and Dadmun MD. Understanding the chemistry of the development of latent fingerprints by superglue fuming. *J Forensic Sci* 2007; 52(5): 1057–1062.
18. Miller MT. *Crime scene investigation laboratory manual*. New York: Academic Press, 2018.
19. Chadwick S, Neskoski M, Spindler X, et al. Effect of hand sanitizer on the performance of fingermark detection techniques. *Forensic Sci Int* 2017; 273: 153–160.
20. Kumari V, Thakar MK, Mondal B, et al. Effects of oils, lotions, hand sanitizers, and mehendi on fingerprints captured through digital fingerprint scanner. *Egypt J Forensic Sci* 2021; 11(1): 1–7.
21. Phanthong P, Praihirunkit P, Jirasirisuk S, et al. Comparison of general cyanoacrylate and Sirchie cyanoacrylate for latent fingerprint on non-porous surfaces by cyanosafe fuming chamber with Airsafe controller. *J Appl Sci* 2021; 20(1): 104–117.
22. International Fingerprint Research Group. Guidelines for the assessment of fingermark detection techniques. *J Forensic Identif* 2014; 64(2): 174–200.
23. Park EJ and Hong S. Development of latent fingerprints contaminated with ethanol on paper surfaces. *Anal Sci Technol* 2019; 32(3): 105–112.
24. Akhtar N, Mehmood A, Khan BA, et al. Exploring cucumber extract for skin rejuvenation. *Afr J Biotechnol* 2011; 10(7): 1206–1216.

Original Research Article

A Comparative Study on Different Machine Learning Algorithms to Explore Sexual Dimorphism in Cephalometric Measurements of North Indian Population

Journal of Indian Academy of Forensic Medicine
47(4) 405–413, 2025

DOI: 10.1177/09710973251405019
journals.sagepub.com/home/iaf
Sage

Arunima Dutta[1] and Vineeta Saini[1]

Abstract

Sex estimation from skeletal remains is an important component of personal identification in forensic anthropology. The different rates of skeletal growth and development pertaining to age, ethnicity and sex form the basis of such identification. The present study has been conducted on the contemporary North Indian Haryanvi population to ascertain the cephalometric measurements and the best machine learning algorithm to study sexual dimorphism. A cross-sectional study was conducted on 200 individuals (M: 100: F:100) aged between 18 and 40 years and 12 cephalometric measurements were obtained using spreading and sliding callipers. Statistical analysis was done using Statistical Package for Social Science (SPSS) version 21.00. All 12 variables showed sexual dimorphism and the sexing accuracy ranged between 62% and 93.5% in univariate analysis. Bizygomatic breadth and bi-gonial width (BiGoW) showed an accuracy of 99% in multivariate analysis. The receiver operating curve (ROC) analysis also depicted BiGoW to have the highest area under the curve (AUC) (1.00) and sexing accuracy of 95.5%. Principal component analysis (PCA) also revealed a similar result with BiGoW, nasal height (NH) and ZyBr having the highest communalities. However, it was concluded that discriminant function analysis (DFA) and ROC analysis showed more promising results in studying sexing accuracy as compared to PCA.

Keywords

Sexual dimorphism, cephalometry, forensic anthropology, discriminant function analysis (DFA), receiver operating curve (ROC) analysis, principal component analysis (PCA)

Received 18 March 2025; **accepted** 20 November 2025

Introduction

Sex estimation is one of the major parameters which help in personal identification from skeletal remains. Furthermore, in cases of mass disasters, charred, mutilated and highly decomposed skeletal remains, identification pose a difficult task for the forensic anthropologists.[1,2] Hence, a systematic approach to determine sex from the morphometric differences of the skeleton is important. Modern humans are found to exhibit a lower level of sexual dimorphism as compared to other primates.[3] Sexual dimorphism in the skull is mostly attributed to a larger size in males as compared to females due to an extended growth period in males during puberty, effects of androgens leading to higher bone deposition in the craniofacial region and increased masticatory forces exerted on the masseter muscles. Most of the sexual differences in the skull are related to physiological and functional features such as muscle mass, volume of oxygen intake, metabolic system and bone development.[4] Cephalometric measurements have also shown statistically significant results in establishing sexual dimorphism among various populations.[5–9] The discriminant functions developed are individual to each population. However, a rise in immigration and population inter-mixing is one of the most important genetic factors, along with other epigenetic factors, that have prompted the development of new and updated cephalometric sexual discriminant formulas.[10,11] With the inclusion of advanced imaging tools such as computed tomography (CT), cone-based CT, magnetic resonance imaging (MRI) and digital radiography, the accuracy of analysis has increased, but the expense and trained personnel can be challenging.[12] Further,

[1]Department of Forensic Science, School of Basic and Applied Science, SGT University, Gurugram, Haryana, India

Corresponding author:
Vineeta Saini, Department of Forensic Science, School of Basic and Applied Science, SGT University, Gurugram, Haryana 122505, India.
E-mail: vineeta_sbas@sgtuniversity.org

machine learning algorithms have also shown promising results while analysing huge volumes of data.[13] Therefore, the present study aims to provide the updated discriminant functions of cephalometric variables for the contemporary North Indian Haryanvi population and compare different machine learning techniques to ascertain the best tool for observing sexual dimorphism among the same.

Material and Methodology

A total of 200 (100 M/100 F) Haryanvi adults aged between 18 and 40 years were included in the study. Informed consent with the approval of the Institutional Ethics Committee in both English and Hindi languages was obtained from all the participants. The inclusion criteria were: (a) Participants belonging to the Haryanvi origin and (b) participants who gave their consent for the study. The exclusion criteria were: (a) Any participant with traumatic or congenital deformities of the head or face and (b) any transgender individual belonging to Haryana.

The participants were asked to sit with their backs straight and feet touching the ground in the Frankfurt Horizontal Plane while taking the measurements. Digital vernier callipers and spreading callipers were used to obtain the measurements. After the measurements were made, all the data were analysed statistically using Statistical Package for Social Science (SPSS) version 21.00. The following frequently used measurements were obtained by the first author at two different time intervals to avoid intra-observer error: Maximum head length (MxHL), maximum head breadth (MxHBr), bi-gonial width (BiGoW), minimum frontal width (MnFW), zygomatic breadth (ZyBr), physiognomic facial height (PhyFH), morphological facial height (MorFH), nasal length (NL), nasal breadth (NBr), nasal height (NH), maximum orbital width (MxOW) and minimum orbital width (MnOW).

Statistical Analysis

Descriptive statistics with the independent *t*-test were performed using IBM SPSS version 21.0. A *t*-test measures the variation between two groups. The sexual dimorphism index (SDI) has been calculated for all the variables. A paired *t*-test has also been done to evaluate the intra-observer error. Stepwise discriminant analysis, univariate and multivariate direct discriminant function analysis (DFA) were also performed to obtain the highest separation between the sexes. The receiver operating curve (ROC) analysis has been used to identify the cut-off points for each variable. These points were determined by analysing the optimum sensitivity (true positive rate) and 1-specificity (true negative rate) values, which are closest to the area under the curve (AUC) for each variable. Principal component analysis (PCA), discovered by Karl Pearson in 1901, is a statistical tool that is used to explore the interrelationships among variables. The loading of the variables on PC1, PC2 and PC3 has been used to distinguish between both sexes.

Results

Table 1 shows the descriptive statistics, including the mean, standard deviation, *t* value, *p* value, SDI and sexing accuracy ranging from 62% to 93.5% after cross-validating the results. All the variables have shown significantly larger dimensions in males ($p < .05$).

Table 2 depicts the results of the paired *t*-test, which has been used to determine the extent of intra-observer error. The correlation values depict a strong correlation between the first and second measurements. The *p* value also exhibits a non-significant difference between the measurements taken at two different times.

Table 1. Descriptive Statistics of the North Indian Population.

Variable (in cm)	Male (n = 100) Mean ± *SD*	Female (n = 100) Mean ± *SD*	*t* Value	*p* Value	SDI	Sexing Accuracy (%)
MxHL	18.38 ± 0.49	17.06 ± 0.57	17.22	<.001	7.73	87
MxHBr	13.63 ± 0.59	12.36 ± 0.82	12.46	<.001	10.27	82.5
BiGoW	9.46 ± 0.18	8.49 ± 0.29	27.71	<.001	11.42	91
MnFW	9.16 ± 0.33	8.57 ± 0.75	7.18	<.001	6.88	82
ZyBr	13.31 ± 0.49	11.93 ± 0.64	17.08	<.001	11.56	87.5
PhyFH	17.15 ± 0.65	16.27 ± 0.87	8.12	<.001	5.40	78.5
MorFH	11.43 ± 0.59	10.18 ± 0.59	14.88	<.001	12.27	89
NL	4.66 ± 0.27	4.22 ± 0.39	9.10	<.001	10.42	70.5
NBr	3.34 ± 0.23	3.12 ± 0.25	6.26	<.001	7.05	62
NH	5.31 ± 0.20	4.51 ± 0.29	22.27	<.001	17.73	93.5
MxOW	10.07 ± 0.15	9.83 ± 0.53	4.30	<.001	2.44	67.5
MnOW	1.35 ± 0.28	1.15 ± 0.06	7.19	<.001	17.39	74

Table 3 shows the results of stepwise DFA, where seven variables were selected, which showed maximum classification accuracy. In stepwise DFA, the SPSS system automatically chooses those variables which provide maximum classification.

Table 4 shows the canonical discriminant coefficients and sexing accuracy for stepwise and direct discriminant functions. In stepwise analysis, seven variables that are MxHL, BiGoW, MxHBr, ZyBr, MorFH, NL and NH were selected and provided 100% sexing accuracy after cross-validation. Direct DFA showed the highest sexing accuracy of 99%

Table 2. Paired *t*-test for Intra-observer Error.

Variables	Correlation	*t* Values	Significance (Two-tailed)
MxHL	0.996	1.523	0.144
MxHBr	0.996	1.000	0.330
BiGoW	1.000	0.224	0.825
MnFW	0.996	−0.900	0.379
ZyBr	0.998	−0.040	0.969
PhyFH	0.999	1.000	0.330
MorFH	0.998	1.512	0.147
NL	1.000	2.423	0.026
NBr	0.998	1.231	0.233
NH	0.999	1.467	0.159
MxOW	0.990	0.698	0.494
MnOW	1.000	2.979	0.008

Table 3. Stepwise DFA.

Variables	Wilk's Lambda	Equivalent F. Ratio	Degree of Freedom
BiGoW	0.205	768.211	1,198
NH	0.146	577.091	2,197
MxHBr	0.122	468.918	3,196
MxHL	0.108	403.413	4,195
MorFH	0.100	348.131	5,194
NL	0.095	304.767	6,193
ZyBr	0.092	271.741	7,192

Table 4. Canonical Discriminant Coefficients.

Variables and Functions	Unstandardised/ Raw Co-efficient	Standardised Co-efficient	Structured Co-efficient	Centroids	Males (*n* = 100) (%)	Females (*n* = 100) (%)	Accuracy	
							Original (%)	Cross-validated
Stepwise DFA								
F1 MxHL	0.586	0.316	0.389	M = 3.132	100	100	100	100
BiGoW	2.465	0.616	0.626	F = −3.132				
ZyBr	0.384	0.220	0.386	SP = 0				
MxHBr	0.438	0.314	0.281					
MorFH	0.369	0.220	0.336					
NL	0.664	0.225	0.205					
NH	1.556	0.394	0.503					
(Constant)	−57.698							
Direct Discriminant Analysis								
F2 MxHL	0.765	0.413	0.735	M = 2.668	100	100	100	100
BiGoW	2.936	0.733	0.456	F = −2.668				
ZyBr	0.681	0.390	0.453	SP = 0				
MxHBr	0.406	0.291	0.330					
(Constant)	−53.803							
F3 MxHL	0.802	0.433	0.766	M = 2.559	100	99	99.5	99.5
BiGoW	2.975	0.743	0.476	F = −2.559				
ZyBr	0.832	0.477	0.472	SP = 0				
(constant)	−51.435							
F4 BiGoW	3.412	0.852	0.849	M = 2.308	100	98	99	99
ZyBr	0.922	0.528	0.523	F = −2.308				
				SP = 0				
F5 MorFH	0.436	0.26	0.331	M = 2.201	98	98	98	98
NH	1.515	0.382	0.495	F = −2.201				
				SP = 0				
F6 MnOW	0.505	0.253	0.401	M = 2.052	98	94	96	96
NH	1.515	0.387	0.486	F = −2.052				
				SP = 0				

Note: SP, sectioning point.

(M = 100%, F = 98%) using the variables BiGoW and ZyBr. A combination of ZyBr and BiGoW shows a minimum of 98.5% accuracy with the addition of any one of the remaining 10 variables. Keeping in view the fragmentary condition of the skull, we created functions using MnOW and MorFH in combination with NH.

Table 5 provides the results of ROC analysis, depicting the cut-off points along with the sensitivity and specificity of each variable. The highest AUC was shown by BiGoW with a sexing accuracy of 95.5% (M = 100%, F = 91%). Figure 1 shows the ROC plot along with the reference line, where most of the variables occupy the top left corner of the plot, thereby depicting a model with high sensitivity and specificity.

Table 6 depicts the Kaiser–Meyer–Olkin measure of sampling adequacy, which ranges from 0 to 1 and is a measure to provide the minimum standard before conducting a PCA. A minimum value of 0.6 or more is suggested to be optimum for the analysis. It also shows Bartlett's Test of Sphericity that the correlation between the variables does not form an identity matrix. PCA cannot be conducted if the correlation matrix forms an identity matrix.

Table 7 shows the communalities, eigenvalues, percentage of variance and loading of each variable on the principal components, which is the correlation between the variable and principal components for both sexes. The communalities depict the proportion of each variable's variance that can be explained by the principal components. BiGoW has depicted the highest communality for both sexes (M = 0.765, F = 0.738). The first principal component for both sexes has accounted for the most variance (M = 33.24%, F = 32.26%), followed by the second component and so on. Three principal components have been extracted and the correlation of BiGoW, followed by NH and ZyBr, has depicted the highest correlation with the principal component 1(PC 1) for both males and females (Figures 2 and 3).

The scree plot (Figure 2) depicts the distribution of variances (eigenvalues) of the principal components. PC 1 shows the highest variance. The plot peaks at the first principal component and eventually falls flat, depicting that each successive principal component accounts for gradually smaller variances.

In Figure 3, the plot for factors in rotated space has been obtained for only PC1 and PC2, as all the variables showed a positive loading on these two components, while some variables which show no correlation with sex loaded negatively on the third component.

Discussions

Population Variability in Sexual Dimorphism

The study of sexual dimorphism from percutaneous measurements can play an imperative role in forensic facial reconstruction and personal identification. The growth and development of the craniofacial region is affected by a plethora of factors, such as nutrition, environmental stress and masticatory forces

Table 5. ROC Analysis Depicting AUC, Cut-off Values and Sexing Accuracy of Each Variable.

Variables	AUC	Cut-off Value	Sensitivity	1-Specificity	Male Identified (*n* = 100) %	Females identified (*n* = 100) %	Total (*n* = 200) %
MxHL	0.957	♂ ≥ 16.7 < ♀	1	0.70	100	70	85
MxHBr	0.898	♂ ≥ 11.5 < ♀	1	0.84	100	84	92
BiGoW	1.000	♂ ≥ 8.15 < ♀	1	0.91	100	91	95.5
MnFW	0.782	♂ ≥ 7.95 < ♀	1	0.90	100	90	95
ZyBr	0.952	♂ ≥ 11.35 < ♀	1	0.84	100	84	92
PhyFH	0.831	♂ ≥ 15.75 < ♀	0.96	0.79	96	79	87.5
MorFH	0.912	♂ ≥ 9.81 < ♀	0.98	0.71	98	71	84.5
NL	0.838	♂ ≥ 4.03 < ♀	0.98	0.72	98	72	85
NBr	0.719	♂ ≥ 3.04 < ♀	0.96	0.70	96	70	83
NH	0.993	♂ ≥ 4.13 < ♀	1	0.90	100	90	95
MxOW	0.684	♂ ≥ 9.45 < ♀	0.99	0.78	99	78	88.5
MnOW	0.829	♂ ≥ 1.125 < ♀	0.88	0.76	88	76	82

Table 6. PCA–KMO and Bartlett's Test.

	Bartlett's Test of Sphericity		
Kaiser–Meyer–Olkin Measure of Sampling Adequacy	Approx. Chi-Square	*df*	Sig.
0.927	1,288.170	78	<0.001

Table 7. Communalities, Eigenvalues and Loading of Factors.

	Males				Females			
	Principal Components				Principal Components			Communality
Variables	**1**	**2**	**3**	**Communality**	**1**	**2**	**3**	
BigoW	0.856	0.09	0.24	0.765	0.876	0.308	0.576	0.738
NH	0.844	0.05	0.262	0.733	0.832	0.303	0.327	0.696
ZyBr	0.827	0.321	0.246	0.692	0.829	0.607	0.422	0.681
MxHL	0.804	0.421	0.19	0.572	0.801	0.638	0.396	0.656
MorFH	0.784	0.021	0.258	0.424	0.743	0.656	−0.349	0.638
MxHBr	0.716	0.393	0.32	0.413	0.606	0.585	−0.392	0.604
MnFW	0.521	0.629	0.342	0.445	0.602	0.561	−0.342	0.539
PhyFH	0.604	0.483	−0.07	0.396	0.593	0.535	0.337	0.611
NL	0.570	0.452	0.302	0.228	0.574	0.577	0.308	0.574
NBr	0.532	0.626	0.351	0.338	0.539	0.529	−0.381	0.681
MnOW	0.519	0.421	0.408	0.291	0.407	0.446	−0.436	0.596
MxOW	0.441	0.576	0.392	0.331	0.426	0.395	0.323	0.554
Eigenvalues	5.610	2.179	1.048		5.388	3.30	1.81	
% of variance	33.24	28.17	19.06		32.26	29.79	21.04	

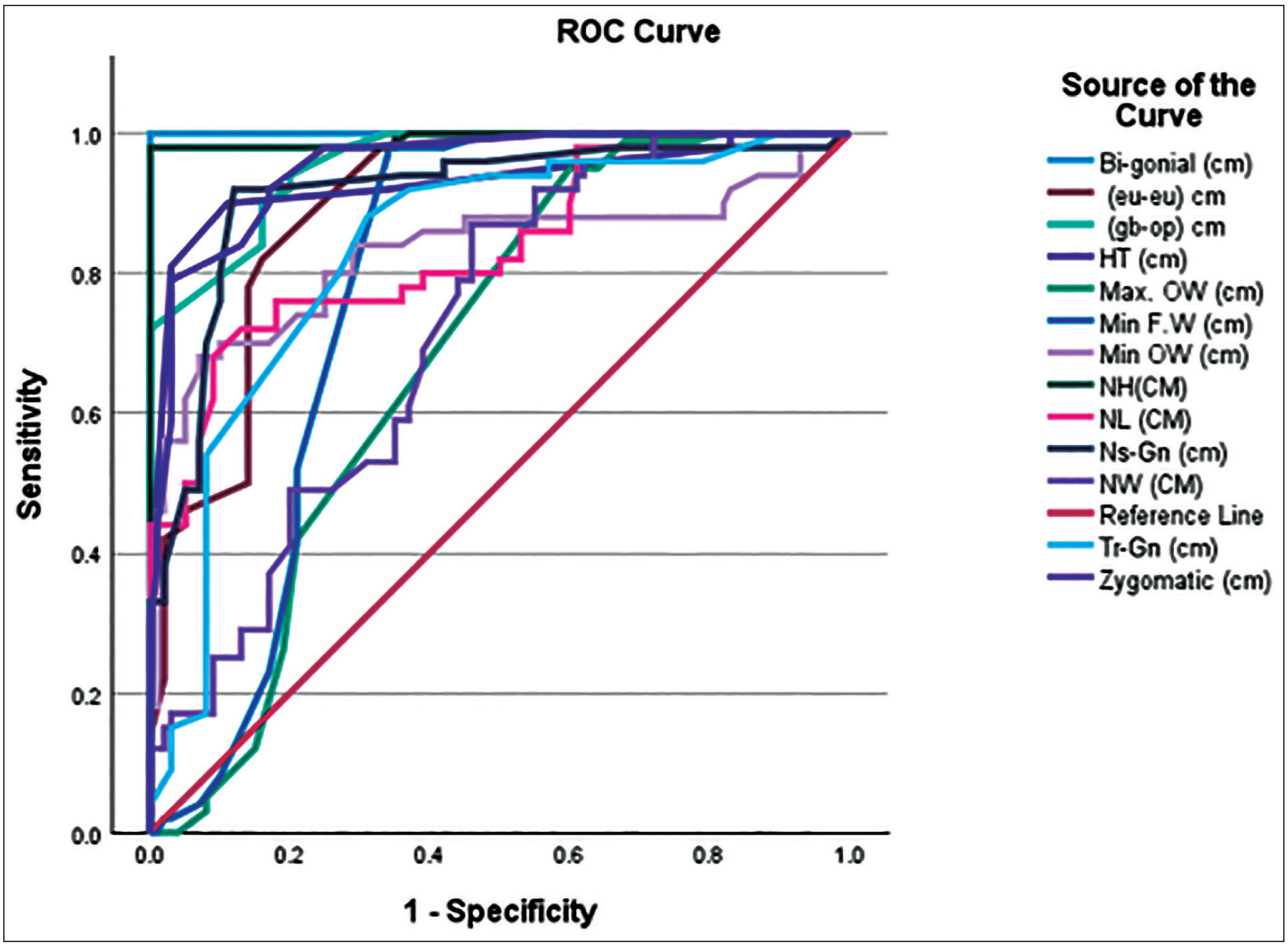

Figure 1. Shows the ROC Plot for all Cephalometric Variables.

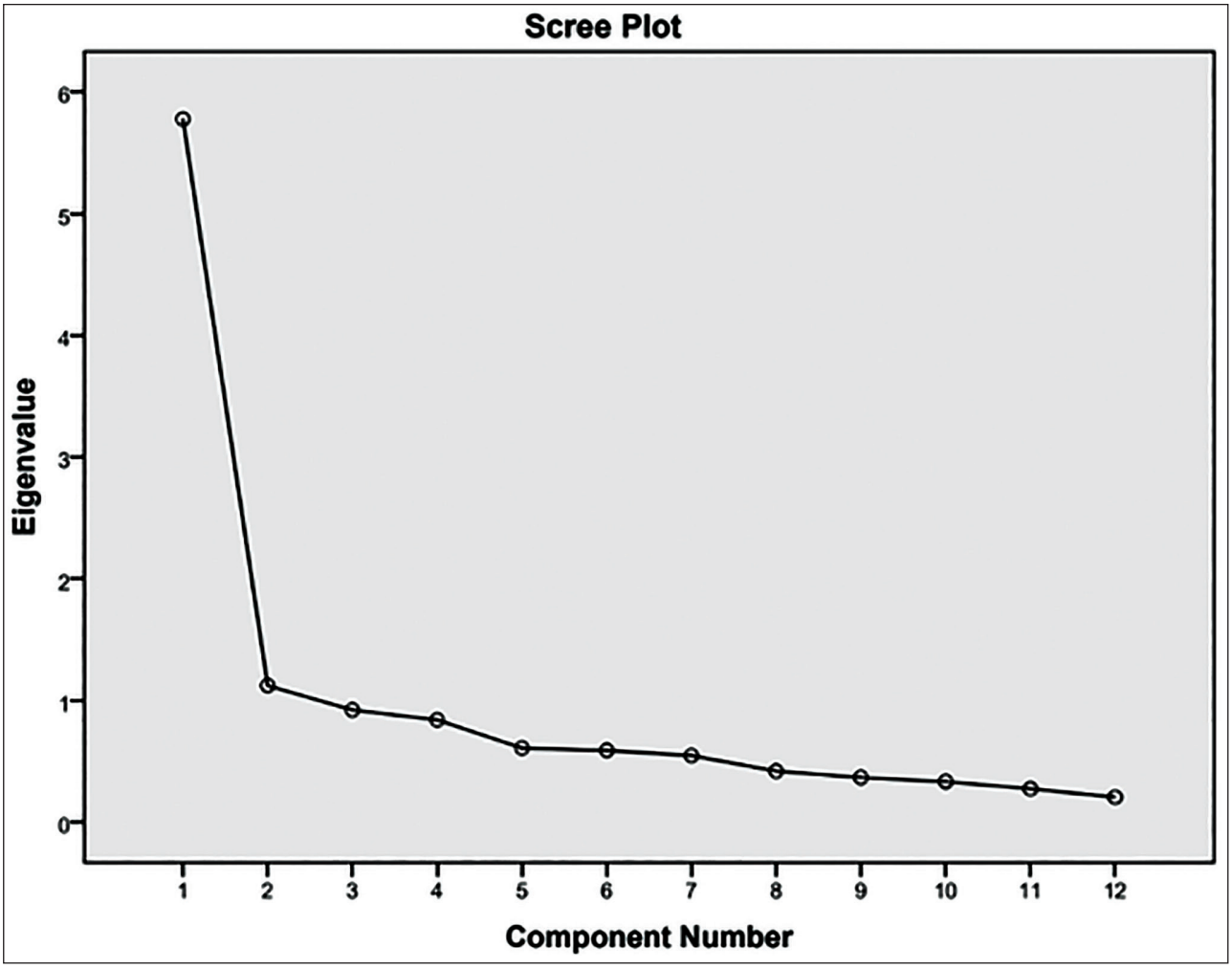

Figure 2. The Scree Plot Depicts the Distribution of Variances (Eigenvalues) of the Principal Components.

influenced by dietary habits.[14] The anatomical and morphological variations are a result of the different ontogenetic trajectories in males and females.[15,16] However, sexual dimorphism is typically found in the adult craniofacial measurements. This explains the age group of 18–40 years for the present study. The viscerocranium is responsible for the development of facial features and undergoes a slower growth rate as compared to the neurocranium. The later-developing areas of the craniofacial region, such as the mandible, maxilla, upper face, cranial base and head height, have a higher likelihood of showing greater classification accuracy.[17]

Univariate Discriminant Analysis

This study depicts that all cephalometric variables are significantly larger among males and have a sexing accuracy ranging between 62% and 93.5%. NH showed the highest classification accuracy (93.5%), as the nasal bone and piriform aperture are sexually dimorphic.[18] Bhargava and Sharma (1959) found that variation is higher within the nasal region compared to the cranium.[19] The findings of the present study are in accordance with the previous literature, where NH provided a sexing accuracy of 70.8% in males and 68% in females in the Ladakhi population, 64.96% in the European population and 77.2% in males and 68.4% in females within the Dehradun population.[20–22] The nasal organ plays a key role in regulating air pressure and temperature before it reaches the lungs. A study by Noback et al. (2011) revealed a strong correlation between the shape of the nasal cavity and two climatic variables, namely temperature and humidity. The nasal cavities of populations living in cold-dry climates tend to be relatively narrower and longer compared to those living in hot-humid regions. This adaptation helps to optimise the warming and humidification of air in colder climates, whereas wider nasal passages are advantageous in hot-humid climates for efficient cooling and moisture management.[23] However, this explanation may not be sufficient in explaining the sexual dimorphism of the NH among the North Indian Haryanvi population. The nasal morphology is a complex trait influenced by multiple factors, including genetics, evolutionary history and adaptation to environmental conditions, which should additionally be considered.

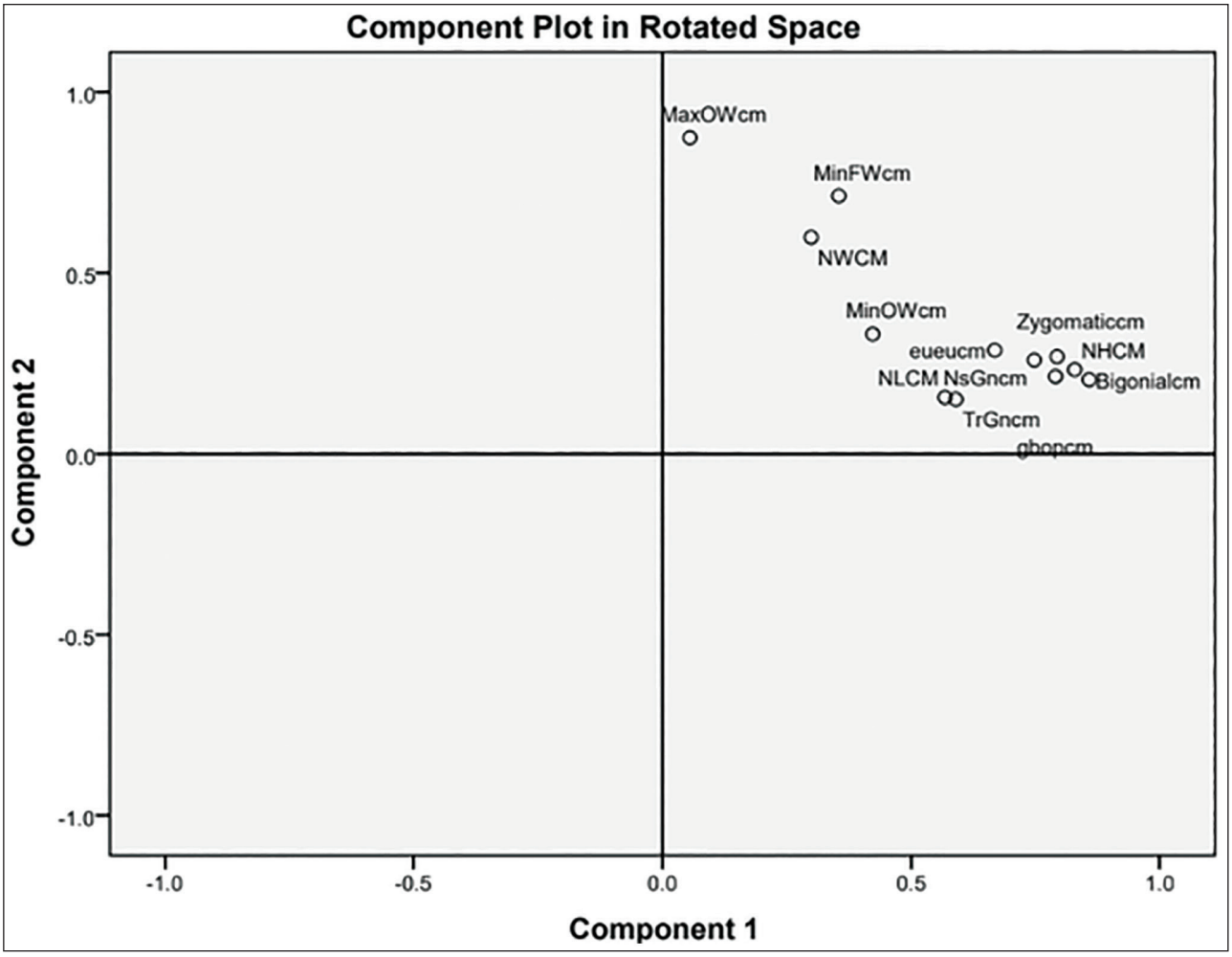

Figure 3. Shows the Plot for Factors in Rotated Space for Only PC1 and PC2, as all the Variables Showed a Positive Loading on these Two Components.

The human mandible is the most durable cranial-facial bone and depicts functional morphological variation due to higher masticatory forces in males. A sexing accuracy of 91% has been obtained in the present study using univariate DFA of BiGoW. This is also, in accordance with other studies depicting a sex accuracy of 92% in the Croatian archaeological samples, 86% in the Brazilian population and 70.7% in the Central Indian population.[24–26]

The sample size, unequal number of male and female participants and secular and temporal variations may lead to different sexing accuracy percentages across different population groups.[27]

Multivariate Sex Discriminant Analysis

We achieved very exceptionally high sexing accuracy using multivariate direct discriminant analysis by a combination of four variables, that is MxHL, BiGoW, ZyBr and MxHBr provided an accuracy of 100% and a little less (99%) by combining two variables, that is BiGoW and ZyBr. The extra-wide curvature of the zygomatic arch can be associated with the robustness of the male skull and increased development of the masseter muscle, which also affects the development of the mandible.[17,28] Multivariate analysis, including bizygomatic width, NH and nasal width, has provided high sexing accuracy also in other population groups, that is, 96.7% in the Chinese crania, 91.7% in North West Indians, 90.3% in Australian skulls, 89.7% in Japanese skulls, 88.2% and 81.5% in the Tibetan and South Indian crania, respectively.[9,29–32]

Best Machine Learning Algorithm for Sex Estimation

In the present study, we have used a combination of machine learning techniques, including ROC analysis, PCA and DFA, to determine the best tool for obtaining accurate sex determination from craniofacial skeleton data. ROC analysis has depicted a sexing accuracy of 82%–95.5% with an AUC of 1.00 for BiGoW. It is in accordance with the other studies that is AUC was 0.809 with 71.7% sex classification in the Central

Chinese population, 0.764 with 79% in the Brazilian population[25] and 0.684 with 79.6% in the Portuguese population.[33,34]

This study has also drawn a comparison between a supervised learning algorithm, namely DFA and an unsupervised technique, that is, PCA, to obtain sexing accuracy of the metric parameters and morphological features. The PCA results focused on identifying differences in the shape and size of cephalometric variables, without considering sex, whereas DFA identified the variables that can best differentiate between males and females. PC1 accounted for 33.24% in males and 32.26% in females. These results concur with the findings of a PCA-based study on sex estimation from skeletal collections containing American white crania, where the principal component explained 38% of the variation in males and 34% in females.[35] This study has thus provided an updated discriminant function for sex estimation and deduced a novel combination of the above-mentioned algorithms to enhance the accuracy of estimation from these metric and morphological features of the North Indian population. The results of this research will also be beneficial in facial reconstruction for forensic anthropology and reconstructive orthognathic surgery. However, the results may be slightly varied due to larger population sizes and an unequal number of males and females. The data collection technique (CT scan, geometric morphometric or direct measurement) also affects the results while assessing sexual dimorphism within the same population.[36]

Acknowledgements

We would like to extend our gratitude to the Department of Forensic Science, SGT University, Gurugram, for their laboratory infrastructure and research support.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Ethical Approval

Informed consent, along with approval from the Institutional Ethics Committee, was obtained (Ref. No. SGTU/FOSC/2023/1481).

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

Informed Consent

As mentioned in the manuscript, an informed consent in both English and Hindi languages were obtained from the participants prior to obtaining their measurements. This was in accordance with the approval of the Institutional Ethical Committee.

ORCID iD

Vineeta Saini https://orcid.org/0000-0002-1396-5683

References

1. Johnson A, Hoggard C, Singh S, et al. Investigating sexual dimorphism of the human mandible in Indian population using geometric morphometric method. *J Indian Acad Forensic Med* 2025; 46(4): 467–473.
2. Kiran M, Shetty M, Shetty SS, et al. Morphometric sex estimation using mastoid triangle: A prospective study. *J Indian Acad Forensic Med* 2021; 43(2): 108–113.
3. Del Bove A, Menéndez L, Manzi G, et al. Mapping sexual dimorphism signal in the human cranium. *Sci Rep* 2023; 13(1): 16847.
4. Toneva D, Nikolova S, Tasheva-Terzieva E, et al. A geometric morphometric study on sexual dimorphism in viscerocranium. *Biology (Basel)* 2022; 11(9): 1333.
5. Keche AS, Keche HA, Sahoo N, et al. Study of cephalic index and its correlation with sex and race in central India. *J Indian Acad Forensic Med* 2024; 46(1): 63–66.
6. Shirpure P, Mendpara H and Dhenge V. A digital retrospective study: Evaluating the reliability of mandibular parameters as sex predictors in the Maharashtra Population. *J Indian Acad Forensic Med* 2025; 46(3): 319–324.
7. Christoloukas N, Mitsea A, Kovatsi L, et al. Sex determination using linear anthropometric measurements relative to the mandibular reference plane on CBCT 3D images. *J Imaging* 2025; 11(7): 224.
8. Bhanarkar U and Koley B. Study of cephalic index in medical students of West Bengal. *J Indian Acad Forensic Med* 2020; 42(1): 44–45.
9. Battan SK, Sharma M, Gakhar G, et al. Cranio-facial bones evaluation based on clinical CT data for sex determination in Northwest Indian population. *Leg Med* 2023; 64: 102292.
10. Ceballos F, Deana NF and Alves N. Sex estimation in a Chilean population by mandibular analysis in cone beam computed tomography images. *BMC Oral Health* 2025; 25(1): 122.
11. Chaudhary S, Kaore A, Kashyap S, et al. Study of mandibular ramus morphology as a tool for sex determination in Indian population. *CME J Ger Med* 2025; 17(1): 79–82.
12. Jangid C, Dalal J, Kumari K, et al. From traditional to virtual: The evolving landscape of autopsy techniques in forensic science. *J Indian Acad Forensic Med* 2025; 46(4): 545–552.
13. Patil V, Vineetha R, Vatsa S, et al. Artificial neural network for gender determination using mandibular morphometric parameters: A comparative retrospective study. *Cogent Eng* 2020; 7(1): 1723783.
14. Kemkes A and Göbel T. Metric assessment of the "mastoid triangle" for sex determination: A validation study. *J Forensic Sci* 2006; 51(5): 985–989.
15. Bastir M, Rosas A and O'Higgins P. Craniofacial levels and the morphological maturation of the human skull. *J Anat* 2006; 209(5): 637–654.
16. Noble JME. Morphometrics of the juvenile skull: Analysis of ontogenetic growth patterns. Master's thesis. University of Western Australia; Perth, Australia, 2015.
17. Parlak ME, Etli Y, Beyhan M, et al. Sex estimation with ensemble learning: An analysis using anthropometric measurements of piriform aperture. *Egypt J Forensic Sci* 2025; 15(1): 10.
18. Kim Y, Park JH, Park M, et al. Differences in nasal shapes and the degree of changes over a decade or more: A paired analysis. *Clin Exp Otorhinolaryngol* 2024; 17(1): 56–63.

19. Bhargava I and Sharma JC. The nose in relation to head and face-an anthropometric study. *Indian J Otolaryngol* 1959; 11(2): 213–218.
20. Ali M, Sehrawat JS and Sehrawat S. Sex determination from discriminant function analysis of cephalometric measurements of Brokpas and Purigpas of Ladakh (UT): A forensic anthropological study. *Rom J Leg Med* 2020; 28: 178–188.
21. Scendoni R, Kelmendi J, Arrais Ribeiro IL, et al. Anthropometric analysis of orbital and nasal parameters for sexual dimorphism: New anatomical evidences in the field of personal identification through a retrospective observational study. *Plos One* 2023; 18(5): e0284219.
22. Barwa J and Singh R. Nasal height as a parameter for stature estimation & sex differentiation in Dehradun region. Med-Leg Update 2020; 20(1): 116–121.
23. Noback ML, Harvati K and Spoor F. Climate-related variation of the human nasal cavity. *Am J Phys Anthropol* 2011; 145(4): 599–614.
24. Vodanović M, Dumančić J, Demo Ž, et al. Determination of sex by discriminant function analysis of mandibles from two Croatian archaeological sites. *Acta Stomatol Croat* 2006; 40(3): 263–277.
25. Lopez-Capp TT, Rynn C, Wilkinson C, et al. Discriminant analysis of mandibular measurements for the estimation of sex in a modern Brazilian sample. *Int J Legal Med* 2018; 132(3): 843–851.
26. Wankhede KP, Bardale RV, Chaudhari GR, et al. Determination of sex by discriminant function analysis of mandibles from a Central Indian population. *J Forensic Dental Sci* 2015; 7(1): 37–43.
27. Inskip S, Constantinescu M, Brinkman A, et al. The effect of population variation on the accuracy of sex estimates derived from basal occipital discriminant functions. *Archaeol Anthropol Sci* 2018; 10(3): 675–683.
28. Franklin D, Freedman L, Milne N, et al. A geometric morphometric study of sexual dimorphism in the crania of indigenous southern Africans. *S Afr J Sci* 2006; 102(5): 229–238.
29. Song HW, Lin ZQ and Jia JT. Sex diagnosis of Chinese skulls using multiple stepwise discriminant function analysis. *Forensic Sci Int* 1992; 54(2): 135–140.
30. Swift L, Obertova Z, Flavel A, et al. Estimation of sex from cranial measurements in an Australian population. *Aust J Forensic Sci* 2023; 55(6): 755–770.
31. Hanihara K. Sex diagnosis of Japanese skulls and scapulae by means of discriminant functions. *J Anth Soc Nippon* 1959; 67: 21–27.
32. Naikmasur VG, Shrivastava R and Mutalik S. Determination of sex in South Indians and immigrant Tibetans from cephalometric analysis and discriminant functions. *Forensic Sci Int* 2010; 197(1–3): 122.e1–6.
33. Deng M, Bai R, Dong H, et al. Sexual determination of the mandible breadth in a central Chinese population sample: A three-dimensional analysis. *Aust J Forensic Sci* 2017; 49(3): 332–343.
34. Pereira C, Bernardo M, Pestana D, et al. Contribution of teeth in human forensic identification–discriminant function sexing odontometrical techniques in Portuguese population. *J Forensic Leg Med* 2010; 17(2): 105–110.
35. Jantz RL, Mahfouz M, Shirley NR, et al. *Improving sex estimation from crania using 3-dimensional CT scans*. *US Department of Justice*. 2013; 1–71. https://www.ojp.gov/pdffiles1/nij/grants/240688.pdf
36. Roy D, Verma A and Bhutia K. Morphometric analysis of foramen magnum and occipital condyles for sexual dimorphism: Exploring reliability through computed tomography investigation. *J Indian Acad Forensic Med* 2024; 46(2): 259–266.

Dental Age Estimation: A Crucial Tool in Forensic Identification and Legal Application—A Literature Review*

Journal of Indian Academy of Forensic Medicine
47(4) 414–422, 2025

DOI: 10.1177/09710973251407376
journals.sagepub.com/home/iaf
Sage

Ravindra B Deokar[1], Neelkamal Battu[2] and Sachin Patil[2]

Abstract

Dental age estimation is a crucial tool in forensic science and legal investigations, used to determine a person's age based on their teeth. Teeth develop in a predictable manner, making them reliable indicators of age, even when other biological markers are unavailable. This technique is widely applied in criminal cases, identifying victims in mass disasters, and resolving legal disputes related to age, such as immigration cases and age verification for legal purposes. Several scientific methods help in estimating dental age across different age groups. In children and adolescents, there is an evaluation of the developmental stages of permanent teeth through radiographic analysis. Another common approach is the atlas method, which provides a series of reference images showing tooth development at different ages. Demerjian stages in developing teeth to estimate age in children and adolescents. For adults, age estimation relies on regressive changes in teeth, such as root translucency and secondary dentin deposition. These methods provide forensic experts with reliable tools for age estimation, though individual variations in genetics, nutrition, and environmental factors can affect accuracy. Recent advancements in digital imaging, artificial intelligence, and machine learning are improving the precision of dental age estimation. Techniques like Cone Beam Computed Tomography (CBCT) and automated analysis of dental structures are helping forensic scientists refine their assessments. Despite some limitations, dental age estimation remains one of the most effective techniques for age determination when birth records are unavailable or disputed. This review article aims to provide a comprehensive analysis of the various methods used in dental age estimation, highlighting their applications, advantages, and limitations in forensic and legal contexts. It will also explore recent advancements in imaging techniques and artificial intelligence that are enhancing the accuracy of age estimation. By examining existing methodologies and emerging technologies, this review seeks to contribute to the continuous improvement of forensic odontology, ensuring more reliable and standardised age estimation practices for legal and investigative purposes.

Keywords

Dental age estimation, forensic medicine, forensic odontology, human identification, medicolegal age

Received 13 March 2025; **accepted** 24 November 2025

Introduction

The use of teeth for age estimation dates back to the Factory Act of 1837 in England, which prohibited children with non-erupted permanent second molars from working in factories. In the same year, Edwin Saunders conducted the first scientific study comparing height and dentition in 1,049 children and demonstrated to Parliament that teeth were a more reliable indicator of age than stature.[1] This early work laid the foundation for modern dental age assessment in legal and forensic settings.

Age determination remains essential across multiple domains of forensic and legal practice. In criminal investigations, it helps distinguish juveniles from adults, influencing criminal responsibility, court jurisdiction, and sentencing. It is also critical for identifying unknown human remains when DNA or fingerprints are unavailable. Age assessment plays

*The first author of this article is an editor of this journal. To avoid any potential conflict of interest, the peer-review process and decision-making for this article were handled by other editors and anonymous reviewers.

[1]Department of Forensic Medicine and Toxicology, Lokmanya Tilak Municipal Medical College and General Hospital, Mumbai, Maharashtra, India
[2]Department of Forensic Medicine and Toxicology, Seth G.S. Medical College and King Edward Memorial Hospital, Mumbai, Maharashtra, India

Corresponding author:
Neelkamal Battu, Department of Forensic Medicine and Toxicology, Seth G.S. Medical College and King Edward Memorial Hospital, Mumbai, Maharashtra 400012, India.
E-mail: battuneelkamal@gmail.com

an equally important role in immigration and asylum proceedings, where determining whether an individual is a minor affects access to services and legal protections.[2] Age additionally governs civil rights and personal autonomy, setting legal thresholds for consent, marriage, contracts, voting, and driving, and is especially significant in sexual offence cases where the ages of both victim and offender determine legal implications.[3,4]

Forensic age estimation relies on a range of techniques, including radiographic assessments, dental development analysis, skeletal evaluation, and histological and biochemical methods.[5] These approaches collectively ensure accurate and defensible age assessments, helping maintain legal standards and protect vulnerable populations.

Given the critical importance of dental indicators in age estimation, this review provides an updated synthesis of classical, contemporary, and emerging dental methods (Figure 1). By examining radiological, morphological, histological, and biochemical approaches—along with recent advancements such as population-specific formulas and improved atlas techniques—this article supports more accurate, standardised, and scientifically robust age estimation in forensic practice.

Material and Methodology

The databases searched were Google Scholar, PubMed and the terms used were 'dental age estimation methods' and 'forensic dentistry'. The studies listed from these terminologies were analysed. Publicly available, peer-reviewed research on dental age estimation techniques which met the inclusion requirements and were found in accordance with the objective of the authors was included in the study.

The various classifications for dental age estimation based on various parameters are as follows.

1. Method of application, whether on living or deceased (Figure 2).[6]
2. Various modalities, that is, visual, radiographic, biochemical (Figure 3).[7]
3. Based on age group—early adolescent or adult (Figure 4).[8]

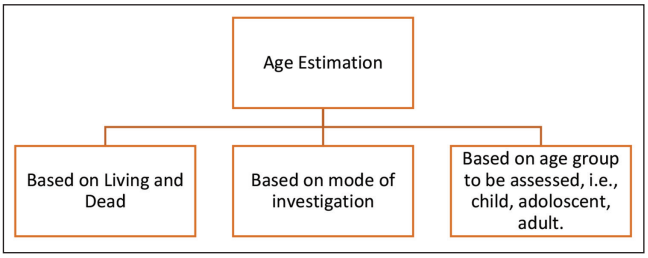

Figure 1. Classification of Age Estimation[5].

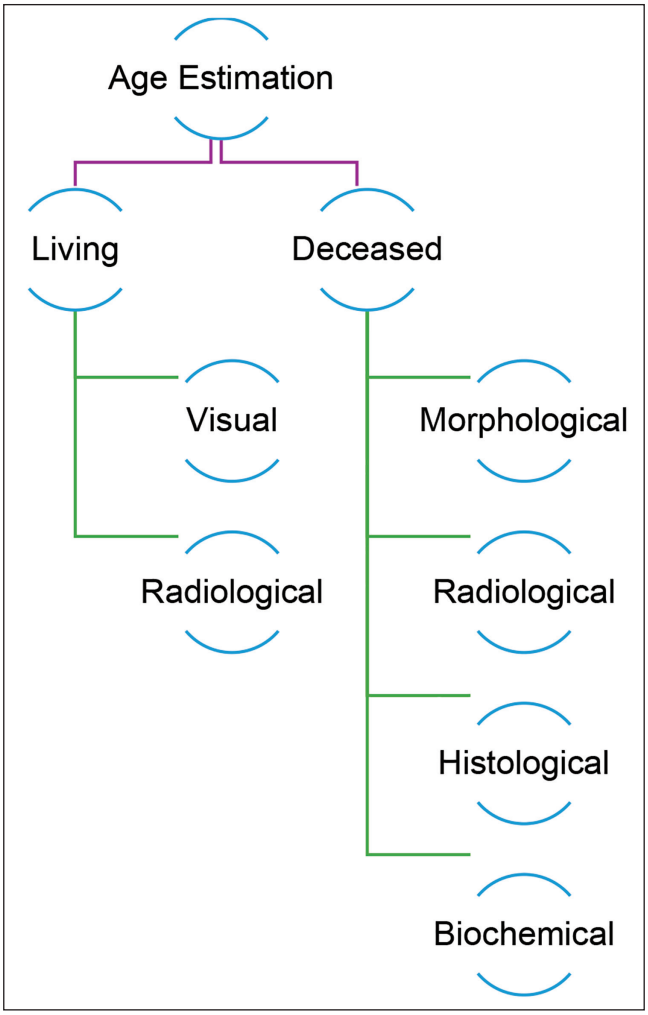

Figure 2. Classification of Methods Based on Living and Deceased[6].

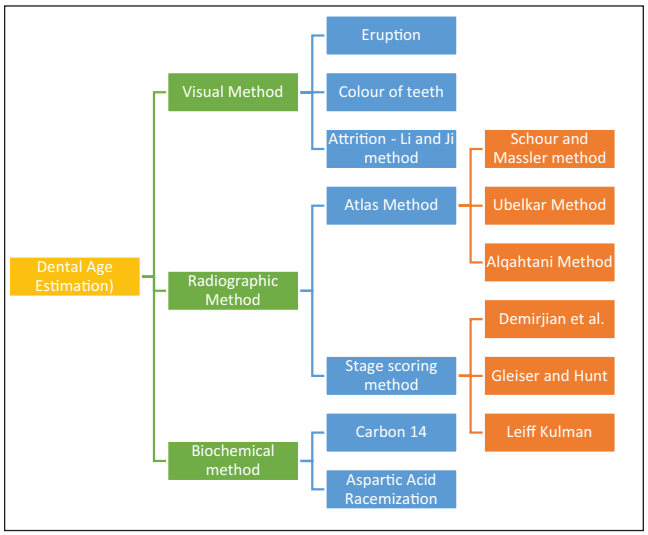

Figure 3. Classification Based on Various Modalities for Age Estimation[7].

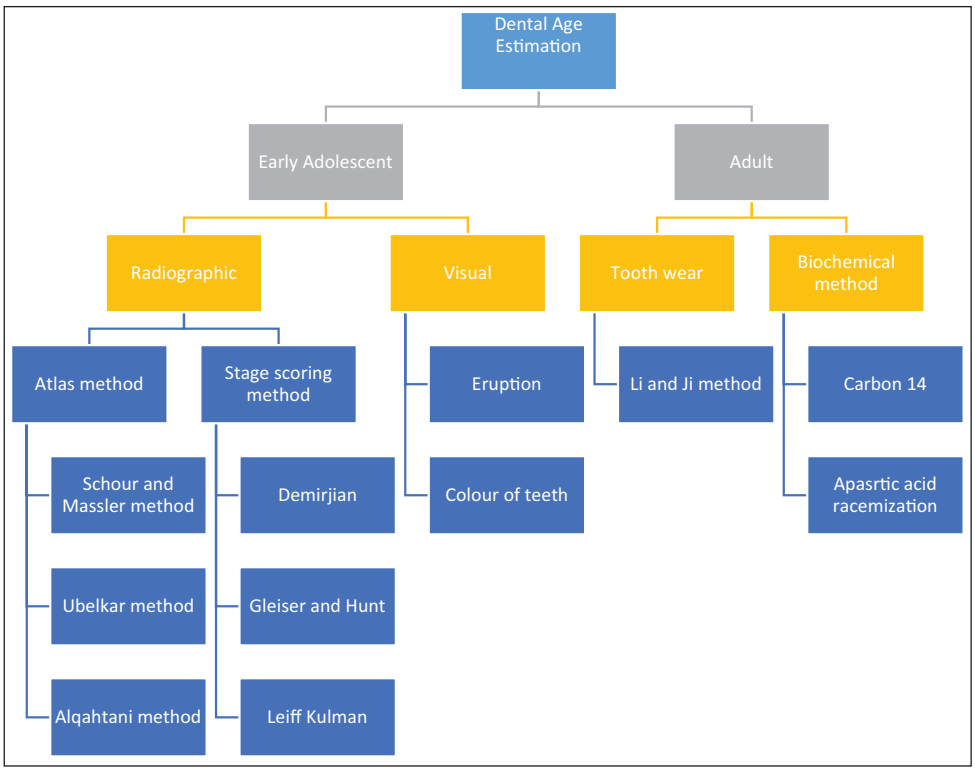

Figure 4. Classification Based on Category of Individual on Age[8].

Dental Age Estimation Techniques

The following categories have been employed to group several distinct methodologies:

1. Radiological methods.
   a. Atlas Method
   b. Scoring method
2. Visual methods.
3. Histological methods.
4. Biochemical methods.

Radiological Methods

Altas Method

In this, the individual's dental X-ray is matched with pre-established reference images that represent different stages of dental development. The atlas provides a standardised chronological sequence of tooth formation, helping estimate age based on observed dental maturity. The majorly used atlas is Schour and Masseler and Ubelkar. In recent times, the London atlas is considered to be a more appropriate method of age estimation in developing dentition.[9]

Schour and Masseler Method

Schour and Masseler tracked the development of permanent and deciduous teeth in 1941, creating development charts that depicted 21 chronological stages from 4 months to 21 years of age. There are no separate charts for men and women because these charts lack individual surveys for each gender (Figure 5).[10] The major advantage is the visual representation of various stages of teeth development. The estimated age is in a narrow range of +6 months.

Ubelkar Method

This method was developed by Douglas H. Ubelaker in 1978 to better suit Native American dental development. The original chart, based on European samples, often overestimated age (Figure 6). In 1989, Ubelaker refined the age ranges to account for natural variations in dental development among individuals of the identical age. Ever since then, this method has become a widely accepted standard for data collection. However, because it was developed using archaeological samples and tailored for Native American populations and broader age groups, it may not be fully accurate for modern or other ancestry groups.[11] The noteworthy inclusion of 5 months intra-uterine life to 35 years of age broadens the scope of its application in a wide range of individuals. Also, the narrow standard deviation of age range at early stages of life and broader in later stages highlights that as age advances, the efficiency to provide a small age range declines.

London Atlas Method

This was held in the Natural History Museum in London, UK, and the Royal College of Surgeons in England. For

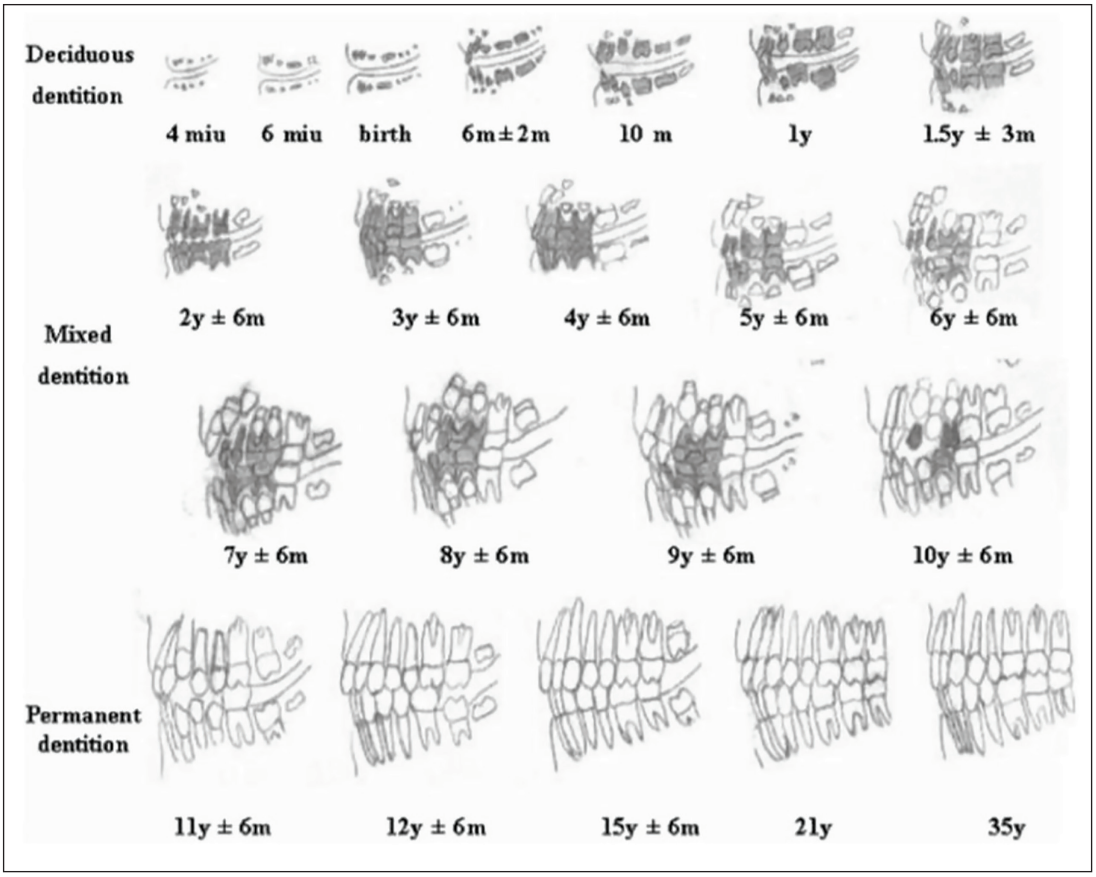

Figure 5. Schour and Massler Dental Development Chart[10].

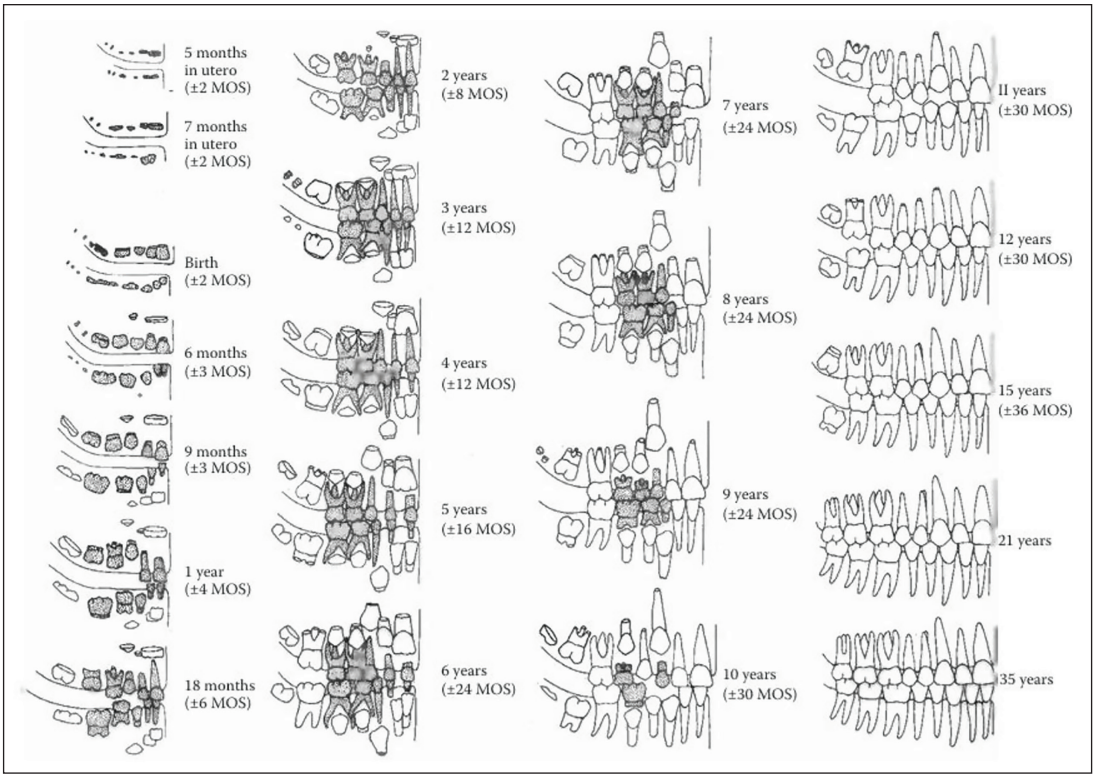

Figure 6. Ubelkar Dental Development Chart[11].

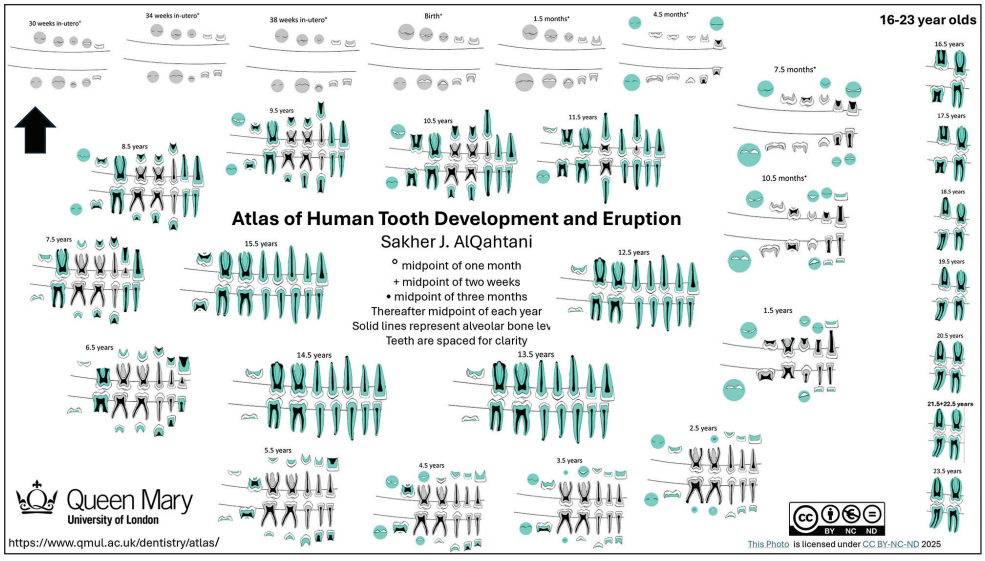

Figure 7. The London Atlas Dental Development Chart[11].

individuals between 28 weeks in utero and 23 years old, a thorough evidence-based atlas was created to determine age using both tooth maturation and alveolar eruption (Figure 7). There are no gaps or overlaps in the series of pictures that depict a continuum of developmental ages. To solve earlier shortcomings of dental atlases and provide more specificity in age predictions, the London atlas was created on a sample of British White and Bangladeshi people.[11] It has taken into consideration not on the development stage of primary and permanent teeth but also the resorptive stages of primary teeth and the emergence level at the alveolar bone. They have also developed an online software application at https://www.qmul.ac.uk, which provides a convenient mode of age estimation by entering the stage of teeth into the portal.

Scoring Methods

Demirjian's Method

A popular approach for determining a child or adolescent's age based on the development of their teeth is the Demirjian dental age estimation method. The original method is based on a seven-stage approach of dental growth using radiographic pictures of the mandibular teeth and was first presented by Arto Demirjian et al. in 1973. It is considered as gold standard for age estimation in the adolescent age group.[12]

Indian Formula

In a study conducted by Ashith Acharya,[13] the age predicted by Demerjian's eight teeth regression equation predicted inferior age than the documented age; hence, it was emphasised to develop population-specific formulas. The Indian population specified formula is.

Male: $\text{Age} = 27.4351 - (0.0097 \times S^2) + (0.000089 \times S^3)$.
Female: $\text{Age} = 23.7288 - (0.0088 \times S^2) + (0.000085 \times S^3)$.

The earlier Demirjian method had eight stages considering seven teeth, and the later had 10 stages of teeth development with the inclusion of 3rd molar. The Indian population-based developed formula surpassed the limitation of overestimation of age and exhibited improved age estimation concerning our population with biologically sex specific formulas.

Gleizer and Hunt Method

In permanent dentition, most teeth have undergone development by 12 years; hence, to determine the most crucial age group, the development of third molars in 17 stages, as stated by Gleizer and Hunt, is of immense importance to be taken into consideration. In a study conducted by Asmidha et al., a high association between age and stages was obtained.[14] The major advantage is that, unlike other method which considers the staging of multiple teeth, in case of congenital absence or extraction of teeth, it questions the applicability of the technique considering the contralateral tooth.

Leiff Kulman Method

Leif Kullman considered the root development of the third molar. In the Indian population, it was found that in the root development between stages 1 and 5, the subject had not attained the age of 18. If the stage of root development was found to be 7, one can be assured that the subject has attained 18 years of age.[15] The maturity stage of the third molar can be appreciated in not just dental radiographs but also lateral cephalograms, which are readily available in a medical set-up. In this technique, only staging the third molar presents it

Table 1. Primary Teeth Eruption and Exfoliation[16].

Tooth Type	Eruption Age (Months)	Shedding Age (Years)
Central incisor	6–10	6–7
Lateral incisor	9–16	7–8
First molar	13–19	9–11
Canines (cuspids)	16–22	10–12
Second molar	23–33	10–12

Permanent teeth	Eruption age (years)
First molars	6–7 years
Central incisors	6–8 years
Lateral incisors	7–9 years
First premolars	10–12 years
Second premolars	10–12 years
Canines (cuspids)	9–12 years
Second molars	11–13 years
Third molars (wisdom teeth)	17–25 years

as a convenient method of dental age estimation, which is extremely significant, especially in juvenile cases.

Visual Methods

Teeth Eruption

Human dentition is diphyodont, heterodont and gomphosis. There are primary teeth and permanent teeth. The sequence of eription of teeth has been depicted in Table 1. Between the ages of 6 and 12 is known as the transition or mixed dentition stage.[16]

The major advantage is that a mere visual oral examination without any aids, such as a radiographic unit and processing of the sample, is needed for assessment of the eruption of teeth. A trained expert who can differentiate primary and permanent teeth and knows the sequence of teeth can examine and estimate the age.

Colour of Teeth

The colour of enamel is influenced by age; as age advances, the value is decreased and chroma increases. A transition to a more reddish colour is observed with an increase in age. The translucency, thickness, and chemical composition of enamel and dentin combine to form enamel shade. Because the characteristics and thickness of dentin and enamel are always changing, the optical character changes with age. As we age, attrition causes enamel to weaken, and secondary dentin deposition causes dentin to develop.[17] The technique cannot the applied to individuals with habits such as tobacco chewing.

The examination of virgin teeth alongside a reference shade guide, with simple training provided to the observer, can help in age estimation. The white and yellow hues are more associated with younger age, and reddish brown and grey hues are associated with older age.

Li and Ji Method

A novel approach to age estimation based on permanent molars, known as the Average Stage of Attrition (ASA) method, was introduced (Figure 8)[18]. A new grading system for molar crown attrition was developed, and six linear regression equations for age estimation were established (Table 2). With a maximum inaccuracy of 4.53 years, the ASA method enables age assessment using a single molar, either M_1 or M_2, from the maxilla or mandible. By averaging wear stages across all cusps rather than concentrating on a

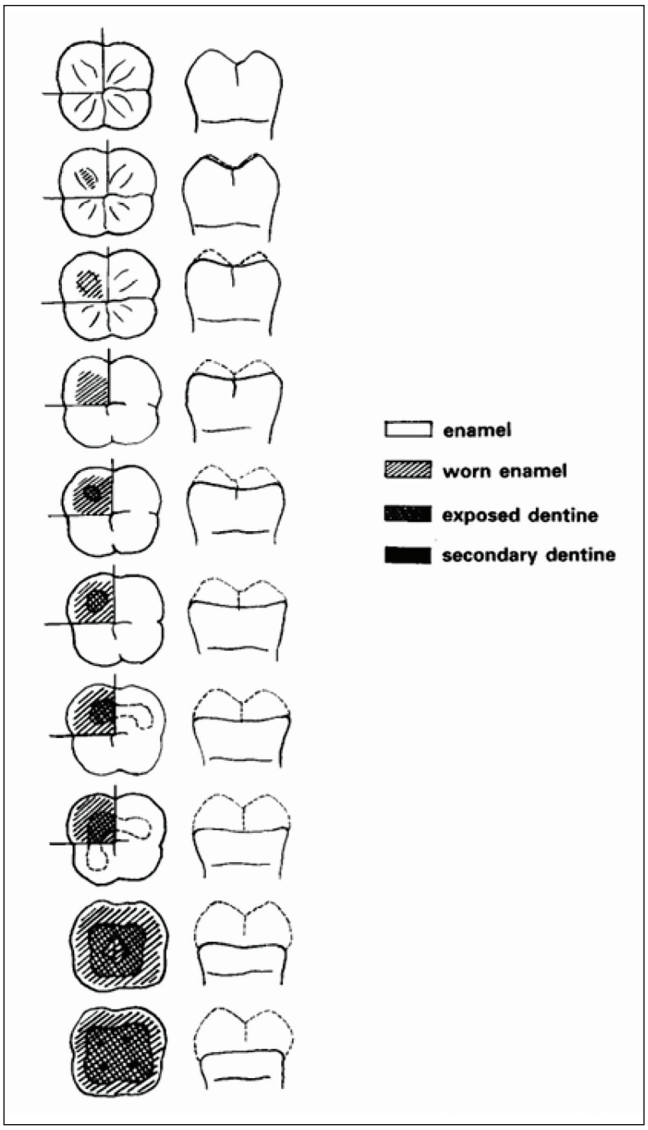

Figure 8. Stages of Crown Attrition from 0 to 9[18].

Table 2. Regression Equation for Age Estimation Based on the Li and Ji Method[18].

Arch	Equation	*SD*	*r*
Maxilla	$Y = 11.42 + 6.32M_1$	3.97	0.96
	$Y = 14.44 + 7.44M_2$	4.53	0.94
	$Y = 12.23 + 4.11M_1 + 2.75M_2$	3.65	0.96
Mandible	$Y = 12.76 + 6.30M_1$	3.94	0.97
	$Y = 15.31 + 7.27M_2$	4.36	0.96
	$Y = 13.63 + 3.98M_1 + 2.83M_2$	3.56	0.97

single cusp or a selection of cusps, ASA offers a more objective assessment of occlusal surface attrition than other dental wear methods.[18]

The molar teeth are not subjected to post-mortem loss by virtue of being multi-rooted and the anchorage they have in the alveolar bone. Therefore, on occlusal and buccal inspection of teeth, and staging the level of attrition without any other equipment is a boon of the technique.

Histological Methods

The assessment of teeth is the foundation of histological techniques. For microscopic preparation, these techniques necessitate the extraction of teeth. However, for ethical, religious, or cultural reasons, these approaches might not be appropriate.

Gustafson's Method (1950) depicted the age changes occurring in the dental tissues and recorded six changes related to age.[19]

They are:

1. Attrition on incisal or occlusal surfaces (A)
2. Periodontitis (P)
3. Secondary dentin formation (S)
4. Apposition of Cementum (C)
5. Resorption of roots (R)
6. Transparency or root (T)

Gustafson recommended the last two changes. In the method proposed, each sign was ranked and allotted 0, 1, 2, or 3 points.

The point values of each age-change are added according to the following formula:

Points are An + Pn + Sn + Cn + Rn + Tn. According to the preceding formula, the precise equation that was computed was y = 11.43 + 4.56x, where y = age and x = points. Gustafson (1950) calculated an error of speculation of ±3.6 years. Its inability to be effectively applied to living individuals is a disadvantage. This is the pioneer method of dental age based on the above-mentioned parameters; most of the histological methods are a modification of Gustafson's method.

Dalitz Method

Dalitz revisited Gustafson's method and introduced a revised 5-point system, ranging from 0 to 4, as opposed to the previous 4-point system. This modification aimed to enhance accuracy. The findings indicated that root resorption and secondary cementum formation were not significant factors. The remaining criteria—attrition (A), periodontitis (P), secondary dentine (S) deposition, and root transparency (T)—were found to be strongly correlated with age, exhibiting similar levels of association. Dalitz proposed the following formula for age estimation:

$$E = 8.691 + 5.146A + 5.338P + 1.866S + 8.411T$$

The study did not include bicuspids and molar teeth.[20]

Bang and Ramm Method

They discovered that, beginning at the root's tip and moving coronally with age, the root dentine appears to become transparent during the third decade. It was discovered that throughout the third decade, the transparency of the root dentin advances coronally from the root tip. A great advantage of the method is that good results are obtained by measuring intact roots.[20]

Johanson Method

Age changes were differentiated into seven different stages (A0–A3) and evaluated for the same six criteria mentioned earlier: attrition (A), secondary dentine formation (S), periodontal attachment loss (P), cement apposition (C), root resorption (R), and apical translucency (T). Johanson made a more detailed study of the root transparency and stated that it is clearer when the thickness of the ground section of the tooth is 0.25 mm.

The following formula was recommended: Age = 11.02 + (5.14 × A) + (2.3 × S) + (4.14 × P) + (3.71 × C) + (5.57 × R) + (8.98 × T)[20]

Maples Method

In this method, only two of the total six Gustafsons were taken into consideration. Translucency of root and secondary dentine formation was selected out of the six criteria of evaluation, which made the method simpler and accurate.

Solheim Method

Except for root resorption, Solheim considered the other five parameters, that is, attrition, secondary dentin formation, periodontitis, cementum apposition, and root transparency, with the inclusion of three new age-related changes—surface roughness, colour, and sex that showed a significant correlation in different types of teeth.[20]

Biochemical Methods

Carbon 14

C dating in dental enamel is made possible by the significant and rapid increase in the level of 14C in the atmosphere due to atmospheric nuclear tests carried out during the Cold War from 1955 to 1963. Before that, the levels of C in the atmosphere had remained constant over the last millennia. Atmospheric nuclear tests resulted in an increase in C in the troposphere, which then entered the atmosphere and was dispersed over the entire globe. Nuclear explosions introduced into the atmosphere approximately 2.1 × 1017 Bq of 14C, that is, a doubling of the 14C/C ratio in the atmosphere. After the Limited Test Ban Treaty was signed in 1963, atmospheric nuclear tests were banned. From then on, the level of atmospheric 14C began to decrease exponentially, not because of radioactive decay but because of the progressive incorporation of 14C into marine and terrestrial reservoirs. Thus, atmospheric C reacts with oxygen to form CO_2, which is incorporated into plants by photosynthesis. By eating these plants and animals feeding on these plants, the concentration of atmospheric carbon in the human body, especially in tooth enamel, evolves at all times in a quasi-parallel manner with the increase in 14C levels in the atmosphere. Therefore, based on this principle, age is estimated.[18] Various studies have cited that age can be claimed with an accuracy of age by the mean error of ±1.5 years.[21]

Aspartic Acid Racemisation

The use of aspartic acid racemisation for age assessment was first introduced by Helfman and Bada in 1975 and has since become a widely utilised method in forensic age estimation. As individuals age, L-amino acids gradually convert to their D-forms through racemisation. At a temperature of +25°C, complete racemisation of all L-amino acids in living tissues would take approximately 100,000 years. This process allows the degree of racemisation to serve as a reliable indicator for estimating the age of various tissues. Among stable amino acids, aspartic acid exhibits one of the fastest racemisation rates, making it the preferred choice for age estimation. The rate of L- to D-form conversion is influenced by factors such as temperature, humidity, and pH. Since continuous amino acid turnover affects accuracy, tissues with low metabolic rates provide more precise age estimates. Given these considerations, teeth are the preferred tissue for forensic age estimation. In cases where the post-mortem interval is extended, forensic experts often rely on bones and teeth as the primary sources for analysis.

It is an advanced method of age estimation with involves technique-sensitive instrumentation such as gas chromatography and high-performance liquid chromatography. The extent of preservation on aspartic acid racemisation in deceased, in case where the dentin of healthy, impacted, and carious teeth was studied and noted that the teeth can be preserved for up to 10 years, showing a negligible effect on estimated values with an error of 4 years.[22]

Conclusion

Dental age estimation techniques play a crucial role in forensic science, anthropology, and clinical dentistry by providing reliable age assessments based on dental development and changes. Various methods, including radiographic, morphological, and biochemical approaches, have been extensively studied and applied to different populations. Traditional techniques such as Demirjian's remain widely used due to their simplicity and accuracy, while newer advancements incorporating artificial intelligence and machine learning show promise for enhanced precision. Despite their effectiveness, these methods have limitations, including population-specific variations, observer subjectivity, and differences in environmental and genetic influences. Future research should focus on refining existing techniques, integrating digital and AI-based approaches, and developing more standardised protocols for broader applicability. Continued advancements in dental age estimation will improve accuracy, making it an indispensable tool in forensic and medical fields.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Ethical Approval

As it is a review article, ethical approval is not applicable.

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

Informed Consent

Not applicable.

ORCID iDs

Ravindra B Deokar https://orcid.org/0000-0003-1539-1035
Neelkamal Battu https://orcid.org/0000-0002-6499-3713
Sachin Patil https://orcid.org/0009-0006-7420-1085

References

1. Verma M, Verma N, Sharma R, et al. Dental age estimation methods in adult dentitions: An overview. *J Forensic Dent Sci* 2019; 11(2): 57.

2. Jagannath TV. Medicolegal aspect of age: A review article. *Int Ayurvedic Med J* 2017; 5(1): 254–261.
3. Vora AR and Dere RC. Application of forensic odontology in forensic investigations. *J Forensic Med Sci Law* 2019; 28(1): 31–33.
4. Aggrawal A. Estimation of age in the living: In matters civil and criminal. *J Anat* 2009; 1(2): 1–25.
5. Al-Billeh TN. The role of forensic dentistry in detecting crimes in Jordanian law and judiciary. *J Forensic Med Sci Law* 2023; 32(2): 70–74.
6. Chaudhary RK and Doggalli N. Commonly used different dental age estimation methods in children and adolescents. *Int J Forensic Odontol* 2018; 3(2): 50–54.
7. Singhal I, Dave A, Arora M, et al. A review on dental age estimation in children and adolescents. *J Forensic Sci Med* 2024; 10(3): 220–233.
8. FR author group. Age estimation from teeth: All forensic odontology tables included. *ForensicReader* [Internet]. n.d. [cited 2025 Feb 20]. Available from: https://forensicreader.com/age-estimation-from-teeth/
9. Alqahtani SJ, Hector MP and Liversidge HM. Accuracy of dental age estimation charts: Schour and Massler, Ubelaker and the London Atlas. *Am J Phys Anthropol* 2014; 154(1): 70–78.
10. George GJ, Chatra L, Shenoy P, et al. Age determination by Schour and Massler method: A forensic study. *Int J Forensic Odontol* 2018; 3: 36–39.
11. Adams DM, Ralston CE, Sussman RA, et al. Impact of population-specific dental development on age estimation using dental atlases. *Am J Phys Anthropol* 2018; 168(1): 190–199.
12. Demirjian A, Goldstein H and Tanner JM. A new system of dental age assessment. *Hum Biol* 1973; 45(2): 211–227.
13. Acharya AB. Age estimation in Indians using Demirjian's 8-teeth method. *J Forensic Sci* 2011; 56(1): 124–127.
14. Arthanari A, Doggalli N, Vidhya A, et al. Age estimation from second & third molar by modified gleiser and hunt method: A retrospective study. *Indian J Forensic Med Toxicol* 2020; 14(4): 1–8.
15. Ramkumar J and Ganesh NN. Age estimation from radiographic evaluation of various developmental stages of maxillary third molars and its associated gender variation. *J Forensic Med Sci Law* 2022; 31(2): 33–37.
16. Bandyopadhyay S, Bose TK and Paul P. Review of estimation of age from eruption of teeth in the age-group 6-11 years. *J Indian Acad Forensic Med* 2024; 46(1): 144–147.
17. Srikant N, Annapurna S, Vaishnavi G, et al. Tooth shade variation in Indian population: An objective guide to age estimation. *Heliyon* 2021; 7(2): e06164. DOI: 10.1016/j.heliyon.2021.e06164
18. Li C and Ji G. Age estimation from the permanent molar in northeast China by the method of average stage of attrition. *Forensic Sci Int* 1995; 75(2–3): 189–196.
19. Gustafson G. Age determination on teeth. *J Am Dent Assoc* 1950; 41(1): 45–54.
20. Puranik M, Priyadarshini C and Uma SR. Dental age estimation methods: A review. *Int J Adv Health Sci* 2015; 1: 19–25.
21. Gunepin MA, Derache FL, Riviere DI, et al. Age estimation by analysis of carbon 14 in dental enamel. *Rev Soc Biometrie Hum* 2014; 31(1–2): 19–25.
22. Alkass K, Buchholz BA, Ohtani S, et al. Age estimation in forensic sciences. *Mol Cell Proteomics* 2009; 9(5): 1022–1030.

'Granny Battering': A Review of Literature on Elderly Abuse in India and Its Medico-legal Implications

Journal of Indian Academy
of Forensic Medicine
47(4) 423–429, 2025

DOI: 10.1177/09710973251405089
journals.sagepub.com/home/iaf
Sage

Ishita Manral[1], Ravi Rautji[2], Rahul Manral[3], KV Radhakrishna[4], Sarala M[5], Thippesh Kumar N[1] and CS Makhani[1]

Abstract

With the growing senior citizen population, crimes such as elder abuse are on the rise. In India, individuals over 60 years are considered senior citizens. Medico-legal challenges stem from under-reporting and the overlap of abuse-related injuries with natural aging processes. A literature review explored elder abuse, forensic markers, legal frameworks, and case studies shaping protective laws in India and globally. Elder abuse includes physical, emotional, and sexual abuse, neglect, and psychological harm. Identifying abuse-related trauma, such as spiral fractures or injuries to the head, face, or neck, is crucial. Due to limited literature and under-reporting, circumstantial evidence plays a significant role in legal proceedings. Research on forensic markers can help in clinical detection, while a multidisciplinary approach, involving geriatricians, forensic experts, dermatologists, and odontologists, ensures a comprehensive assessment. Strengthening guidelines and raising awareness will enhance the identification and management of elder abuse cases.

Keywords

Elderly abuse, granny battering, physiology, trauma

Received 06 March 2025; **accepted** 10 November 2025

Introduction

India's aging population is rapidly increasing, creating unique healthcare, social, and medico-legal challenges, with elder abuse remaining under-recognized and under-reported.[1,2]

The term "granny battering," coined by G. R. Burston in 1975, was a significant early attempt to highlight the hidden problem of elder mistreatment within domestic settings. Despite increasing recognition, elder abuse remains grossly under-reported due to factors such as emotional dependence on caregivers, cognitive impairments, fear of abandonment, and lack of accessible reporting mechanisms.[3] It is defined as "a single or repeated act, or lack of appropriate action, occurring within any relationship where there is an expectation of trust, which causes harm, or distress to an older person."[4]

Elder abuse in India remains a significantly under-recognized medico-legal problem with major forensic implications. Most cases go unreported due to dependence on caregivers and misinterpretation of inflicted injuries as age-related changes. The absence of standardized medico-legal proformas, limited forensic training for healthcare professionals, and a lack of a forensic databank hinder accurate identification. Inadequate autopsies often label suspicious deaths as "natural," while minimal research and case law obscure the forensic differentiation between senile degeneration and trauma from assault. There are no standardized medico-legal proformas for elder abuse comparable to those for child abuse or sexual assault, and healthcare providers receive limited training in recognizing suspicious injury patterns in older adults. Injury markers unique to elder abuse are poorly studied in the Indian setting, and there is no forensic databank to help distinguish between natural senile changes (such as osteoporosis-related fractures or senile purpura) and trauma caused by assault.[5–7]

[1]Department of FMT, AFMC, Pune, Maharashtra, India
[2]Bhartiya Vidyapeeth (Deemed to be University) Medical College, Pune, Maharashtra, India
[3]High Altitude and Medical Research, General Hospital, Ladakh, India
[4]Military Hospital, Agra, Uttar Pradesh, India
[5]ACMS, New Delhi, India

Corresponding author:
Ishita Manral, Department of FMT, AFMC, Pune, Maharashtra 411040, India.
E-mail: atihsi532@gmail.com

The doctor's role in both clinical and post-mortem settings is critically important. Recognition, diagnosis, treatment, and ongoing follow-up are essential. Elder abuse should always be considered as a differential diagnosis rather than being overlooked. Physicians are responsible for reporting suspected cases to the police. Medico-legal examinations must be conducted with the same rigor as any other case, and any abnormalities should be meticulously documented with relevant photographs or diagrams. In cases of uncertainty, consultation with senior colleagues is recommended. Common obstacles to reporting include concerns about missing a treatable condition, fear of damaging family relationships, potential breaches of confidentiality, and doubts regarding the benefits of reporting.[1,2,7–12]

Highlighting and addressing this gap is essential to enhance the accuracy of forensic assessments, ensure proper legal redressal, and ultimately protect one of the most vulnerable sections of society.

Methodology

This systematic review discusses the literature on forensic markers of elderly abuse.

The research questions in our study were

1. Are there forensic markers of elderly abuse?
2. When should an alarm be raised for elderly abuse, as signs overlap between signs of aging and abuse?

Search Strategy

A systematic review was conducted following the PRISMA guidelines, using electronic databases such as PubMed, Google Scholar, government websites, and elderly non governmental organisations (NGOs) such as HelpAge India and Annapurna Yojna, up to 2023. Textbooks on forensic and geriatric medicine were also referenced. Keywords included: Offenses against the elderly, age criteria, promulgation of guidelines, pioneers of guidelines globally and locally, and relevant case studies. The study was done over a year in 2023. This review included studies that specifically investigated elder abuse, including its types and associated forensic markers. Eligible sources encompassed original research articles, book chapters, theses, dissertations, systematic reviews, literature reviews, meta-analyses, and conference papers reporting primary research findings. Only publications available in English and published up to and including 2023 were considered. Studies were excluded if they did not focus on elder abuse or its forensic markers, or if they were not available in English.

The quality of the included studies was independently assessed by the first two authors using the Critical Appraisal Skills Program checklists. Differences in opinion between the authors were resolved by consensus.

The extracted data included authors, titles, the type of abuse reported to be prevalent, forensic markers, and other markers.

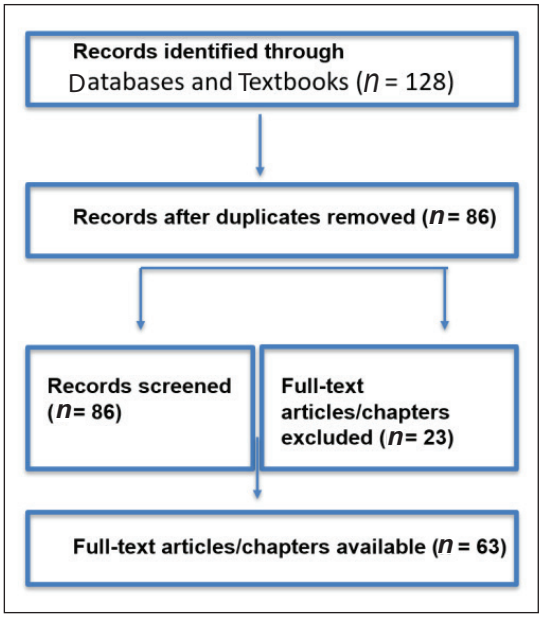

Figure 1. PRISMA Flowchart of the Records Identified and Screened.

The data extraction was implemented by two researchers and was checked for accuracy by a third researcher. This is summarized in Figure 1.

Discussion

Elderly individuals may exhibit signs of abuse such as weight loss, dehydration, injuries, and behavioral changes, leading to malnutrition and depression.[12,13] Abuse includes physical harm, neglect, and sexual exploitation. Recognizing subtle signs is crucial for accurate diagnosis and identifying forensic markers of abuse.[13–31] A comparative of features of elderly abuse are as depicted in Table 1 with differentials enlisted in Table 2. Comparative glimpse of the studies are mentioned in Table 3.

Blunt Force Injury and Old Age

Aging skin is prone to abrasions, contusions, and lacerations. Malnutrition, steroid use, and bed rest increase fracture risk. Medico-legal implications include documenting imprint abrasions, multiple tears, traumatic alopecia, and spiral fractures, which may suggest physical abuse or neglect.[14–16] The features are as depicted in Figure 2.

Bedsores

Bedsores result from interrupted blood flow, with risk factors such as cognitive impairment, diabetes, and poor nutrition. Preventive strategies include repositioning and nutrition. Deep bedsores and necrotic ulcers may indicate neglect due to poor hygiene.[17–19]

Table 1. Summary of Forensic Markers of Abu Differential Diagnosis.[13–31]

Feature	Forensic Marker of Abuse	Rule Out
Blunt force	Abrasion, contusion, laceration, and fracture	History taking: Contusion: Blood thinners make the person susceptible to bruisingLaceration: Medication causing skin to thin, such as steroids
	Forearm and legs: Shearing strain	Investigations: Hip and wrist: Nutritional deficiency, prolonged use of steroids, osteomalacia, metastatic cancer, and alcohol increase the susceptibility to pathological fracture in old age.(Dual energy X-ray absorptiometry scanning, revealing osteopenia, is helpful)
	Multiple tears other than in legs or arms at different stages of healing	History:However, due to a change in gait and balance, they may have abrasion, laceration, etc.
	Head, spine, and trunk fractures, a spiral fracture in long bones, are likely to be injuries sustained due to assault	Investigations:Pathological fractures due to underlying deficiencies
	Injuries to the eyes, nose, and mouth are mostly assault	History
	Adults with a bruise of >5 cm on the head, neck, ears, outer side of arms, buttocks, sole of feet, palms of hands	
	Bite marks are suggestive of assault	
Bed sores	Deep ulcers, necrotic Immobile older adult	History and investigations: Mental illness, cognitive impairment, acute illness, peripheral vascular diseases, diabetes mellitus, and poor nutritional status are risk factors for the development of bedsores
Malnutrition, weight loss, and dehydration	Signs of neglect with dependency on caregivers for food	History: Due to drugs, mental illness, senility, etc.
Sexual abuse	Bleeding from the anogenital region, oral venereal lesions, and bruising of the palate indicate oral sexual abuse. Institutionalized women with UTIs, fear, or behavioral changes may also suggest abuse	History and investigations: Prone to urinary tract infection due to diseases such as diabetes mellitus or drugs

Note: UTIs: Urinary tract infections.

Table 2. Differentials for Elderly Abuse.

Type of Abuse	Differentials Considered
Neglect	Chronic diseases: Diabetes Mellitus, Alzheimer's disease, uncontrolled diabetes mellitus, hyperpigmentation disorders
Physical abuse	Syncope and loss of consciousness, such as dysrhythmia, seizures, acute coronary syndromes, and hypoglycemia Aging: Delayed healing Medications: Causing increased risk of falls, such as antipsychotics, opioids, anti-cholinergics, antihypertensives, and antiparkinsonian drugs Non-syncopal mechanical causes: Such as decreased visual acuity, alcohol, sedatives, and neurological diseases
Sexual abuse	Menopausal, atrophy, cancer, polyps, dermatological conditions such as lichen sclerosis, vulvovaginitis, prolapsed urethra/urethrocoele Rectal bleed: Due to constipation, inflammatory bowel disease, infectious diarrhea, polyps, and lichen sclerosis

Table 3. Comparative Glimpse of the Studies.

Author	Type of Abuse	Prevalence	Forensic Markers	Other Markers
Mattoo et al.[35]	Combination of abuse > psychological abuse > neglect	39.85%	Enumerated and data shown	Individuals with dementia and depression are more prone to further abuse
Joyce[36]	Sexual abuse > verbal abuse	Not mentioned	Not mentioned	The aggressor had a cognitive impairment
Patel et al.[37]	psychological abuse > neglect, > exploitation > physical abuse	24%.	Not mentioned	Daughters-in-law and sons were the most common perpetrators. Illiteracy and severe depression were found to be the predictors of abuse
Martins et al.[38]	emotional kind > neglect	23.5%	No	Unmarried, widows, lower academic qualifications are at-risk.
Petti[39]	–	–	"Traumatic injuries due to lack of caregiver vigilance (e.g., maxillofacial fractures)diseases due to oral hygiene deficiency (e.g., root caries); diseases typical of the elderly with late/no diagnosis (e.g., oral cancer); and[4] diseases typical of the elderly exacerbated by psychological distress (oral lichen planus)."	
Wiklund et al.[40]	Not mentioned	17.8%.	Not mentioned	Being abused before the age of 65 was the only background factor associated with elder abuse
van Houten et al.[41]	Physical abuse > sexual abuse		Bruises: head, face/maxillofacial area (including eyes, ears, and dental area), neck, upper extremities, and torso (especially posterior).	

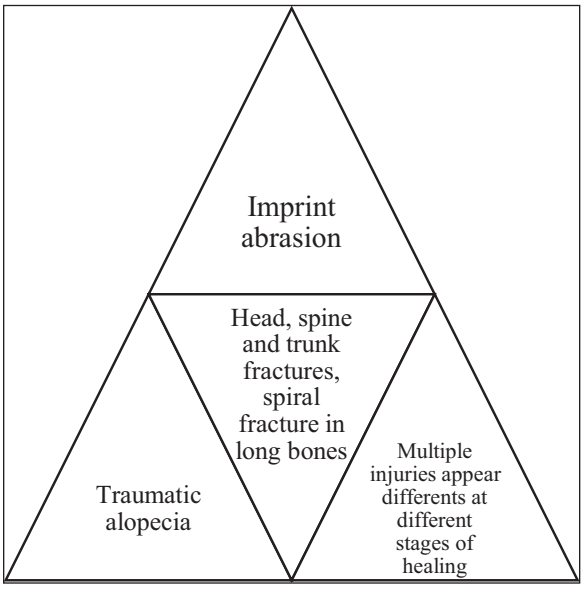

Figure 2. Markers of Physical Abuse in the Elderly.

Malnutrition

Dental issues, medications, and impaired cognition in older adults lead to weight loss and nutritional deficiencies, suggesting neglect.[14,15,21]

Dehydration

Hydration status in older adults is hard to assess. Confusion, somnolence, weight changes, or vital fluctuations may indicate neglect.[14,20,21]

Bone fractures by radiological exams, coagulation profile, liver tests, and bone densitometry help evaluate fractures and neglect signs.[22]

Negligence

Inadequate care in elderly patients, such as untreated wounds and pressure sores, raises suspicion of negligence.[23,24] The features are as depicted in Figure 3.

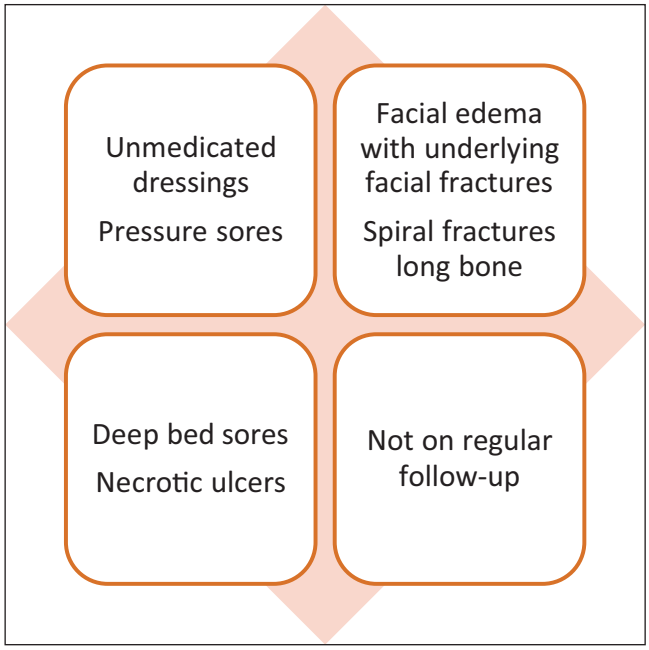

Figure 3. Markers of Neglect in the Elderly.

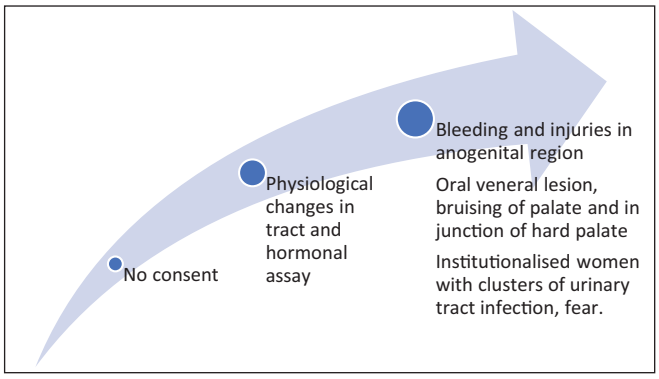

Figure 4. Markers and Reasons of Sexual Abuse in the Elderly.

Sexual Abuse

Sexual abuse includes non-consensual contact. Anogenital bleeding, oral lesions, and recurrent urinary tract infections (UTIs) in elderly women suggest possible abuse or victimization.[25]

Elders often hesitate to report abuse, blaming themselves and choosing silence. In clinical settings, the Hwalek–Sengstock Elder Abuse Screening Test assesses psychological factors. The Conflict Tactics Scale is modified for elders, while the Vulnerability to Abuse Screening Scale helps identify at-risk individuals, aiding early detection and intervention.[27]

Physicians are legally obligated to report suspected elder abuse under the Married Women Protection Act, Indian Penal Code Criminal Procedure Code Sec. 44, and CrPC Sec. 125; however, under-reporting persists, often due to fear, uncertainty, and limited awareness. The medico-legal challenges in proving abuse are significant: Age-related physiological changes, delayed disclosure, and incomplete documentation can obscure trauma or mimic injury, complicating both clinical assessment and legal proceedings. While an autopsy can reveal critical evidence—such as malnutrition, pressure ulcers, untreated injuries, and fractures inconsistent with history—the interpretation of findings requires careful consideration to distinguish neglect or abuse from natural age-related conditions.[11,26–28,31–34] The features are as depicted in Figure 4.

Structured screening tools such as the Hwalek–Sengstock Elder Abuse Screening Test, Elder Abuse Suspicion Index, and Vulnerability to Abuse Screening Scale show promise in enhancing early detection, systematic documentation, and generation of legally admissible evidence. Yet, their routine implementation remains limited, raising questions about feasibility, clinician training, and integration into workflow.

Post-mortem examinations offer important insights into abuse-related deaths, but reliance on autopsy alone is insufficient. Forensic evaluation—including nutritional assessment, examination of skin and soft tissue injuries, skeletal analysis, and toxicology—must be interpreted alongside clinical history, caregiver interviews, and comorbidity profiles. Even then, distinguishing neglect from natural deterioration is often ambiguous, highlighting the need for rigorous standards and multi-disciplinary input.

Forensic markers—unexplained bruises, fractures, burns, rope marks in varying stages of healing, unusual pressure ulcers, and behavioral changes—provide important clues, yet overlap with age-related or iatrogenic changes, complicating interpretation. Effective detection requires pattern recognition, comprehensive assessment, and consistent professional training. Critically, delayed reporting not only worsens patient outcomes but also undermines the legal process, emphasizing that meticulous documentation and early intervention are as essential as the forensic findings themselves.

Conclusion

Elderly abuse is under-researched and under-reported, forcing authorities to rely on circumstantial evidence. Research on forensic markers aids healthcare professionals in identifying abuse. A multidisciplinary approach, including geriatricians, forensic experts, dermatologists, and odontologists, is crucial for accurate evaluations, considering aging-related changes that may obscure abuse signs.

Recommendations

Further studies are needed to amend laws, mandate reporting of elder deaths in care homes, and develop evidence-based screening tools for abuse.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

Not applicable.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent

Not applicable.

ORCID iD

Ishita Manral https://orcid.org/0000-0002-5998-9832

References

1. Govt. of India. *Census of India 2011*. New Delhi: Govt. Press; 2012 [cited 2025 Dec 21]. https://censusindia.gov.in/vital_statistics/SRS_Report/9Chap%202%20-%202011.pdf
2. Central Statistics Office, Ministry of Statistics and Programme Implementation Government of India. *Situation analysis of the elderly in India*. New Delhi: Government of India, 2016, pp. 7–9. https://www.mospi.gov.in/sites/default/files/publication_reports/ElderlyinIndia_2016.pdf
3. World Health Organization (WHO). A global response to elder abuse and neglect: Building primary health care capacity to deal with the problem worldwide: Main report. 2008. http://apps.who.int/iris/bitstream/10665/43869/1/9789241563581_eng.pdf
4. World Health Organization. *The Toronto Declaration on the Global Prevention of Elder Abuse*. Geneva: World Health Organization, 2002. https://www.who.int/news-room/fact-sheets/detail/abuse-of-older-people
5. Burston GR. Letter: Granny-battering. *Br Med J* 1975; 3(5983): 592. DOI: 10.1136/bmj.3.5983.592-a
6. Homer AC and Gilleard C. Abuse of elderly people by their carers. *Br Med J* 1990; *301*(6765): 1359–1362. DOI: 10.1136/bmj.301.6765.1359
7. Podnieks E, Pillemer KN, Phillip J, et al. *National survey on abuse of the elderly in Canada: The Ryerson study*. Toronto: Ryerson Polytechnical Institute, 1990. https://www.ojp.gov/ncjrs/virtual-library/abstracts/national-survey-abuse-elderly-canada-ryerson-study
8. Skirbekk V and James KS. Abuse against elderly in India–the role of education. *BMC Public Health* 2014; *14*: 336. DOI: 10.1186/1471-2458-14-336
9. Acuña HR. The United Nations World assembly on the elderly. *Bull Pan Am Health Organ* 1981; *15*(1): 1981. https://iris.paho.org/handle/10665.2/26860
10. Jin K, Simpkins JW, Ji X, et al. The critical need to promote research of aging and aging-related diseases to improve health and longevity of the elderly population. *Aging Dis* 2014; 6(1): 1–5. DOI: 10.14336/AD.2014.1210
11. Maintenance and Welfare of Parents and Senior Citizens Act 2007 (2007) Ministry of Law and Justice, New Delhi. https://www.indiacode.nic.in/bitstream/123456789/6831/1/maintenance_and_welfare_of_parents_and_senior_citizens_act.pdf
12. DiMaio VJM and DiMaio DJ. *Forensic pathology*. 2nd ed. CRC Press, Boca Raton, FL, 2001, pp. 91–116.
13. Quinn MJ and Tomika SK. *Elder abuse and neglect*. 2nd ed. Springer: New York, NY, 1997, pp. 49–179.
14. Marshall CE, Benton D and Brazier JM. Elder abuse: Using clinical tools to identify clues of mistreatment. *Geriatrics* 2000; 55: 42–53.
15. Malone M, Rozario N, Gavinski M, et al. The epidemiology of skin tears in the institutionalized elderly. *J Am Geriatrics Soc* 1991; 39: 591–595. https://pubmed.ncbi.nlm.nih.gov/2037750/
16. Singer AJ and Clark RAF. Cutaneous wound healing. *N Engl J Med* 1999; 341: 738–746. https://pubmed.ncbi.nlm.nih.gov/10471461/
17. Saukko P and Knight B. *Knight's forensic pathology*. 3rd ed. Oxford University Press: New York, NY, 2004, pp. 136–173.
18. Fulmer T, Street S and Carr K. Abuse of the elderly: Screening and detection. *J Emerg Nurs* 1984; 10: 131–140. https://pubmed.ncbi.nlm.nih.gov/6374226/
19. Freedman VA, Martin LG and Schoeni RF. Recent trends in disability and functioning among older adults in the US: A systematic review. *JAMA* 2002; 288: 3137–3146. https://pubmed.ncbi.nlm.nih.gov/12495394/.
20. Schor JD, Selby A and Bertone CA. Geriatric assessment in the diagnosis and treatment of elder abuse. *N J Med* 1995; 92: 108–110. https://pubmed.ncbi.nlm.nih.gov/7870375/
21. Harrell R, Toronjo CH and McLaughlin J, et al. How geriatricians identify elder abuse and neglect. *Am J Med Sci* 2002; 323(1): 34–38. https://pubmed.ncbi.nlm.nih.gov/11814140/
22. Kavak RP and Özdemir M. Radiological appearance of physical elder abuse. *Eur Geriatr Med* 2019; 10(6): 871–878. https://pubmed.ncbi.nlm.nih.gov/34652775/
23. Ho CS, Wong SY, Chiu MM, et al. Global prevalence of elder abuse: A metaanalysis and meta-regression. *East Asian Arch Psychiatry* 2017; 27(2): 43–55. https://search.informit.org/doi/10.3316/informit.903958411380250
24. Kyu HH, Abate D, Abate KH, et al. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; 392: 1859–1922. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)32335-3/fulltext
25. Butler RN and Lewis MI. Sexuality in old age. In: Tallis R and Fillit HM (eds) *Brocklehurst's textbook of geriatric medicine and gerontology*, 6th ed. Churchill Livingstone: London, UK, 2003, pp. 1407–1412.
26. Ratanlal R and Dhirajlal KT. The Indian penal code. New Delhi, 2017. https://archive.org/details/in.ernet.dli.2015.95798
27. Rosen T, Platts-Mills TF and Fulmer T. Screening for elder mistreatment in emergency departments: Current progress and recommendations for next steps. *J Elder Abuse Negl* 2020; 32(3): 295–315. DOI: 10.1080/08946566.2020.1768997
28. Dhirajlal R. *Criminal procedure code*. Universal, Delhi, 1999. https://archive.org/details/in.ernet.dli.2015.95798
29. Soneja S. Elder abuse in India. *Country report to World Health Organization*. HelpAge India, New Delhi, 2011. https://www.helpageindia.org/donate/?utm_source=google&utm_medium=cpc&utm_campaign=brandkeywords&gad_source=1&gad_campaignid=16493678325&gbraid=0AAAADzmkaaRSGjCiSQVxtyFRaubArlTt&gclid=Cj0KCQjw9czHBhCyARIsAFZlN8QQUF519fFQ_bHO4x3bAQ_kXaqAYjnh-gT93Zqi7eeOdxthHNz7xCU8aAtWMEALw_wcB

30. Paris BE, Meier DE, Goldstein T, et al. Elder abuse and neglect: How to recognize warning signs and intervene. *Geriatrics* 1995; 50(4): 47–51. quiz 52–53. https://pubmed.ncbi.nlm.nih.gov/7721114/
31. Help Age India. *A Youth Perspective on Elder Abuse (Elder Abuse: The Indian Youth Speaks Out)*. New Delhi, 2015. https://www.scirp.org/reference/referencespapers?referenceid=1862575
32. Community Policing for Senior Citizens. Micromission 2020. *National mission compendium for Police*. https://bprd.nic.in/uploads/pdf/20191206034544717139 5NPMCompendium2018.pdf
33. Wang XM, Brisbin S, Loo T, et al. Elder abuse: An approach to identification, assessment and intervention. *CMAJ* 2015; 187(8): 575–581. DOI: 10.1503/cmaj.141329
34. Mosqueda L, Sivers-Teixeira T and Hirst S. Recognizing elder mistreatment: A guide for courts. *Ct. Rev* 2017; 53: 54. https://digitalcommons.unl.edu/ajacourtreview/620/
35. Mattoo KA, Garg R and Kumar S. Geriatric forensics-Part 2 "Prevalence of elder abuse and their potential forensic markers among medical and dental patients". *J Forensic Dent Sci* 2015; 7(3): 201–207. DOI: 10.4103/0975-1475.172436
36. Joyce CM. Prevalence and nature of resident-to-resident abuse incidents in Australian residential aged care. *Australas J Ageing* 2020; 39(3): 269–276. DOI: 10.1111/ajag.12752
37. Patel VK, Tiwari DS, Shah VR, et al. Prevalence and predictors of abuse in elderly patients with depression at a tertiary care centre in Saurashtra, India. *Indian J Psychol Med* 2018; 40(6): 528–533. DOI: 10.4103/IJPSYM.IJPSYM_18_18
38. Martins R, Neto MJ, Andrade A, et al. Abuse and maltreatment in the elderly. *Aten Primaria* 2014; 46(Suppl 5): 206–209. DOI: 10.1016/S0212-6567(14)70093-9
39. Petti S. Elder neglect-oral diseases and injuries. *Oral Dis* 2018; 24(6): 891–899. DOI: 10.1111/odi.12797
40. Wiklund N, Ludvigsson M, Nägga K, et al. Elder abuse and life-course victimization in hospitalized older adults in Sweden: Prevalence and associations with mental ill-health. *BMC Geriatr* 2022; 22(1): 929. DOI: 10.1186/s12877-022-03638-8
41. van Houten ME, Vloet LCM, Pelgrim T, et al. Types, characteristics and anatomic location of physical signs in elder abuse: A systematic review: Awareness and recognition of injury patterns. *Eur Geriatr Med* 2022; 13(1): 53–85. DOI: 10.1007/s41999-021-00550-z

Sudden Death Due to Rupture of Undiagnosed Saccular Aneurysm in a Young Adult Female: A Case Report

Journal of Indian Academy
of Forensic Medicine
47(4) 430–433, 2025

DOI: 10.1177/09710973251411628
journals.sagepub.com/home/iaf
Sage

Surya Prakash L. R. A.[1], Mahendra Sharma[1] and Bajrang Kumar Singh[1]

Abstract

Intracranial saccular (berry) aneurysms often remain asymptomatic until rupture, posing considerable diagnostic and medico-legal challenges when sudden death occurs outside healthcare facilities. We report the case of a 30-year-old female police officer who collapsed suddenly at home, with a history of occupational stress and recurrent headaches. Autopsy revealed diffuse subarachnoid hemorrhage, a 0.8 cm saccular aneurysm on the left posterior communicating artery, and a collapsed aneurysmal sac with multiple rupture sites on the left anterior communicating artery, with approximately 200 g of intracranial blood and cerebral edema. The findings confirmed a fatal aneurysmal rupture. Neither toxicological analysis nor histopathological examination was undertaken in this case, and other organs were unremarkable. This case underscores the risk of sudden death from multiple aneurysms in young adults and highlights the medico-legal significance of missed sentinel symptoms, emphasizing the necessity of timely neuroimaging in at-risk individuals.

Keywords

Saccular aneurysm, subarachnoid hemorrhage, posterior communicating artery, anterior communicating artery, sudden death

Received 17 May 2025; **accepted** 14 December 2025

Introduction

Saccular aneurysms constitute the majority of intracranial aneurysms and typically manifest only upon rupture, resulting in subarachnoid hemorrhage (SAH) with high mortality.[1–3] Although their prevalence in the general population is low, multiple aneurysms are reported in a significant minority of cases, particularly among females.[1] The present case is noteworthy for the coexistence of multiple aneurysms in a young adult, with acute occupational stress serving as a possible temporal trigger preceding sudden collapse. This raises important pathogenetic and medico-legal considerations concerning asymptomatic disease and unexpected death in the community. The case also highlights that recurrent headaches may represent sentinel events preceding rupture, and failure to investigate such warning symptoms may have legal implications when sudden death ensues. Previous medico-legal studies published in the Journal of Indian Academy of Forensic Medicine have also reported patterns of sudden unexpected natural deaths, including cases involving intracranial hemorrhage and neurovascular pathology.[4,5]

Case History

On September 27, 2024, the body of a 30-year-old married female police officer was brought to the mortuary of our institute with an alleged history of sudden, unexpected death of unknown cause. The deceased had no known comorbidities or history of substance abuse and was reportedly carrying out her routine activities until the terminal event. She had a history of recurrent headaches for which she had consulted general practitioners. From the evening of September 25, 2024, until late night on September 26, 2024, she remained continuously on duty. After returning home and having dinner around 11:30 PM, she discussed work-related stress with her husband. At approximately 5:30 AM on the day of death, she developed

[1]Department of Forensic Medicine and Toxicology, MGM Medical College, Indore, Madhya Pradesh, India

Corresponding author:
Surya Prakash L R A, Department of Forensic Medicine and Toxicology, MGM Medical College, Indore, Madhya Pradesh 452001, India.
E-mail: stanlean2012@gmail.com

a sudden, severe headache and collapsed. She was immediately taken to a hospital, where she was declared dead.

Autopsy Findings

The eyes and mouth were closed; the corneas were hazy; the tongue was inside; and the nostrils were clear. The extremities were straight with semi-open fists; rigor mortis was present throughout the body; and hypostasis was fixed over the back. Faint cyanosis was noted on the ear lobules and nose. A petechial hemorrhage (1.0 × 0.5 cm) was observed on the mid-left upper eyelid. Multiple old, healed hesitation cut marks were noted on the left wrist, consistent with remote self-harm, without active inflammation or fresh hemorrhage. Petechial hemorrhages were present on both parietal scalp regions; the skull and neck vertebrae were intact and healthy; and the meninges were tense. SAH was present over the cerebrum and cerebellum, with clotted and fluid blood in the posterior aspect of the lateral ventricles (Figure 1). A collapsed saccule with multiple bleeding points was found on the left anterior communicating artery (Figure 2). A 0.8 cm saccule was present on the left posterior communicating artery near its junction with the left middle cerebral artery (Figure 3). The base of the brain showed ruptured arterial branches and ecchymosis, mainly laterally; the brain was congested and edematous (Figure 4). The cranial cavity contained approximately 200 g of fluid and clotted blood. Pinkish froth was present in the trachea. The heart weighed 247 g with grossly patent coronaries. The other internal organs were grossly normal and congested, and the stomach contained yellowish, pasty material with normal mucosa. Neither toxicological analysis nor histopathological examination was undertaken.

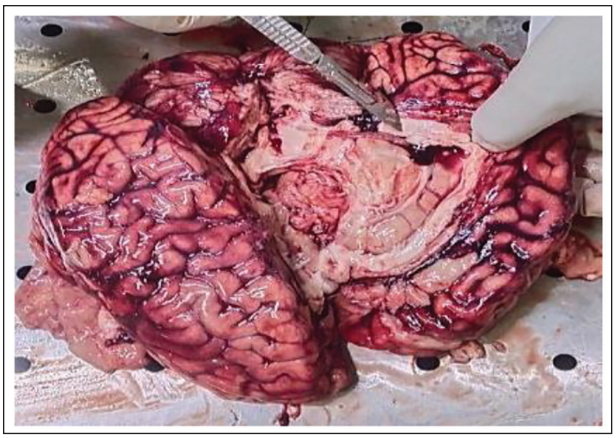

Figure 1. Presence of Subarachnoid Hemorrhage All Over the Brain Surface with the Presence of Clotted and Fluid Blood in Posterior Aspect of Lateral Ventricles.

Source: Medicolegal autopsy records provided by investigating officers.

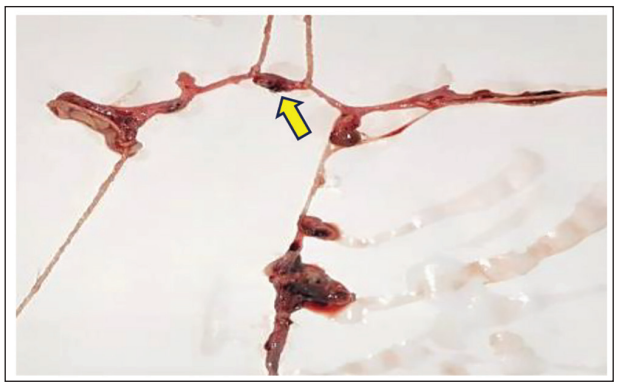

Figure 2. Collapsed Saccule with Multiple Bleeding Points on the Left Anterior Communicating Artery (Yellow Arrow).

Source: Medicolegal autopsy records provided by investigating officers.

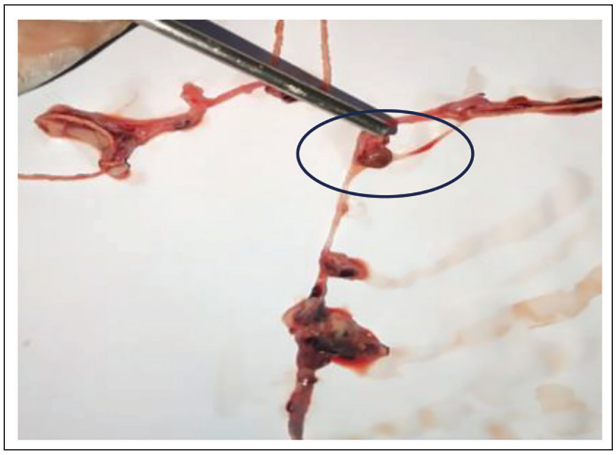

Figure 3. Saccule on the Left Posterior Communicating Artery Near Its Junction with the Left Middle Cerebral Artery (Blue Circle).

Source: Medicolegal autopsy records provided by investigating officers.

Figure 4. Base of the Brain Showing Ruptured Arterial Branches and Ecchymosis.

Source: Medicolegal autopsy records provided by investigating officers.

Discussion

Death in this case was due to cardiorespiratory failure consequent to rupture of an intracranial saccular aneurysm with diffuse SAH, in the presence of multiple aneurysms. Although the heart was anatomically normal, systemic hypertension cannot be fully excluded.

The mean age of incidence of intracranial saccular aneurysms is approximately 50 years.[1] Rupture leading to sudden death in the third decade of life is uncommon and poses diagnostic challenges because of its often silent antecedent course.

Common sites of intracranial saccular aneurysms include the anterior communicating artery, posterior communicating artery, internal carotid artery, middle cerebral artery, and basilar artery bifurcation.[6] These findings correspond with the observations in the present case.

The pathogenesis of intracranial aneurysms is multifactorial. Hemodynamic stress and associated inflammatory responses cause maladaptive vascular remodeling, which weakens the arterial wall and predisposes it to aneurysm formation.[7] Risk factors include female sex, smoking, hypertension, and genetic predisposition.[1,6,8,9] Multiplicity of aneurysms is frequently associated with a familial component,[8] although such a history was unavailable in this case. While a genetic contribution remains possible, it cannot be confirmed in the absence of specific genetic or syndromic markers.

The presence of aneurysms in the anterior and posterior communicating segments of the circle of Willis in the present case is consistent with observations reported by Koutsothanasis GA et al.[1]

Psychological or physical stress has been shown to precipitate aneurysmal rupture by transiently increasing transmural pressure and wall stress in predisposed vessels.[10–12] In this case, prolonged duty, occupational stress, and a thunderclap headache preceding collapse strongly suggest that acute stress may have acted as a precipitating trigger. This finding aligns with the work of Cooke DL et al.,[10] Hoyer C et al.,[11] and Müller-Forell W and Bohl J,[12] who described associations between psychiatric comorbidity, stress, and cerebrovascular events.

Healed hesitation cuts were observed over the left wrist, consistent with a prior episode of self-harm. They showed no evidence of recent hemorrhage or vital reaction and had no causal relationship with the terminal event. Although unrelated to death certification, documentation of such findings is essential for comprehensive medico-legal evaluation and may provide insight into psychosocial background, particularly in cases where psychiatric comorbidity may influence cerebrovascular vulnerability. Similar associations between psychiatric conditions and cerebrovascular events have been reported by Cooke DL et al.[10] and Hoyer C et al.[11]

No gross autopsy findings or circumstantial evidence suggested ingestion of any toxic substance; therefore, viscera were not preserved for chemical analysis. The coronary arteries were patent on gross examination, and the heart, as well as other visceral organs, appeared normal and healthy. Consequently, tissues were not retained for histopathological examination to avoid unwarranted use of laboratory resources in the absence of specific diagnostic indications.

This case demonstrates that fatal rupture of previously silent intracranial aneurysms can occur even in young adults, an age group considerably below the mean incidence of approximately fifty years reported in population studies.[1] The aneurysms in this patient involved the anterior and posterior communicating arteries, the sites most frequently described in published literature,[6] and their coexistence supports the established role of hemodynamic stress and inflammatory remodeling in aneurysm formation.[7] The presence of multiple aneurysms further indicates a potential genetic or familial predisposition.[8] Although no hereditary disorder was identified in this case, previous studies have shown that inherited conditions such as autosomal dominant polycystic kidney disease are associated with an increased risk of intracranial aneurysm formation.[13] From a medico-legal perspective, these findings underscore the importance of promptly recognizing sentinel headaches and ensuring appropriate neuroimaging in symptomatic individuals. Furthermore, therapeutic experiences reported by Mitsuhashi et al.[14] emphasize that early identification and timely management of posterior communicating artery aneurysms are vital to prevent catastrophic rupture.

Conclusion

Fatal rupture of undiagnosed intracranial aneurysms reinforces the necessity for heightened clinical vigilance in individuals presenting with unexplained or recurrent headaches. Early recognition of such warning symptoms and appropriate diagnostic evaluation are essential to prevent missed diagnoses and potential allegations of medical negligence. It further underscores the necessity of meticulous autopsy examination and accurate death certification to ensure precise determination of the cause of death and to uphold the integrity of medico-legal adjudication.

Authors' Contribution

All authors have contributed to this manuscript.

Availability of Data and Materials

Data sharing are not applicable.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

Not applicable as a Medico-legal autopsy does not require consent.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent

Authors declare consent for publication.

ORCID iD

Surya Prakash L R A https://orcid.org/0009-0004-8574-446X

References

1. Koutsothanasis GA and Sampath R. Berry aneurysm. In: *StatPearls* [Internet]. Treasure Island (FL): StatPearls Publishing, 2025 January. Available from: https://www.ncbi.nlm.nih.gov/books/NBK557480/
2. Sapate AB, Petkar MR, Arora P, et al. Evaluation of intracranial pathologies causing sudden deaths and its survival time: An autopsy study. *J Indian Acad Forensic Med* 2018; 40(2): 209–212.
3. Punitha R, Pradeep Kumar MV, Rayamane AP, et al. Natural intracranial hemorrhage and its forensic implications: A case review. *J Indian Acad Forensic Med* 2014; 36(2): 215–217.
4. Dayananda R, Pradhan P and Kumar MP. Pattern of sudden natural deaths among autopsies conducted at Mysore Medical College. *J Indian Acad Forensic Med* 2018; 40(2): 146–150.
5. Angam G, Maring SK, Singh KP, et al. A study of pattern of sudden natural deaths: A JNIMS experience. *J Indian Acad Forensic Med* 2017; 39(2): 180–183.
6. Zhou S, Dion PA and Rouleau GA. Genetics of intracranial aneurysms. *Stroke* 2018; 49(3): 780–787. DOI: 10.1161/STROKEAHA.117.018152
7. Turjman AS, Turjman F and Edelman ER. Role of fluid dynamics and inflammation in intracranial aneurysm formation. *Circulation* 2014; 129(3): 373–382. DOI: 10.1161/CIRCULATIONAHA.113.001444
8. Huguenard AL, Gupta VP, Braverman AC, et al. Genetic and heritable considerations in patients or families with both intracranial and extracranial aneurysms. *J Neurosurg* 2021; 134(6): 1999–2006. DOI: 10.3171/2020.8.JNS203234
9. Hitchcock E and Gibson WT. A review of the genetics of intracranial berry aneurysms and implications for genetic counseling. *J Genet Couns* 2017; 26(1): 21–31. DOI: 10.1007/s10897-016-0029-8
10. Cooke DL, Shen H, Duvvuri M, et al. Association of select psychiatric disorders with incident brain aneurysm and subarachnoid hemorrhage among veterans. *Front Integr Neurosci* 2023; 17: 1207610. DOI: 10.3389/fnint.2023.1207610
11. Hoyer C, Schmidt HL, Kranaster L, et al. Impact of psychiatric comorbidity on the severity, short-term functional outcome, and psychiatric complications after acute stroke. *Neuropsychiatr Dis Treat* 2019; 15: 1823–1831. DOI: 10.2147/NDT.S206771
12. Müller-Forell W and Bohl J. Psychic stress as a trigger of the spontaneous development and rupture of an aneurysm? A case report. *Interv Neuroradiol* 1999; 5(2): 179–186. DOI: 10.1177/159101999900500212
13. Niemczyk M, Gradzik M, Fliszkiewicz M, et al. Natural history of intracranial aneurysms in autosomal dominant polycystic kidney disease. *Neurol Neurochir Pol* 2017; 51(6): 476–480. DOI: 10.1016/j.pjnns.2017.07.010
14. Mitsuhashi T, Takeda N and Oishi H. Parent artery occlusion for ruptured "true" posterior communicating artery aneurysm. *Interv euroradiol* 2015; 21(2): 171–174. DOI: 10.1177/1591019915581215

Analysis of a Rare Case of Complex Suicide Involving Hanging and Abdominal Cuts: A Case Report

Journal of Indian Academy
of Forensic Medicine
47(4) 434–439, 2025

DOI: 10.1177/09710973251411981
journals.sagepub.com/home/iaf
Sage

Gebremariam Tewelemedhin Gebremariam[1], Charles Karangwa[1], Innocent Nkurunziza[1], Justin Kabera[1] and Muvunyi Jean Baptiste[1]

Abstract

Complex suicide is a rare and intricate occurrence posing considerable difficulties in forensic practice in determining the manner of death. We present a case involving a 48-year-old right-handed man with a history of depression who was discovered dead and hung from a tree. Autopsy revealed an oblique ligature mark and multiple superficial horizontal incised wounds in the abdominal wall, with no evidence of defensive injuries, restraint marks, or poisoning. The individual's medical history, patterns of the ligature mark and abdominal wounds, and lack of disturbance supported the classification of the case as a complex suicide. This case report contributes to the existing literature on the forensic handling of complex suicides, emphasizing the vital role of a multidisciplinary approach in postmortem investigations. This study also highlights the importance of improved management strategies for individuals with depressive disorders to prevent such outcomes.

Keywords

Ligature mark, abdominal hesitation cuts, suicidal hanging, complex suicide

Received 21 July 2025; **accepted** 14 December 2025

Introduction

Suicide, defined as the deliberate act of ending one's own life, is a major global public health concern.[1,2] Suicide methods include, but are not limited to, suffocation or hanging, poisoning or drug overdose, injuries from firearms, drowning, leaping from high places, stabbing, and other techniques, with hanging being the most prevalent in developing countries.[3,4] Individuals who commit suicide may opt for a single method, referred to as simple suicide, or they might employ a combination of two or more methods, either simultaneously or sequentially, which is termed complex suicide.[5] Complex suicide is a rare and intricate occurrence, accounting for 1.5%–5% of all suicide cases.[5] Nevertheless, forensic experts face considerable difficulties in differentiating it from other homicides or accidents.[6] Complex suicides may involve several injuries, a mix of methods, atypical situations, or unusual wound types that are not characteristic of straightforward suicides and may resemble those from an assault.[7–9] In addition, the absence of clear suicide indicators, such as a missing suicide note or weapon at the scene, can complicate the confirmation of suicide and may lead to suspicions of murder or accidental deaths.[10] The staging of crime scenes in murder cases, where offenders might arrange the scene to look like a suicide when it is actually a homicide, adds another layer of complexity to the discrimination.[11] Another crucial challenge is the need to integrate various data sources, which may not always be easily accessible, including the deceased's medical and psychosocial history and the circumstances of death, with autopsy findings.[12] This necessitates a thorough multidisciplinary postmortem investigation approach involving forensic pathologists, investigators, and other experts in the field.[13,14]

This case report concerns a rare instance of complex suicide involving both hanging and self-inflicted abdominal cuts. The aim of the study is to understand the importance of using a multidisciplinary approach in postmortem investigations to distinguish complex suicide cases from potential

[1]Rwanda Forensic Institute, Kigali, Rwanda

Corresponding author:
Gebremariam Tewelemedhin Gebremariam, Rwanda Forensic Institute, KN 8 Avenue, Gasabo-Kacyiru, P.O. Box 979, Kigali, Rwanda.
E-mails: gtewe21@gmail.com; gebremariam.tewelemedhin@rfi.gov.rw

homicides or accidents. By examining the deceased's medical history, crime scene findings, autopsy results, and circumstances of death, this study enhances the understanding of complex suicide techniques and their significance in forensic practice.

Case Presentation

A 48-year-old right-handed male was found dead hanging from a tree in a wooded area close to his residential area. Five years prior, the patient was diagnosed with a depressive disorder and was prescribed antidepressant medications. However, over time, it became apparent that the patient was not consistently following the prescribed treatment. The patient then disappeared after he was last observed to be in relatively good health. Thereafter, he inflicted several superficial cuts on his abdomen and ultimately ended his life by hanging himself from a tree using his shirt as a ligature. He was then found deceased, hanging from a tree, 10 hours after he went missing, and an autopsy was conducted the day after his body was discovered. No evidence of suicide notes or sharp materials was detected at the death scene. The patient had no history of substance abuse or other long-term medical conditions and was a married man living with his family. The body was fully suspended by the shirt, with the feet 30 cm above the ground, and there was no evidence of recent damage or disturbance to the dressing. Dried blood stains were detected on the fingertips of the left hand.

External examination revealed a shirt ligature material entangled over the neck, with the right sleeve encircling the neck and the left sleeve forming the suspension part (Figure 1). A 38 cm × 01 cm × 0.6 cm dark brown oblique incomplete ligature mark was revealed encircling the neck above the thyroid cartilage, which extended upward and laterally to the left and faded on the left lateral side (Figure 2). The ligature mark was positioned 08 cm below the center of the mandible, 06 cm below the right external auditory meatus, and 11 cm below the occipital protuberance, with swollen and subtle hemorrhagic edges and a furrowed, dry base. The ligature material measured 115 cm in its suspension part and 42 cm in its encircling part, showing no signs of tears or blood stains. No dried saliva stains were observed around the mouth, neck, or on the T-shirt or the ligature. The tongue, lips, and fingernails appeared cyanotic, and the tip of the tongue was trapped between the tightly clenched teeth. The abdominal wall showed eight superficial, closely spaced, horizontal, and roughly parallel overlapping incised wounds 03 cm above the umbilicus traversing the midline and tailing to the right, with one more pronounced and deeper wound in the center (Figure 3). The wounds were clean-cut, everted, and a combination of linear and spindle-shaped without significant staining of the spurted blood. In addition, two superficial, shallow, and horizontal incised wounds were noted in the right upper quadrant of the abdominal wall, tailing to the right (Figure 3).

Internal examination of the neck revealed dry, shiny, and pale tissues underneath the ligature mark, with no hemorrhage in the muscle compartments. The hyoid bone and thyroid cartilage showed no evidence of fracture. The abdominal wounds were confined to the superficial skin layers. Other examination findings were normal. Blood, stomach contents, bile, and urine samples were collected for drug and toxicology screening, which yielded negative results for all samples. The autopsy report concluded that the cause of death was hanging, the manner of death was determined to be suicide,

Figure 1. The Body on the Autopsy Table Showing a Shirt Ligature Material (the Deceased's Own Shirt) In Situ Over the Neck, with the Right Sleeve of the Shirt Encircling the Neck (Red Arrow) and the Left Sleeve Forming the Suspension Part (Yellow Arrow).

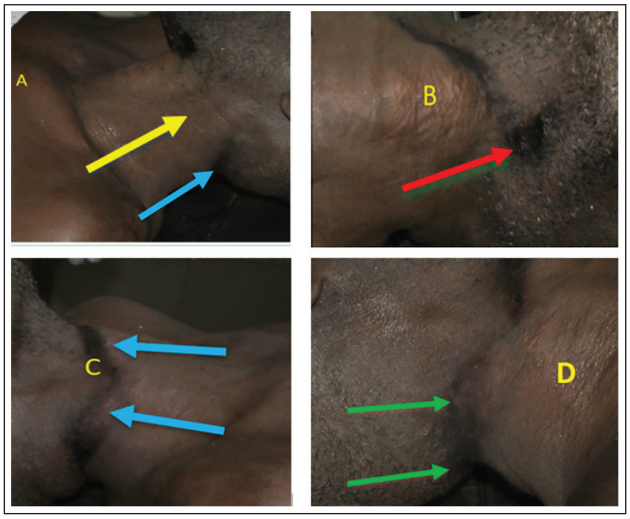

Figure 2. A Parched Oblique Ligature Mark Encircling the Upper Third of the Neck With the Following Features; A: Faded Part of the Ligature Mark Located Over the Left Lateral Side of the Front of the Upper Third of the Neck (Yellow Arrow) Extended to the Upper Third of the Left Posterolateral Aspect of the Neck (Blue Arrow); B: An Abrasion Knot of the Ligature Mark Located Over the Left Submental Area (Red Arrow); C: Front of the Upper Third of the Neck Showing a Pronounced Oblique Ligature Mark Directed to the Left and Upwards (Blue Arrows); D: Furrowed Ligature Mark Located Over the Right Posterolateral Aspect of the Upper Third of the Neck Directed Upwards and to the Back of the Neck (Green Arrow).

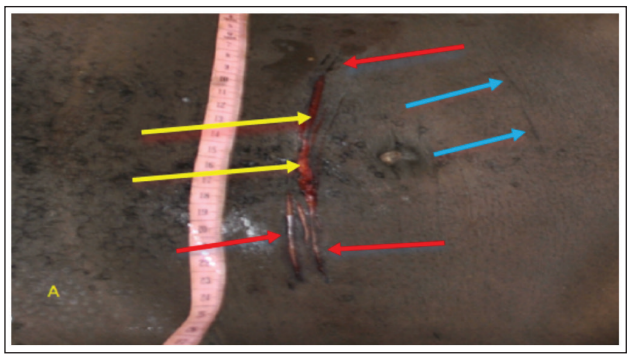

Figure 3. Abdominal Self-inflicted Incised Wounds Composed of Multiple Horizontal Sharp Weapon Strikes Located Over the Abdominal Wall Crossing the Midline Showing Multiple Superficial Hesitation Cuts Originating From the Left Side of the Abdominal Wall Below the Umbilicus Directed to the Right Side Ending on the Right Side of the Abdominal Wall (Red Arrows), Coalescing at the Midline Making One More Pronounced and Deeper Cut in the Center (Yellow Arrows), and Two Faint and Horizontal Self-Inflicted Incised Wounds on the Right Upper Quadrant of the Abdomen (Blue Arrows).

and the abdominal incised wounds were classified as self-inflicted.

Methodology/Methods

We conducted a retrospective analysis of the crime scene, circumstantial investigation, autopsy, and records of the case and reviewed pertinent literature. A detailed crime investigation was conducted, which included an examination, photographic documentation, and collection and preservation of physical evidence. An in-depth review of the deceased's medical and psychosocial history was undertaken, involving an examination of available medical records and interviews with family members and health care providers. Forensic autopsy was conducted at the Rwanda Forensic Institute located in Kigali, the capital of Rwanda. Written informed consent for the autopsy procedure and associated research and publication of findings was obtained from the deceased's bereaved family and the requesting authority before the commencement of the autopsy. A forensic autopsy was performed, which entailed a detailed description of external features, documentation of ligature marks, abdominal wounds, and other findings, measurement and photography of all visible injuries, along with a systematic examination of all organ systems and internal structures, and a detailed analysis of neck structures and abdominal injuries. In addition, blood, urine, bile, and gastric content samples were collected for screening for drugs, alcohol, and other substances. The Research and Community Service Council Ethical Review Board of the Rwanda Forensic Institute granted ethical approval for this study. Furthermore, official permission was obtained from the Forensic Medicine Division of the Rwanda Forensic Institute, from which the autopsy records were accessed. The institution's administration was briefed on the study's purpose, expected benefits, and data collection methods. The information was kept confidential, and all identifying details were anonymized.

Discussion

Complex suicides present a significant challenge in forensic practice, requiring forensic experts to exercise great care in differentiating these cases from those that are homicidal or accidental.[15–17] To our knowledge, reported cases of complex suicide involving suicide by hanging and self-inflicted abdominal incised wounds are scarce.

In our case, the autopsy revealed multiple shallow and horizontal sharp weapon strikes on the abdominal wall, with dried bloodstains on the fingertips of the left hand. The wounds started on the left side of the abdomen and ended on the right side, traversing the midline. The incised wounds coalesced in the middle, forming a more pronounced and deeper, irregular horizontal cut. Hesitation wounds are self-inflicted superficial sharp-force injuries inflicted after deciding not to commit suicide or muster courage before making a final, fatal wound.[18,19] Abdominal hesitation cuts are often found in the upper abdominal wall, accessible to the victim's hand, and follow a horizontal pattern.[20,21] In this study, the location and pattern of the wounds, coupled with the fact that the deceased was right-handed, indicated that the injuries were self-inflicted. In addition, the findings suggest that the victim likely used a sharp object with his right hand and touched the wound with his left-hand fingertips, probably because of intense pain, before ultimately hanging himself. These observations are consistent with previous findings indicating that victims of complex suicide may employ less lethal methods before resorting to more deadly techniques, possibly due to frustration, uncertainty about their chosen method, anguish, or assessment of their pain tolerance before inflicting a fatal injury.[22]

Moreover, the current case revealed an oblique ligature mark situated above the thyroid cartilage, with the victim's own shirt serving as the ligature material, and with no evidence of struggle that aligns with the features of suicidal hangings, unless in some atypical scenarios.[23] In cases of homicidal hanging involving healthy adults, victims usually resist, leading to injuries to their body parts, disturbances to clothing, or the scene.[24] Furthermore, individuals who are unconscious or under the influence of a drug can be hung by someone else without significant resistance, which can make it challenging to differentiate them from self-hanging.[25] In this case, the determination of self-hang was supported by the presence of a ligature mark characteristic of suicidal hanging, coupled with the lack of defensive or offensive wounds, signs of restraint, disturbance to clothing or scene, and any other

evidence of another person's involvement. Furthermore, the negative results from toxic substance tests and the absence of any serious medical condition that could alter the individual's consciousness support ruling out the state of unconsciousness of the victim. Because of their low lethality, individuals with self-inflicted abdominal incised wounds may perform voluntary or involuntary actions that can obscure the crime scene, making it difficult to trace the sharp weapons used, thereby complicating the determination of the manner of the resulting injuries.[18] As a result, the lack of recovery of a sharp instrument from the scene of death in our case is most probably attributable to this typical trait of self-inflicted abdominal wounds.

Furthermore, it is crucial to consider the medical and psychosocial background of the deceased to understand the intent of injury in such unique cases.[26,27] Significantly, depressive disorders, which are known for their unique effects of increasing impulsivity and emotional turmoil, are frequently associated with suicide.[28] Depression increases the risk of suicide by cultivating feelings of hopelessness, which can be exacerbated by impulsivity, leading to sudden, premeditated suicide attempts. Impulsivity, characterized by a lack of self-control and careful decision-making, can result in actions driven by strong emotions without regard for the consequences. Consequently, those who are depressed and exhibit impulsive tendencies may struggle to effectively address problems and manage stress, increasing the likelihood of resorting to impulsive suicide methods to escape their problems.[29,30] Individuals with depression are five times more likely to attempt suicide than the general population.[31] Additionally, failing to adhere to antidepressant medication regimens is associated with impulsive suicide methods, primarily because it causes depressive symptoms to resurface, which can heighten suicidal thoughts and behaviors, diminish impulse control, and increase the chances of relapse and rehospitalization, potentially leading to more lethal suicide attempts.[32,33] The intricate relationship between depression and suicidal behavior calls for comprehensive prevention and intervention strategies that span multiple levels of care. This strategy involves the early detection of at-risk individuals, application of evidence-based therapeutic methods, use of pharmacological treatments, and implementation of crisis management protocols. Furthermore, it is essential to raise community awareness of the social factors influencing mental health and family education, enhance access to care, develop personalized treatment plans, and establish follow-up procedures along with innovative techniques to promote adherence among high-risk patients, all of which are vital elements of an all-encompassing suicide prevention framework.[34–36] Suicide disproportionately affects low- and middle-income countries, with men being three times more likely to be victims than women, particularly those in the young to middle-aged demographic.[26,37] Our study involved a middle-aged male victim with a history of depressive disorder characterized by poor adherence to antidepressant medication, which most likely contributed to the sequence of self-inflicted injuries observed. Consequently, stakeholders are advised to maintain effective suicide prevention strategies, particularly for patients with depressive disorders. This includes strict adherence to prescribed medical treatments, educating families, implementing psychosocial interventions, and ensuring consistent follow-up care, all of which are crucial for long-term stability and minimizing the risk of suicide.[36,38] This case report highlights the challenges in distinguishing complex suicides from homicides and accidents. Comprehensive and detailed autopsy findings are crucial for accurately determining the manner of death.[39,40] In this case, we used the patterns of the ligature mark and abdominal wounds, the medical background of the deceased, and crime scene examination findings to classify the case as a complex suicide who attempted to kill himself by stabbing his abdomen and finally ended his life by hanging.

Findings and Contributions

This case report details a rare suicide incident involving both hanging and self-inflicted abdominal wounds, contributing to the limited literature on complex suicide methods. This study highlights the difficulties in identifying complex suicides and the potential for misclassification, stressing the importance of a comprehensive postmortem examination that integrates autopsy findings, crime scene evidence, and the deceased's medical history to accurately distinguish complex suicides from homicides or accidents, which will benefit experts involved in death investigations. Furthermore, it outlines the unique patterns of self-inflicted ligature marks and abdominal cuts, providing a valuable reference for forensic professionals in future investigations. The report also underscores the significant impact of depressive disorders, especially when medication is not followed, on increasing the likelihood of impulsive suicidal actions, which requires careful consideration in similar cases. These findings also highlight the need for improved management strategies for individuals with depressive disorders, including ensuring medication adherence and regular follow-up.

Conclusions

The history of depressive disorder with medication nonadherence and characteristic suicidal hanging and self-inflicted abdominal injuries, along with the absence of defensive or struggle injuries and negative toxicological results, were pivotal in classifying the case as a complex suicide. A thorough autopsy can pinpoint and rule out particular injuries and intoxication, while a meticulous examination of the crime scene can reveal evidence of staging or a struggle. Additionally, a thorough psychosocial history offers insight into whether the intent was suicidal or influenced by external pressures. Together, these elements provide crucial evidence for accurately identifying complex suicide cases. This triad

forms a multidisciplinary strategy for reconstructing events, ensuring precision in cases where surface appearances, such as staged homicides, might otherwise be deceptive. Depressive disorders, particularly when accompanied by a lack of adherence to medications, significantly increase the risk of impulsive suicide methods, which is most likely to occur in this scenario, according to the evidence found.

This study contributes to the existing literature on complex suicides by emphasizing the value of conducting prompt and comprehensive postmortem forensic investigations and accurately analyzing the findings to ascertain the intent and origin of injuries. Additionally, this case report reinforces the need for increased awareness and improved management strategies for individuals with depressive disorders to minimize such serious outcomes. Further research using a sufficient number of participants to explore the factors and motivations behind different suicide methods is warranted to enhance forensic investigation practices and develop effective suicide-intervention strategies.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

The outlined study protocol for this case report obtained ethical approval from the research project committee of Rwanda Forensic Institute (RFI) by REF NO 009/2025 dated June 10, 2025. Following the ethical approval, the Forensic Medicine Division of Rwanda Forensic Institute granted permission of this study on June 20, 2025.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent

This study is a case report and written informed consent for conducting the study and publishing the findings in scientific international journal was obtained from the next of kin of the deceased. In addition, written informed consent was obtained from all participants of the study.

ORCID iD

Gebremariam Tewelemedhin Gebremariam https://orcid.org/0009-0008-4291-6777

References

1. Lovero KL, Dos Santos PF, Come AX, et al. Suicide in global mental health. *Curr Psychiatry Rep* 2023; 25: 255–262.
2. Sreedevi G, Thomas Z and Saritha SR. Profile of suicidal deaths—an autopsy based study. *J Indian Acad Forensic Med* 2023; 45: 124–127.
3. Cai Z, Junus A, Chang Q, et al. The lethality of suicide methods: A systematic review and meta-analysis. *J Affect Disord* 2022; 300: 121–129.
4. Nagar N and Bastia BK. The demographic profile of suicidal hanging deaths in North India. *Cureus* 2022; 14: e30409.
5. Hösükler E, Hösükler B, Çoban İ, et al. Complex suicides: 21 cases and a review of the literature. *Egypt J Forensic Sci* 2022; 12. Epub ahead of print December 2022. DOI: 10.1186/s41935-022-00269-3.
6. Beltrame B, Baig S and Verzeletti A. Forensic remarks regarding 35 cases of complex suicides and 4 cases of complicated suicides investigated at the Institute of Legal Medicine of Brescia during the period 1983–2022. *Leg Med* 2023; 65: 102324.
7. Santelli S, Berti L, Giovannini E, et al. Homicide, suicide, or accident? Complex differential diagnosis: A case series. *Leg Med* 2024; 66: 102357.
8. Barranco R, Diana C and Ventura F. Forensic pathological study of complex and complicated suicides: A twelve-year case series in Genoa (Italy). *J Forensic Leg Med* 2019; 65: 5–8.
9. Chouksey V, Baveja V, Sabu N, et al. A suicidal death which was treated and masqueraded as an accidental death. *J Indian Acad Forensic Med* 2023; 45: 419–421.
10. Kryezi A and Kryezi A. Distinguishing murder from suicide: Prevalence and general investigative features. *SEEU Rev* 2022; 17: 87–103.
11. Prahlow SP, Cohle S, Shattuck B, et al. Homicides disguised as staged suicides. *Acad Forensic Pathol* 2020; 10: 104–112.
12. Gentile G, Galante N, Tambuzzi S, et al. A forensic analysis on 53 cases of complex suicides and one complicated suicide assessed at the Bureau of Legal Medicine of Milan (Italy). *Forensic Sci Int* 2021; 319: 110662.
13. Pallocci M, Passalacqua P, Zanovello C, et al. Forensic characterisation of complex suicides: A literature review. *Forensic Sci* 2024; 4: 277–288.
14. Indelicato M. Homicidal or suicidal death? Evidence-based approach to assessing cause of death in a peculiar forensic case. *Clin Ter* 2024; 175: 40–43.
15. Alexandri M, Tsellou M, Kapsali A, et al. Forensic investigation of complex and complicated suicides in Attica, Greece: A 12-year retrospective study. *Forensic Sci Med Pathol* 2025; 21: 90–97.
16. Pallocci M, Treglia M, Passalacqua P, et al. Forensic analysis of planned and unplanned complex suicides: A case series. *Aust J Forensic Sci* 2025; 57: 39–52.
17. Jayanth S, Singh A and Hugar B. Unplanned complex suicide—poisoning followed by hanging. *J Indian Acad Forensic Med* 2022; 44: 99–101.
18. Parajuli A, Mishra A, Ghimire R, et al. Self-inflicted stab injury with abdominal evisceration: A case report. *Int J Surg Case Rep* 2021; 88: 106543.
19. Chabra HS, Singh A, Kumar A, et al. Self-inflicted injuries vis-à-vis injuries due to assault: Two case reports. *J Indian Acad Forensic Med* 2017; 39: 426.
20. Vinci A, Ambrosi L, Benevento M, et al. A singular case of complex suicide by hanging with hesitation marks by axe. *Forensic Sci Med Pathol*. Epub ahead of print 20 February 2025. DOI: 10.1007/s12024-025-00964-2.

21. Sangma MM, Patowary A and Slong D. A fatal case of self-inflicted abdominal stab wound. *J Indian Acad Forensic Med* 2021; 43: 281–283.
22. Kulkarni C, Mohite S and Meshram V. Unplanned complex suicide by self-stabbing and rail suicide: A case report and review of literature. *Am J Forensic Med Pathol* 2020; 41: 78–80.
23. Vadukapuram R, Trivedi C, Mansuri Z, et al. Common methods of suicide and self-inflicted poisoning/injury by individuals with major depressive disorder and bipolar disorder: A nationwide inpatient sample analysis. *Prim Care Companion CNS Disord* 2022; 24: 21m03159.
24. Safitry O, Putra AB, Gustinanda J, et al. Homicide by hanging: A comprehensive review of published literature. *Int J Leg Forensic Sci* 2023; 13: 1.
25. Commins C, Bolster M and Mulligan L. Pattern of neck injuries and role of toxicology in cases of hanging and manual/homicidal ligature strangulation in Ireland between 2016–2020: A retrospective review. *J Forensic Leg Med* 2024; 103: 102686.
26. Brito MA, Amad A, Rolland B, et al. Religiosity and prevalence of suicide, psychiatric disorders and psychotic symptoms in the French general population. *Eur Arch Psychiatry Clin Neurosci* 2021; 271: 1547–1557.
27. Tambuzzi S, Gentile G, Boracchi M, et al. Forensic and psychopathological framing of complex suicides: A retrospective study over the last 30 years. *Med Sci Law*. Epub ahead of print 21 February 2025. DOI: 10.1177/00258024251319694.
28. Kalin NH. Insights into suicide and depression. *Am J Psychiatry* 2020; 177: 877–880.
29. Gómez-Tabares AS, Arango-Tobón OE, Núñez C, et al. Effect of depression and hopelessness on suicidal risk in young people: Mediating role of impulsivity. *Clin Psychol Eur* 2025; 7: e11331.
30. Zhang J, Zhang X, Yang G, et al. Impulsiveness indirectly affects suicidal ideation through depression and simultaneously moderates the indirect effect: A moderated mediation path model. *Front Psychiatry* 2022; 13: 913680.
31. Riera-Serra P, Navarra-Ventura G, Castro A, et al. Clinical predictors of suicidal ideation, suicide attempts and suicide death in depressive disorder: A systematic review and meta-analysis. *Eur Arch Psychiatry Clin Neurosci* 2024; 274: 1543–1563.
32. Su K-P, Lu N, Tang C-H, et al. Risk of medication noncompliance and suicidal behavior among patients with depressive disorders using different monotherapy antidepressants in Taiwan. *J Affect Disord* 2019; 250: 170–177.
33. Muhammad N, Ullah SR, Nagi TK, et al. Factors associated with non-adherence to antidepressant medication in adults: A systematic review and meta-analysis. *Cureus*. Epub ahead of print 19 April 2023. DOI: 10.7759/cureus.37828.
34. Sołek P, Mytych J, Tabęcka-Łonczyńska A, et al. Molecular consequences of depression treatment: Potential in vitro mechanism for antidepressants-induced reprotoxic side effects. *Int J Mol Sci* 2021; 22: 11855.
35. Wasserman D, Carli V, Iosue M, et al. Suicide prevention in psychiatric patients. *Asia Pac Psychiatry* 2021; 13: e12450.
36. Mann JJ, Michel CA and Auerbach RP. Improving suicide prevention through evidence-based strategies: A systematic review. *Am J Psychiatry* 2021; 178: 611–624.
37. Arensman E, Scott V, De Leo D, et al. Suicide and suicide prevention from a global perspective. *Crisis* 2020; 41: S3–S7.
38. Turner K, Sveticic J, Almeida-Crasto A, et al. Implementing a systems approach to suicide prevention using the Zero Suicide Framework. *Aust N Z J Psychiatry* 2021; 55: 241–253.
39. Arjun T and Venkatesan M. Complex suicide involving hanging and self-inflicted incision: A case report. *Cureus* 2024; 16. https://www.cureus.com/articles/268157-complex-suicide-involving-hanging-and-self-inflicted-incision-a-case-report.pdf (2024, accessed 17 July 2025).
40. Duval I, Doberentz E and Madea B. Unusual self-inflicted injuries in a case of hanging. *Forensic Sci Med Pathol* 2021; 17: 354–361.

DNA Recovery from Blood and Seminal Fluid Stains Exposed to Sodium Hypochlorite (Bleach)

Journal of Indian Academy
of Forensic Medicine
47(4) 440–448, 2025

DOI: 10.1177/09710973251411982
journals.sagepub.com/home/iaf
Sage

Tuğba Ünsal Sapan[1,2] and Engin Damla Gök[1]

Abstract

Physical and sexual violence remains among the most prevalent crimes in contemporary society, with women and children comprising the majority of victims. In such cases, biological evidence—such as blood, semen, and saliva—plays a critical role in the investigation and resolution of criminal incidents. However, this evidence may be compromised, either unintentionally due to environmental exposure or intentionally by the perpetrator or victim, with the aim of concealing the crime.

This study investigates the potential for DNA recovery from blood and semen stains that have been deliberately exposed to diluted sodium hypochlorite (bleach), a common household chemical used in attempts to destroy forensic evidence. Biological stains were deposited on various fabric types and subsequently subjected to washing with bleach and detergent at 90°C. The samples were then examined using ultraviolet (UV) light and luminol for preliminary detection, followed by DNA isolation and quantification procedures.

The findings demonstrate that DNA recovery is possible even after exposure to bleach, thereby affirming the viability of forensic analysis under compromised conditions. This study underscores the potential for retrieving genetic material in scenarios where biological evidence has been subjected to intentional destruction, thereby contributing valuable insights to forensic science and criminal investigations.

Keywords

Sexual assault, semen stains, blood stains, forensic genetics, sodium hypochlorite, DNA recovery from chemically treated stains

Received 03 June 2025; **accepted** 14 December 2025

Introduction

Forensic genetics is a scientific discipline frequently utilized in the resolution of criminal cases, the identification of perpetrators or victims, and the establishment of relationships between crime scenes and individuals. Since the 1990s, the application of DNA analysis to biological evidence collected from crime scenes has marked a new era in forensic investigations. The identification process from collected evidence is made possible through DNA isolation techniques. By comparing DNA profiles obtained from crime scene samples with those from reference samples, identification studies are conducted.[1–6]

As in other forensic cases, the presence of biological evidence is critically important in incidents of sexual assault and abuse. Depending on the victim's ability or attempt to resist during the act, a substantial amount of biological material may be present. The seminal fluid of perpetrators can be detected in the victim's anal, oral, or genital regions, on their body, clothing, or on items involved in the act, such as bed linens, sheets, blankets, carpets, sofa upholstery, or—if used—inside condoms. The victim's body is among the most important sources of forensic samples.[6–9]

Following the incident, the victim may experience psychological distress and attempt to cleanse themselves as a coping mechanism, or the perpetrator(s) may intentionally try to eliminate evidence. Such actions may include washing, burning, or wiping of evidence. While the goal for perpetrators is

[1]Institute of Addiction and Forensic Sciences, Üsküdar University, Istanbul, Turkey
[2]Faculty of Engineering and Natural Sciences, Department of Forensic Sciences, Üsküdar University, Istanbul, Turkey

Corresponding author:
Tuğba Ünsal Sapan, Institute of Addiction and Forensic Sciences, Üsküdar University, Altunizade Main Campus, Üsküdar, Istanbul 34662, Turkey.
E-mail: tugba.unsalsapan@uskudar.edu.tr

often to destroy evidence, numerous studies have shown that it is still possible to recover DNA from clothing exposed to multiple washes, including at various temperatures, and using different methods. Although limited, the literature includes some studies on DNA recovery from samples exposed to diluted sodium hypochlorite (bleach) in addition to washing. However, the concentration of diluted bleach, the duration of exposure, and the type of substrate (fabric/surface) significantly affect the quantity of DNA that can be recovered.[9–13]

In this study, the aim was to recover DNA using the Spin Column Method following serological testing of two types of fabric containing blood and semen stains that had been exposed to diluted sodium hypochlorite (bleach) and subsequently washed. The primary objective was to determine whether identification is possible from evidence intentionally or unintentionally subjected to bleach—either as a means of destruction or due to psychological distress—by assessing the feasibility of DNA recovery under such conditions.

Material and Methods

In this study, semen samples were obtained from 20 healthy male volunteers aged over 18 years, and blood samples were collected from ten healthy individuals who provided informed consent to participate in the study.

The biological samples were applied as stains onto presterilized denim and cotton fabric types. The stained fabrics were allowed to air-dry at room temperature and subsequently examined under ultraviolet (UV) light. Characteristic blue-white luminescence, indicative of the presence of blood and seminal fluid, was observed and documented through photography.

Following initial documentation, the stained fabric samples were exposed to diluted sodium hypochlorite (bleach) for 15 minutes. Thereafter, each participant's samples were grouped and washed in a washing machine at 90°C with detergent.

After the washing process, the fabric samples were left to air-dry at room temperature for 24 hours. Once completely dry, the samples were re-examined under UV light and re-photographed. DNA was then extracted from the stained areas of the fabric using standard isolation procedures, and the quantity of DNA recovered from each sample was measured.

Preparation of Fabric Samples

Two types of fabric—denim and cotton—were used in this study. To prevent potential contamination, all fabric materials were new and unused. The fabrics were initially washed at 90°C using ARIEL-brand liquid detergent in a BEKO WD 854 YK washing machine, followed by a second rinse cycle without detergent. After drying at room temperature for 24 hours, the fabrics were sterilized under UV light for three hours. Sterile scissors were used to cut the fabrics into 5 × 5 cm squares, which were then prepared for the application of blood and semen samples.

Collection of Blood Samples

Blood samples were collected from 20 volunteers who provided written informed consent, using sterile syringes. All procedures were carried out under sterile conditions, with the use of appropriate personal protective equipment.

Collection of Semen Samples

Semen samples were collected from 20 male volunteers using sterile containers in their home environments. Participants were provided with detailed instructions to prevent contamination during the collection and transport process. All samples were transported to the laboratory under cold chain conditions at +4°C.

Preparation of Semen and Blood Stains

For each volunteer, four fabric samples (two cotton and two denim) were designated, with one sample of each fabric type left untreated to serve as a reference for baseline DNA quantity. Upon arrival at the laboratory, semen samples were processed immediately to prevent degradation. Using a sterile Pasteur pipette, 1 mL of semen was applied to each fabric square. Blood samples were collected from 20 volunteers using sterile syringes, and 1 mL of blood was similarly applied to the designated fabric squares. All samples were allowed to air-dry at room temperature for 24 hours and subsequently stored in paper envelopes until further analysis.

Exposure of Stained Fabrics to Diluted Sodium Hypochlorite (Bleach)

Dried and packaged fabric samples were exposed to a diluted bleach solution prepared by mixing 100 mL of ACE-brand bleach (containing 5% sodium hypochlorite) with 1 L of water. Each stained fabric piece was fully submerged in the solution for 15 minutes, then thoroughly rinsed with distilled water before being grouped for subsequent washing.

Washing of Stained Fabrics

The bleach-treated fabric samples were washed in a BEKO WD 854 YK washing machine at 90°C using Ariel liquid detergent. Blood- and semen-stained fabrics from each volunteer were processed separately to prevent cross-contamination. In total, 40 blood-stained and 40 semen-stained samples were analyzed. To ensure no carryover contamination between washes, the machine was run empty with detergent between each group.

Detection of Residual Stains Using Luminol and UV Light

After the washing process, residual biological stains were examined using both luminol testing and UV light. All visual findings were photographed and recorded using a Canon EOS 500 camera.

Detection of Blood Stains Using Luminol

Luminol reagent (Merck/Sigma-Aldrich) was freshly prepared and applied to the washed fabric samples in a dark environment. The presence of blood was confirmed by characteristic blue-white chemiluminescence, which was documented photographically.

Detection of Semen Stains Using UV Light

Semen stains were visualized using an Obelüx-brand multi-wavelength light source (350–400 nm) in combination with orange-filtered goggles. The typical blue-white fluorescence emitted by semen was observed and recorded through photographic documentation.

DNA Isolation

Following visual detection, all samples were coded based on stain type and donor identity. Under sterile conditions, 0.5 cm^2 sections were excised from each stained fabric and placed into 2 mL microcentrifuge tubes. DNA extraction was performed using the QIAamp® DNA Investigator Kit, according to the manufacturer's protocol.[14]

DNA Quantification

The concentration of the extracted DNA was measured using a Qubit 4.0 Fluorometer and the Qubit dsDNA HS Assay Kit. Each sample was prepared by combining 190 µL of working solution with 10 µL of extracted DNA. Quantification was performed in triplicate, and results were expressed in ng/µL. All procedures were conducted under light-sensitive conditions, with aluminum foil used to protect reagents from light exposure.[15]

Statistical Analysis

The Wilcoxon signed-rank test and the Mann–Whitney U test were performed using SPSS to evaluate the impact of sodium hypochlorite treatment and fabric type on DNA recovery.

Results

Blood- and semen-stained fabric samples were treated with diluted sodium hypochlorite (bleach) and subsequently subjected to washing in an automatic washing machine at 90°C with the addition of detergent. After the washing process, the samples were air-dried at room temperature for 24 hours prior to DNA analysis. Semen stains were visualized under UV light using presumptive screening tests, whereas blood stains were identified through luminol application. Despite exposure to both chemical and thermal treatment, the biological stains remained detectable. Characteristic blue-white luminescence was observed and documented photographically (Figure 1).

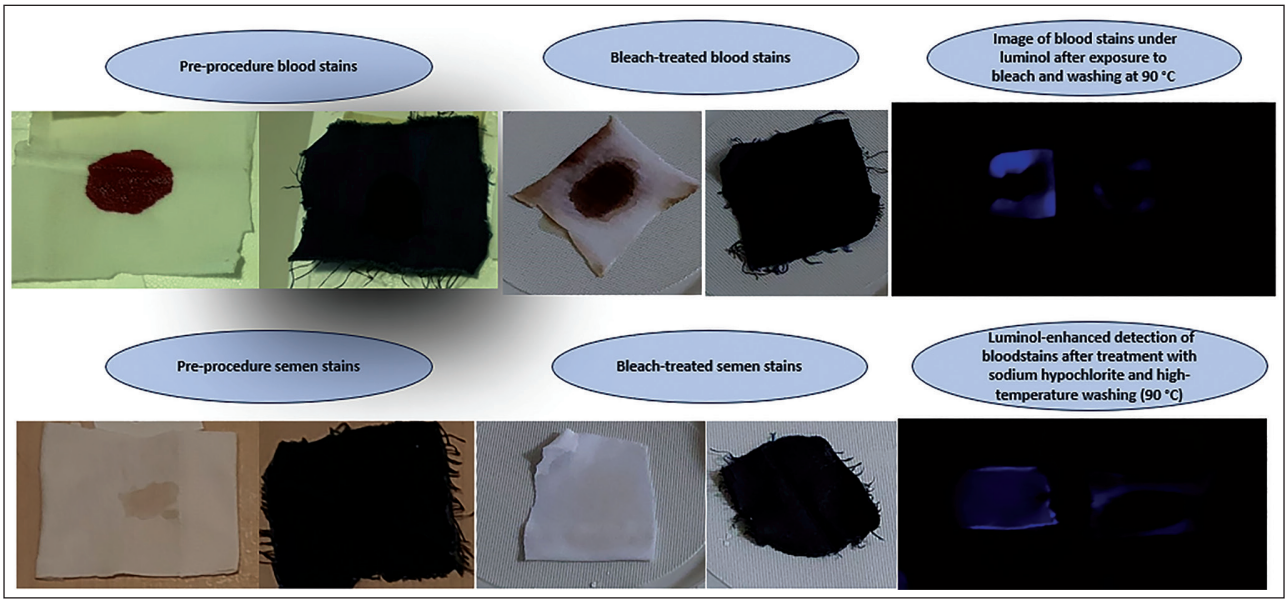

Figure 1. Visualization of Blood and Semen Stains Under UV Light and Luminol Treatment, Shown Before and After Exposure to Diluted Bleach and Laundering at 90°C.

Note: *The images demonstrate the persistence or degradation of biological traces following chemical and thermal treatment commonly associated with attempted forensic evidence removal.

DNA was successfully recovered from untreated control samples (40 denim and 40 cotton). For blood-stained fabrics, DNA concentrations ranged from 0.109 to 5.5 ng/μL in cotton and 0.316–8.34 ng/μL in denim (Tables 1 and 2). In semen-stained fabrics, concentrations ranged from 0.076 to 14 ng/μL in cotton and 0.068–4.57 ng/μL in denim (Tables 2 and 3).

Following treatment with diluted sodium hypochlorite and washing at 90°C, DNA was successfully extracted from all 40 denim and 40 cotton samples. For blood-stained fabrics, DNA concentrations ranged from 0.0899 to 3.47 ng/μL in cotton and 0.105–6.58 ng/μL in denim (Table 1 and Figure 2). Similarly, in semen-stained fabrics, concentrations ranged from 0.056 to 7.9 ng/μL in cotton and 0.23–2.76 ng/μL in denim (Tables 2 and 3, and Figure 2).

According to the Wilcoxon Signed Ranks Test results, there was a statistically significant difference between pre- and post-exposure detection values for both blood and semen stains on cotton and denim fabrics ($p < .001$). These findings

Table 1. DNA Concentrations in Blood-stained Fabric Samples Exposed to Diluted Sodium Hypochlorite and Washed at 90°C.

Blood Samples	Untreated Cotton Samples (ng/μL)	Cotton Fabric Exposed to Diluted Sodium Hypochlorite DNA Quantification (ng/μL)	Untreated Denim Samples (ng/μL)	Denim Fabric Exposed to Diluted Sodium Hypochlorite DNA Quantification ng/μL)
1.	1.91	0.868	1.49	1.12
2.	2.99	0.358	0.98	0.947
3.	4.62	3.06	6.11	2.70
4.	2.96	1.25	0.752	0.702
5.	1.62	0.487	0.80	0.716
6.	3.013	0.456	1.32	0.929
7.	1.39	0.354	1.16	1.02
8.	4.126	1.10	0.716	0.658
9.	0.109	0.0899	0.773	0.474
10.	3.16	0.370	4.08	1.17
11.	2.5	2.09	0.982	0.828
12.	2.23	1.73	1.36	0.80
13.	3.01	2.86	0.177	0.340
14.	4.76	3.47	0.162	0.105
15.	4.68	3.29	0.484	0.430
16.	2.65	2.22	0.752	0.548
17.	5.5	3.03	0.316	0.214
18.	2.7	2.19	1.16	0.88
19.	1.96	1.96	0.716	0.606
20.	1.76	1.76	8.34	6.58
Mean	2.98	1.65	1.63	1.09
STD	1.23	1.11	2.11	1.40

Table 2. Minimum, Maximum, and Mean Values of DNA Quantities Obtained From Blood- and Semen-stained Samples Exposed to Diluted Sodium Hypochlorite (Bleach) and Subsequently Washed at 90°C.

		Untreated Samples			Samples Exposed to Diluted Sodium Hypochlorite (Bleach)		
Blood stains		**Min DNA (ng/μL)**	**Max DNA (ng/μL)**	**Mean DNA (ng/μL)**	**Min DNA (ng/μL)**	**Max DNA (ng/μL)**	**Mean DNA (ng/μL)**
	Cotton	0.109	5.5	2.98	0.0899	3.47	1.65
	Denim	0.316	8.34	1.63	0.105	6.58	1.09
Semen stains		**Min DNA (ng/μL)**	**Max DNA (ng/μL)**	**Mean DNA (ng/μL)**	**Min DNA (ng/μL)**	**Max DNA (ng/μL)**	**Mean DNA (ng/μL)**
	Cotton	0.076	14	1.9	0.056	7.9	0.9
	Denim	0.068	4.57	1.84	0.023	2.76	0.42

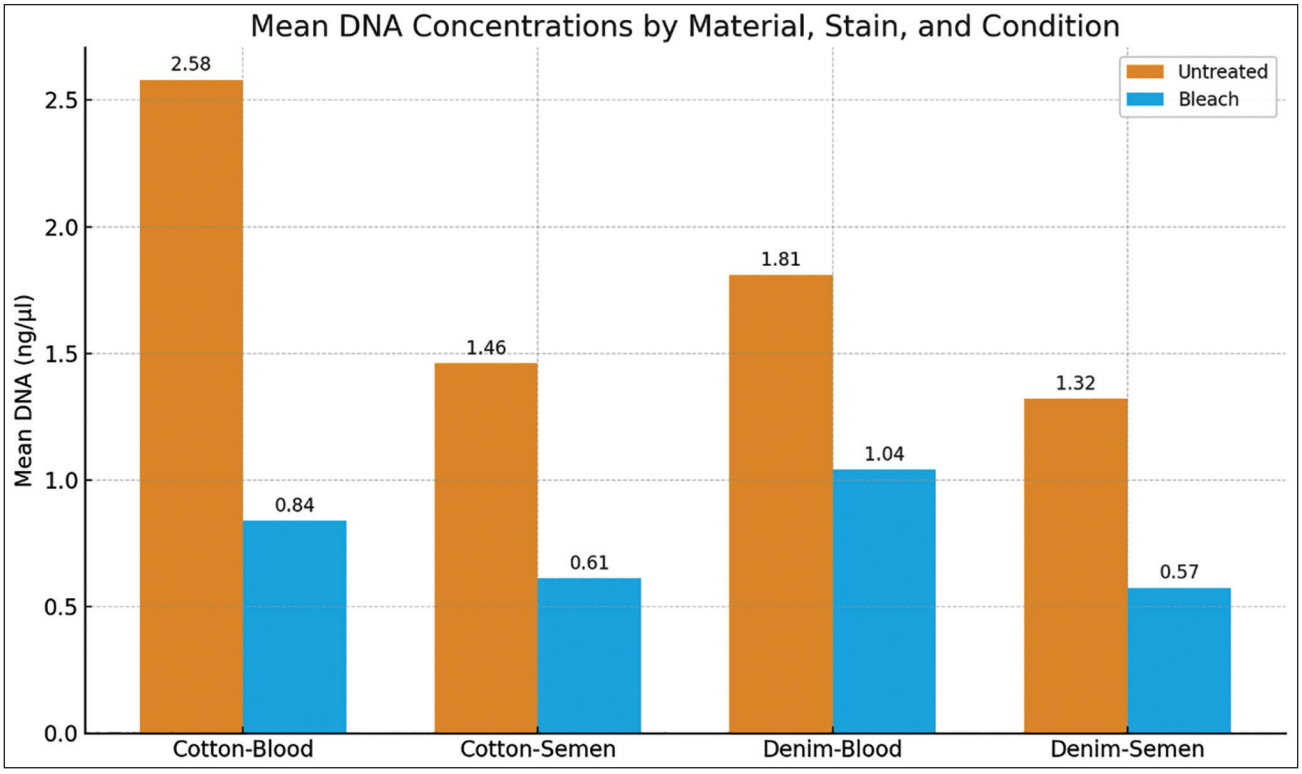

Figure 2. Comparison of Minimum, Maximum, and Mean DNA Quantities Recovered From Blood- and Semen-stained Cotton and Denim Fabrics, Both Untreated and Treated with Diluted Sodium Hypochlorite Followed by Washing at 90°C.

Table 3. DNA Concentrations in Semen-stained Fabric Samples Exposed to Diluted Sodium Hypochlorite and Washed at 90°C.

Semen Stains	Untreated Cotton Samples (ng/µL)	Cotton Fabric Exposed to Diluted Sodium Hypochlorite DNA Quantification (ng/µL)	Untreated Denim Samples (ng/µL)	Denim Fabric Exposed to Diluted Sodium Hypochlorite DNA Quantification (ng/µL)
1.	3.1	1.77	4.570	2.76
2.	0.0760	0.0564	3.707	0.712
3.	2.5	1.43	0.921	0.379
4.	2.1	0.822	0.471	0.234
5.	1.9	0.496	0.944	0.402
6.	1.1	0.0947	0.068	0.0380
7.	1.25	1.12	0.191	0.162
8.	1.1	0.0755	0.434	0.362
9.	1.4	0.163	1.037	0.464
10.	0.133	0.0954	0.889	0.234
11.	0606	0.319	0.889	0.520
12.	0.318	0.166	0.921	Too Low
13.	1.04	0.547	1.037	0.678
14.	0.500	0.155	0.068	0.023
15.	0.799	0.232	10.6	0.191
16.	0.680	0.432	0.471	0.084
17.	1.7	0.450	0.944	0.058
18.	0.606	0.272	3.707	0.398
19.	14	7.9	0.434	0.023
20.	4.6	1.5	4.570	0.275
Mean	1.9	0.9	1.84	0.42
STD	2.9	1.6	2.53	0.60

indicate that exposure to diluted sodium hypochlorite significantly affects the detectability of biological traces, likely reducing the visibility or detection potential of the stains. The negative Z-scores suggest that post-exposure detection levels were generally lower than those observed before treatment, implying that sodium hypochlorite has a destructive or degrading impact on biological evidence deposited on textile surfaces (Table 4).

The Mann–Whitney U test demonstrated that the reduction in DNA yield following sodium hypochlorite treatment differed significantly between cotton and denim fabrics for blood-stained samples but not for semen-stained samples (Blood: U = 287.00, $p = .019$; Semen: U = 200.50, $p = 1.000$) (Table 5).

Discussion

Sexual assault and abuse rank among the most prevalent crimes in contemporary society, with victims primarily comprising women and children, although male victims are also reported. In forensic investigations of such incidents, biological evidence yields the most conclusive findings. Despite its high reliability, this type of evidence is extremely vulnerable to environmental and physical factors, which may complicate its admissibility and interpretation in judicial processes. Victims, often experiencing psychological trauma, may inadvertently compromise forensic evidence by washing the clothing worn during the assault or cleaning affected surfaces such as sofas, beds, or bed linens. Similarly, perpetrators may deliberately attempt to eliminate biological traces by cleansing themselves, their clothing, or the crime scene. The use of condoms in sexual assault cases is infrequent; consequently, absorbent materials such as bedding, clothing, and upholstery often retain significant amounts of forensic biological material.[9,11] Studies have demonstrated that, despite attempts at intentional destruction or cleaning prompted by psychological trauma, it is still possible to recover trace amounts of DNA from laundered fabrics.[9]

An evaluation of the findings obtained in this study, which was specifically designed to assess DNA recovery after exposure to diluted sodium hypochlorite and subsequent washing, presents comparative results for cotton and denim fabrics:

In line with the aim of this study, blood and semen samples were applied to two different fabric types—cotton and denim—and subsequently exposed to diluted sodium hypochlorite (bleach). After this chemical exposure, the fabrics were washed in a washing machine at 90°C with detergent. Despite the harsh treatment conditions, a small amount of DNA was successfully recovered from the samples.

The primary conclusion of this study is that it is possible to recover DNA from samples exposed to diluted sodium hypochlorite for 15 minutes and subsequently washed at 90°C with the addition of detergent. Variations in the amount of DNA recovered from different samples are believed to result from several factors, including the molecular structure of the fabric used, the chemical properties of the diluted sodium hypochlorite and detergent, and the duration of exposure. These variables are considered to significantly influence the amount of DNA recovered under the experimental conditions.

DNA Recovery by Fabric Type

For blood samples: A higher amount of DNA was recovered from denim fabric compared to cotton fabric (Table 1). This difference is attributed to the tightly woven and rigid structure of denim, which likely facilitates better retention of

Table 4. Wilcoxon Test Results.

Test Statistics[a]				
	Blood		**Semen**	
	Cotton Exposed to Diluted Sodium Hypochlorite—Cotton Not Exposed	**Denim Exposed to Diluted Sodium Hypochlorite—Denim Not Exposed**	**Cotton Exposed to Diluted Sodium Hypochlorite—Cotton Not Exposed**	**Denim Exposed to Diluted Sodium Hypochlorite—Denim Not Exposed**
Z	−3.724[b]	−3.509[b]	−3.920[b]	−3.920[b]
Asymp. sig. (2-tailed)	0.000	0.000	0.000	0.000

Notes: [a]Wilcoxon signed ranks test.

[b]Based on positive ranks.

Table 5. Mann–Whitney U Test Results.

Sample	**Comparison**	**U Value**	***Z* Value**	***p* (2-tailed)**
Blood	Cotton & denim	113.000	–2.353	.019
Semen	Cotton & denim	200.000	0.000	1.000

blood cells, preventing them from being easily dislodged during washing.

For semen samples: Like the results observed with blood samples, more DNA was recovered from denim fabric than from cotton fabric (Table 3). Although the biological sample type differed, the same explanation applies: the dense weave and firm structure of denim provide a surface that promotes the adherence of semen cells and reduces their loss during washing.

Despite exposure to sodium hypochlorite and subsequent washing at 90°C, DNA was still recoverable from both blood- and semen-stained fabrics. An average yield of 1.65 ng/μL was obtained from bloodstains on cotton and 1.09 ng/μL from bloodstains on denim, while semen-stained fabrics yielded 0.61 ng/μL on cotton and 0.42 ng/μL on denim. These results demonstrate that measurable quantities of DNA can persist even after combined chemical and thermal treatment.

Overall, statistical analyses demonstrated that sodium hypochlorite exposure significantly reduced DNA yields in both blood- and semen-stained fabrics, regardless of sample type (Wilcoxon signed-rank test: $Z \approx -3.80$, $p < .001$). However, the extent of DNA reduction differed significantly between cotton and denim fabrics for blood-stained samples, but not for semen-stained samples (Mann–Whitney U test: Blood, $U = 287.000$, $p = .019$; Semen, $U = 200.500$, $p = 1.000$). These results indicate that while bleach consistently compromises DNA integrity, its impact on DNA degradation varies with fabric type in bloodstains but remains uniform across fabric types in semen stains, highlighting its destructive role in forensic DNA analysis.

Suitability of Recovered DNA for Identification

Fluorometric analysis indicated that DNA concentrations from bloodstains ranged from 0.08 to 3.47 ng/μL on cotton and from 0.105 to 6.58 ng/μL on denim. Considering that full STR profiles can be obtained with ≥0.125 ng/μL using GlobalFiler™ kits,[16] successful identifications were achievable in 95% of cotton and 90% of denim bloodstain samples, even following bleach exposure and washing at 90°C (Table 1).

For semen stains, DNA concentrations ranged from 0.05 to 7.9 ng/μL on cotton and from 0.02 to 2.76 ng/μL on denim. Full STR profiles were successfully obtained in 80% of cotton and 65% of denim samples, indicating higher identification success on denim under the same chemical and thermal treatment conditions (Table 3).

Comparison with Previous Studies

In a 2018 study, Thabet et al. examined the effects of various cleaning agents, including bleach (Clorox), disinfectant (Dettol), stain remover (Vanish), detergent (Persil), and distilled water—on DNA recovery from blood-stained cotton and silk fabrics. Their results showed significantly lower DNA yields from silk compared to cotton across all treatments, with Vanish causing the greatest reduction. Clorox-treated samples yielded the highest DNA quantities for both fabric types. Gel electrophoresis revealed that Vanish and Dettol had the most detrimental effects on DNA quality, while Clorox, Persil, and distilled water had minimal impact.[17] Unlike Thabet et al.'s study, the present research incorporated both diluted bleach exposure and washing at 90°C with detergent. DNA was successfully isolated and quantified from all cotton and denim samples containing blood and semen (Tables 1 and 3). Consistent with Thabet et al., our findings also indicate that fabrics with lower fiber density, such as cotton, show greater DNA loss than denser fabrics like denim.

In a study by Ünsal Sapan et al., semen-stained samples on two different fabric types (cotton and nylon) were washed at 40°C, 60°C, and 90°C with detergent, and subsequently analyzed for DNA presence and suitability for profiling. DNA extraction was performed using both the spin column and organic methods, with successful recovery from all samples. The organic method yielded higher DNA quantities. Notably, DNA profiles were obtainable even after washing at 90°C with detergent.[12] In contrast to this study, the present research involved prior exposure of samples to diluted sodium hypochlorite (bleach), a chemical known for its high DNA-degrading potential. Based on the findings of Ünsal Sapan et al., which demonstrated successful profiling at 90°C, all samples in the current study were washed at this temperature following bleach treatment. Consistent with their results, DNA was successfully extracted and quantified from all samples despite the additional chemical exposure.

Similarly, de Silva Wijeyeratne and Gweon (2025) assessed the effectiveness of sodium hypochlorite for genomic DNA decontamination across different concentrations. Their results showed that low concentrations (≤0.1%) allowed partial DNA detection, whereas concentrations of 0.5% and above completely inhibited DNA amplification and fragment visualization. These findings reinforce the highly disruptive role of sodium hypochlorite on genetic material, supporting the current study's conclusion that bleach exposure significantly compromises DNA integrity, even though measurable quantities may still persist under certain conditions.[18]

Similarly, a study published in *Forensic Genomics* (2023) investigated the persistence of human DNA after exposure to common household cleaning agents such as soap, bleach, and hydrogen peroxide. The authors demonstrated that while bleach and hydrogen peroxide caused significant degradation, partial DNA detection and successful amplification remained possible in some cases. These findings align with the current study by emphasizing that, although sodium hypochlorite has a severe degrading effect on DNA, genetic material may still persist at detectable levels even after chemical treatment.[19]

Conclusion

In this study, DNA was successfully extracted from all blood- and semen-stained fabric samples that had been treated with diluted sodium hypochlorite (bleach) for 15 minutes and subsequently laundered at 90°C using detergent. All samples

were subjected to DNA isolation using the spin column method. The results indicate that DNA recovery is feasible following this protocol. Although DNA was successfully recovered from all fabric and stain types, the quantity of DNA obtained varied depending on the fabric type, suggesting a proportional relationship between fabric characteristics and DNA yield.

Although the quantity of DNA recovered was limited, likely because of diluted sodium hypochlorite, detergent, and high-temperature exposure, the results indicate that the recovered DNA was sufficient for identification purposes, even under conditions associated with significant degradation. This study provides the first evidence that DNA can be successfully recovered from blood- and semen-stained samples subjected to treatment with diluted sodium hypochlorite and subsequent laundering at 90°C with detergent.

This study demonstrates that DNA recovery is feasible even under conditions where forensic evidence has been deliberately or unintentionally compromised. Such scenarios may include attempts by perpetrators to destroy biological traces in cases of sexual assault or abuse, delays in reporting due to psychological trauma or societal pressure on the victim, or instances where victims themselves attempt to eliminate evidence due to emotional distress. Forensic evidence in these cases often consists of items such as clothing, bed linens, or other fabric-covered materials associated with the victim or offender. The findings indicate that, even after exposure to diluted sodium hypochlorite (bleach) and subsequent laundering at high temperatures with detergent, it is still possible to recover DNA from such evidence.

Acknowledgements

We would like to thank Üsküdar University Institute of Addiction and Forensic Sciences for the use of the laboratory.

Authors' Contributions

TUS designed, conceptualized, edited, and supervised the entire study. EDG collected the materials and conducted DNA extraction and quantification. EDG prepared the draft manuscript, while TUS finalized the manuscript. All authors reviewed and approved the final version of the manuscript.

Availability of Data and Materials

Not applicable.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

Before starting the study, ethics committee approval numbered 61351342/JUN 2020-701 was obtained from Üsküdar University's Non-Interventional Research Ethics Committee. Following ethical clearance, semen samples were collected from twenty healthy male volunteers and blood samples from twenty healthy individuals, all of whom were over the age of 18. Prior to sample collection, each participant provided written informed consent.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Informed Consent

Not applicable.

ORCID iDs

Engin Damla Gök https://orcid.org/0000-0003-0615-6340
Tuğba Ünsal Sapan https://orcid.org/0000-0003-4744-2298

References

1. Goodwin W, Linacre A and Hadi S. *An introduction to forensic genetics*. 2nd ed. Chichester: John Wiley & Sons, 2011.
2. Lee HC, Ladd C, Bourke MT, et al. DNA typing in forensic science I: Theory and background. *Am J Forensic Med Pathol* 1994; 15(4): 269–282. DOI: 10.1097/00000433-199412000-00001
3. Unsal T, Filoglu G, Altuncuk H, et al. Profiling of six mini STR loci (D1S1677, D2S441, D4S2364, D10S1248, D14S1434, D22S1045) on blood spots stored on various surfaces. *Med Sci* 2017; 6(1): 51–56. DOI: 10.5455/medscience.2016.05.8521
4. Dumache R, Ciocan V, Muresan CO, et al. Molecular genetics and its applications in forensic sciences. In: Shetty BS and Padubidri JR (eds) *Forensic analysis – From death to justice*. London: IntechOpen, 2016, pp.88–96. DOI: 10.5772/63530
5. Nolan A, Speers SJ, Murakami B, et al. A pilot study: The effects of repeat washing and fabric type on the detection of seminal fluid and spermatozoa. *Forensic Sci Int* 2018; 289: 51–56. DOI: 10.1016/j.forsciint.2018.05.021
6. Kulstein G, Schacker U and Wiegand P. Old meets new: Comparative examination of conventional and innovative RNA based methods for body fluid identification of laundered seminal fluid stains after modular extraction of DNA and RNA. *Forensic Sci Int Genet* 2018; 36: 130–140. DOI: 10.1016/j.fsigen.2018.06.017
7. Brayley-Morris H, Sorrell B, Revoir CP, et al. Persistence of DNA from laundered semen stains: Implications for child sex trafficking cases. *Forensic Sci Int Genet* 2015; 19: 165–171. DOI: 10.1016/j.fsigen.2015.07.016
8. Nilsson M, De Maeyer H and Allen M. Evaluation of different cleaning strategies for removal of contaminating DNA molecules. *Genes* 2022; 13(1): 162. DOI: 10.3390/genes13010162
9. Mason F and Lodrick Z. Psychological consequences of sexual assault. *Best Pract Res Clin Obstet Gynaecol* 2013; 27(1): 27–37. DOI: 10.1016/j.bpobgyn.2012.08.015
10. Snedeker J, Houston RM and Hughes S. Twenty eight days later: The recovery of DNA from human remains submerged in aggressive household chemicals. *J Forensic Sci* 2025; 70(2): 460–475. DOI: 10.1111/1556-4029.15682
11. Stene LE, Ormstad K and Schei B. Implementation of medical examination and forensic analyses in the investigation of sexual assaults against adult women: A retrospective study of police files and medical journals. *Forensic Sci Int* 2010; 199(1–3): 79–84. DOI: 10.1016/j.forsciint.2010.03.016

12. Unsal Sapan T, Gungor A, Sandikci N, et al. DNA recovery and human identification from semen stains washed at different temperatures. *Int J Legal Med* 2023; 137(2): 303–310. DOI: 10.1007/s00414-022-02937-4
13. Unsal Sapan T, Erdogan IT and Atasoy S. Human identification from washed blood stains. *Bull Natl Res Cent* 2021; 45: 148. DOI: 10.1186/s42269-021-00600-3
14. QIAGEN. *QIAamp DNA investigator handbook*. Hilden: QIAGEN, 2020, pp.1–80.
15. Thermo Fisher Scientific. (2025, March 1). *Qubit dsDNA HS assay kit handbook*. https://assets.thermofisher.com/TFSAssets/LSG/manuals/Qubit_dsDNA_HS_Assay_UG.pdf
16. Thermo Fisher Scientific. (2019). GlobalFiler and GlobalFiler IQC PCR amplification kits user guide (pp. 99–100). Thermo Fisher Scientific. https://assets.thermofisher.cn/TFS-Assets/LSG/manuals/MAN0029969-GlobalFilerIQC-PCRAmpKit-UG.pdf
17. Thabet HZ, Ghandour NM and Salama RH. Effect of some cleaning products on blood DNA retrieval from cloth. *Egypt J Forensic Sci Appl Toxicol* 2018; 18: 53–66.
18. de Silva Wijeyeratne A and Gweon HS. Evaluating the effectiveness of sodium hypochlorite for genomic DNA decontamination. *Environ DNA* 2025; 7(1): e70057. DOI: 10.1002/edn3.70057
19. Chapman B, Giammo J and Coumbaros J. An environmental DNA approach to the isolation of human genetic material under different household chemical exposures. *Forensic Genomics* 2023; 3(2): 87–95. DOI: 10.1089/forensic.2023.0007

Journal of Indian Academy of Forensic Medicine

Aims and Scope

Journal of Indian Academy of Forensic Medicine (JIAFM) is a quarterly peer-reviewed specialty medical journal which is the official publication of the Indian Academy of Forensic Medicine. The Journal covers all technical, medico-legal and clinical aspects of the Specialty including the Ethical and Social issues. JIAFM presents a comprehensive and meticulous exploration of the intricate facets within the realm of Forensic Medicine. It serves as a pivotal platform for scholarly investigations, discussions, and insights into ethical and social dimensions that intersect with Forensic Medicine.

Priority is accorded to Original Research Articles, Review Papers, and impactful Case Reports that significantly contribute to the field. By spotlighting these crucial areas, JIAFM endeavours to foster a deeper understanding of Forensic Medicine and promote best practices.

Manuscript Submission Guidelines

To view the manuscript submission guidelines, please visit
https://journals.sagepub.com/author-instructions/iaf

Journal of Indian Academy of Forensic Medicine

ISSN: 0971-0973 Online ISSN: 0974-0848

***Journal of Indian Academy of Forensic Medicine* (JIAFM)** is a quarterly peer-reviewed specialty medical journal which is the official publication of the Indian Academy of Forensic Medicine. The basic ideology of publication of this journal is based on the objectives of Indian Academy of Forensic Medicine (IAFM). It is a quarterly published, multidisciplinary, Multispeciality, international, peer reviewed IAFM (society) journal published by SAGE as a medium for the advancement of scientific knowledge of Forensic Medicine, Medical Ethics, Medical Education, Law and allied sciences.

The Journal covers all technical, medico-legal and clinical aspects of the Specialty including the Ethical and Social issues. JIAFM presents a comprehensive and meticulous exploration of the intricate facets within the realm of Forensic Medicine. It serves as a pivotal platform for scholarly investigations, discussions, and insights into ethical and social dimensions that intersect with Forensic Medicine.

Priority is accorded to Original Research Articles, Review Papers, and impactful Case Reports that significantly contribute to the field. By spotlighting these crucial areas, JIAFM endeavours to foster a deeper understanding of Forensic Medicine and promote best practices. To view the manuscript submission guidelines, please visit https://journals.sagepub.com/author-instructions/iaf

From Editor's Desk

Dear All,

You have my sincere gratitude for believing in me and giving me this distinguished role as the Editor-in-Chief of Journal of Indian Academy of Forensic Medicine. Big thanks to all IAFM members and Esteemed voters. Words cannot describe how grateful I am. I am grateful to the former IAFM President - Dr Mukesh Yadav Sir and former IAFM Secretary- Dr Manish Kumath Sir for their kind blessings and continued support. With blessings and support from current IAFM President- Dr C B Jani Sir and IAFM Secretary- Dr Rajesh Dere Sir, I will prove myself with continued hard work, dedication and constant efforts towards upliftment of the journal status.

I am well aware of the obligations that you have placed on me. With your ongoing assistance, I hope that everyone will have a great time for their own academic upliftment, including upgradation of the journal quality and indexing status at par excellence. I will strive to improve the calibre and standard of JIAFM publications. Throughout the trip, I ask for your participation, understanding, and direction as needed. I would like to express my sincere gratitude to all of our past editors and co-editors who have distinguished this journal via their tireless efforts and dedication, which has allowed JIAFM to grow every year.

Being the Editor-in-Chief, on the behalf of my new editorial team including officially elected Joint Editor Dr Mohammed Ziyauddin G. Saiyed, I assure you a hassle-free and user friendly manuscript submission, handling and management system via SAGE platform for speedy process and final decision through editorial team. A few highly active national and international faculties with outstanding knowledge in a range of subspecialties have also been added as National, international editorial board and reviewer board panels, and they will be able to provide constructive criticism to help us get better.

Additionally, by including case series, research briefs, brief communications, book reviews, and letters to the editor, we intend to improve the publication sections. We genuinely anticipate our fraternity's academic advancement through high-calibre publications with your help.

Dr Ravindra B Deokar

MD (FM), LLB, LLM(HR), ACME, PGDFAO, FAIMER, EPGDHA (TISS), MBA (HAHCM)

Editor-in-Chief, Journal of Indian Academy of Forensic Medicine (Scopus indexed Journal).
Official Publication of Indian Academy of Forensic Medicine.

Email id: Jiafmeditor@gmail.com (M): +91-9423016325

https://journals.sagepub.com/editorial-board/IAF

Professor (Additional), Forensic Medicine, Lokmanya Tilak Municipal Medical College & LTMG Hospital, Sion , Mumbai 400022 Maharashtra.
Senate Member, Maharashtra University of Health Sciences, Nashik, Maharashtra.

Sage
www.sagepub.com