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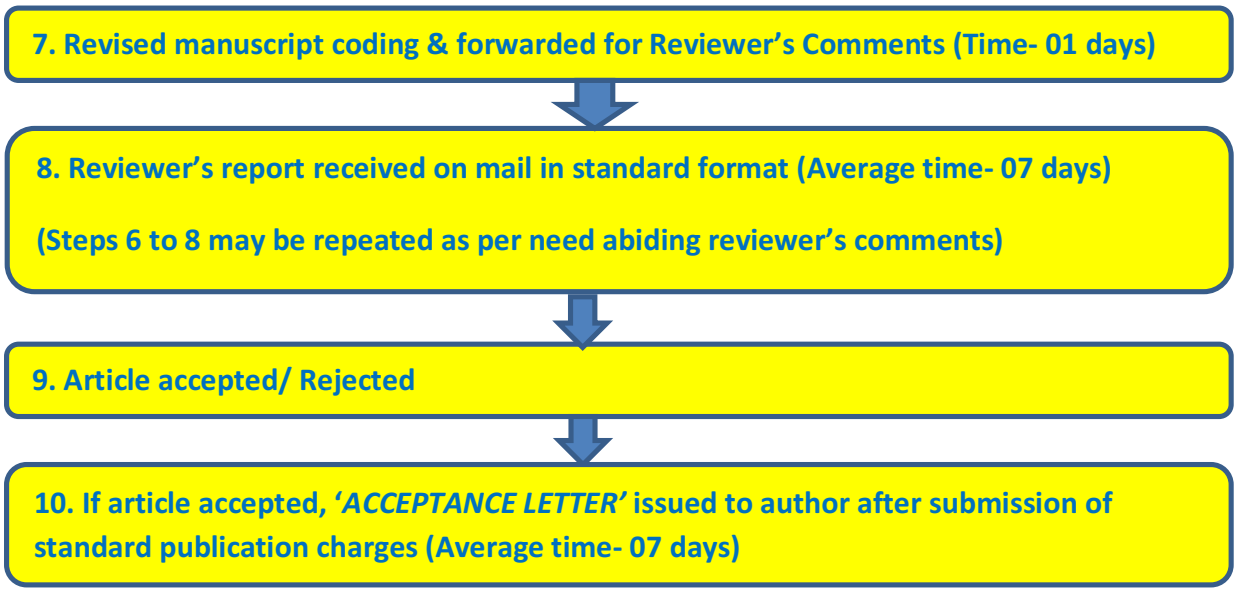

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Editorial

Cybercrime: Medicolegal Perspective

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1. Introduction

Cybercrime refers to illegal activity carried with the use of computers or an internet, mainly targeting individuals, organisations, public or governments for financial gains, creating nuisance or causing harm to others with a wide range of malicious activities. Various main types of cybercrimes based on targets are against individuals (identity theft, cyberstalking, credit card fraud, etc.), against organisations (malware attacks, denial of service attacks, ransom ware) and against property (intellectual property theft, credit card theft). Cybercrime poses significant hurdles in terms of its detection, prevention and long term negative impact on the victim of such attacks.[1] There is big data at healthcare institution with personal sensitive information. The medicolegal perspective of cybercrime mainly includes legal and ethical challenges related to digitally committed crimes. There are main ethical concerns related to digital crimes involving hacking, unauthorised access and leakage of sensitive health data and consequent exploitation of the patients. The field is evolving and there is no appropriate defined processes to deal with the cases of digital abuse and hospital guidelines on reporting such incidences and how to secure the forensic evidence in such crimes.[2] In medicolegal context, cybercrime is the complex issue related to patient data privacy, telemedicine, accountability, hospital information management system (HIMS) and digital health records.[3]

The main key issues at healthcare institutions in cyber-attacks are defining legal liability, patient's data privacy and consent, establishing forensic evidence and the existing legal framework. Cybercrime at healthcare institutions may involves fraud, mischief, defamation and forgery of healthcare professionals and patients. Digital advancement leads to multiple challenges to law enforcement agencies, policymakers, and governments to deal with cybercrime cases.[4]

2. Various Medico-Legal Implications of Cybercrime at healthcare institutions

1. Patient Confidentiality: Patient's data should be protected from unauthorized access and data breach should be avoided by Healthcare providers.[5]
2. Informed Consent: There is need of valid informed consent of the patients after informing them about the risks and benefits of digital health services. They should be well aware of the implications of telemedicine and electronic health records.
3. Cyber Forensics unit at healthcare institution: There is need of specialised unit at healthcare institution under Forensic

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Medicine with trained cyber forensic experts who will collect and preserve the digital forensic evidence and facilitate appropriate investigation in cybercrimes at healthcare institution.

3. Various Cybercrime Challenges in Healthcare[4-6]

1. Data Breaches: The unauthorized access to digital records containing sensitive patient information at healthcare institution by various stakeholders lead to serious consequences such as identity theft and financial fraud.
2. Digital Health Records: To ensure the safety, security and integrity of electronic health records of patient is one of the crucial thing to uphold patient's trust and confidentiality.[7]
3. Telemedicine: Nowadays, there is rise of telemedicine. It is increasing the new risks of data interception and unauthorized access to patient's confidential information.

4. Legal Framework related to cybercrime

1. Information Technology Act, 2000: A legal framework for addressing cybercrimes in India is provided by this act. It covers hacking, data theft and unauthorized access to digital systems and computers.
2. The Digital Personal Data Protection Act 2023: It aims to safeguard individual privacy and permitting lawful data processing. It regulates the collection, storage and processing of personal data, including sensitive health information. In India, it is the prime comprehensive data protection law.
3. Bharatiya Nyaya Sanhita (BNS): The BNS complimentary to the IT Act, addressing various cybercrimes and providing penalties for offenses like Cyberstalking (BNS Section 78), Voyeurism (BNS section 77) and cyber frauds (BNS section 318 and 336).

5. Key issues of cybercrime at healthcare institution[7,8]

1. Patient's Data Privacy:
   The protection of the sensitive patient's healthcare data is one of the most important role of healthcare provider. Healthcare institution must ensure legal compliance with data privacy laws. Organisation should protect the patient's valuable information from unauthorized access.
2. Informed Consent:
   The patient should be informed about the risk associated with digital health services. There are chances of personal data compromise due to cyber threat challenges, patient's informed consent is important and patient's data should be protected from unauthorised access.
3. Data Tampering and Manipulation:
   Health data can illegally modified by cybercriminals with use of artificial intelligence causing misdiagnoses and compromised treatments or other malicious outcomes that directly impact patient care.[9]
4. Erosion of Patient Trust:
   In healthcare industry, Cyberattacks leading to loss of patient's confidence about the security of their personal confidential health information. This is causing a great fear and anxiety in patient leading to reluctance to share their crucial personal healthcare information.
5. Disruption of Medical Care:
   As there is loss of patient's trust and data breach, there may be healthcare mis-management and wrong treatment. The emergency medical care may be directly hampered by sophisticated cyberattacks causing hindrance in the emergent healthcare delivery. This may affect patient's safety and security leading to endanger life.
6. Forensic Evidence collection experts/ Forensic nurse:
   There is need of trained forensic nurse or staff having digital literacy to identify, collect, and preserve online forensic evidence in cybercrime. Such person should work with forensic cyber experts, meticulously document incidents. Such experts should able to provide trauma-informed care to victims.
7. Data Breaches:
   Poor standardisation and unauthorized access to patient's sensitive information may lead to fraud, identity theft, and personal blackmail. Accidental or malicious insider threats to data privacy causing data security compromise, including selling patient data, leaking financial information, passwords or downloading malware have great impact on proper functioning of healthcare organisation.

8. Jurisdictional Issues:
   Cybercrimes are often transnational, creating complex jurisdictional challenges for investigations and prosecutions, requiring international cooperation.[10, 11]

6. Roles of Medical and Legal Professionals

1. **Healthcare Providers:**
   Healthcare professionals should aware of their duty to report cybersecurity incidents and facilitate investigations to prevent further harm ensuring accountability.
   Healthcare professionals should uphold ethical principles like patient autonomy and confidentiality. At cybersecurity threats, they have legal obligations to report the security-breach incident and cooperate with investigations.
2. **Lawmakers, policyholders and Government:**
   Lawmakers should evolve and update the laws addressing the emerging cybercrimes to ensure the admissibility of digital evidence. It need to strike a balance between individual privacy rights and law enforcement.

7. Conclusion and Recommendations:

Deceptive emails or messages forcing healthcare workers to reveal sensitive information or login credentials. In the era of advancement and artificial intelligence, such attacks are often enhanced and more effective to cause immediate damage to healthcare delivery system. There is need to implement best practices involving robust security measures including firewalls, encryption, controlled access to the digital record at healthcare institutions.

Healthcare professionals should be trained on data confidentiality importance, cybersecurity and maintenance of forensic evidence. There should be stringent monitoring and regular audits in healthcare to detect and prevent cybercrimes. There is a need of cross-disciplinary legal reforms with integrated legal models for dealing with cyber threats in the healthcare sector effectively.

To combat cybercrime effectively, there is need of comprehensive legislation to deal all aspects considering digital advancements. To enhance cybercrime investigation and prosecution, there is need to establish specialized cybercrime units and even the special forensic cyberunit may be established to deal with forensic evidence at the healthcare organisations. Educating people and creating public awareness about cyber risks and best practices is helpful for prevention.

Contribution ship of authors: All the authors have contributed equally.

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Original Research Article

Radiological Age Estimation from Epiphyseal Fusion of Distal Femur and Proximal Tibia

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Abstract

Introduction: Forensic anthropology utilizes age estimation techniques based on the examination of the distal femur and proximal tibia to determine the age of an individual. This method involves analyzing the fusion of epiphyseal plates, which are located at the ends of these long bones and play a key role in bone growth during childhood and adolescence. To estimate age, radiographic imaging techniques such as X-rays are used to visualize the skeletal structure of the distal femur and proximal tibia. **Materials and Methods:** This study involved patients who underwent digital X-ray examinations in Department of Radiology, Sri Ramachandra Institute of Higher Education and Research, Chennai during the year 2023. Total of 200 cases (108 males and 92 females) were randomly selected between the age group of 10 – 20 years. The stages of ossification at the epiphyseal fusion of the distal femur and proximal tibia were analyzed in Department of Forensic Medicine after obtaining the digital X-rays of the knee joint in antero-posterior view. **Results:** The results are significant in concluding that if the union of distal femur and proximal tibia are in stage 0 and 1, the age of the individual is less than 13 years, if in stage 2 and 3, the age is between 14-17 years and if in stage 3 and 4, the age is more than 18 years.

1. Introduction

Forensic anthropology utilizes age estimation techniques based on the examination of the distal femur and proximal tibia to determine the age of an individual. The bones of human skeletons develop from separate ossification centers. From these centers, ossification progresses till the bone is completely formed. These changes can be studied by means of X-rays.

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It is therefore possible to determine the approximate age of an individual by radiological examination of bones till ossification is complete.[1,2] This method involves analyzing the fusion of epiphyseal plates, which are located at the ends of these long bones and play a key role in bone growth during childhood and adolescence. To estimate age, radiographic imaging techniques such as X-rays are used to visualize the skeletal structure of the distal femur and proximal tibia. By examining the fusion patterns of the epiphyseal plates in these regions, forensic anthropologists can make inferences about the individual's age. [3, 4, 5]

X- rays of the long bones can be examined to determine the degree of fusion, which can then be compared to established age standards to estimate the individual's age. This method is particularly useful when other methods of age estimation are inconclusive or unavailable, and can provide important information in cases where the individual's identity is unknown or disputed.[6] Forensic age assessment in living subjects has become increasingly important over the last few years in both civil and criminal cases, especially in the age group between 14 and 21 years.[7] This information can also help to identify the deceased human remains, particularly in cases of mass disasters, unidentified bodies and age assessment in legal contexts.[8] Age determination by radiography of the relevant bones and joint is a well-accepted fact in the field of forensic medicine and among the various parameters available, skeletal age determination is considered the best. Sometimes, it serves an important piece of evidence of age determination in sensitive criminal cases to fix the punishment for the accused especially in cases of juvenile or young perpetrator. Estimating the age from ossification of bones radiographically is very crucial in cases of child sexual abuse & sexual assaults, trafficking, violent deaths and also in civil cases of inheritance, child labor and marriage.[9] It is imperative in medico-legal proceedings to accurately estimate the age of an individual as many laws and criminal codes are dependent on the age of the victim or the accused.[10, 11, 12]

2. Materials and Methods

This study involved patients who underwent digital X-ray examinations in Department of Radiology, Tertiary care hospital during the year 2023 for various medical reasons. A total of 200 cases (108 males and 92 females) were randomly selected between the age group of 10 – 20 years based on specific inclusion and exclusion criteria. The study design for this research was a cross-sectional study and individuals willing to participate in the study were included after obtaining informed consent. The stages of ossification at the epiphyseal fusion of the distal femur and proximal tibia were analyzed in Department of Forensic Medicine after obtaining the digital X-rays of the knee joint in antero-posterior view. Chi-square and ANOVA tests were performed using SPSS software (Statistical Package for the Social Sciences) to demonstrate the significance of the estimated ages and to compare different age groups.

The distal femur has an epiphyseal growth plate called the distal femoral epiphysis and the proximal tibia has an epiphyseal growth plate called the proximal tibial epiphysis located near the knee joint. The appearance and fusion status of this growth plate were examined. The degree of closure or ossification of the distal femoral and proximal tibial growth plates were evaluated and compared to established age standards. Based on the appearance and fusion status of the distal femoral and proximal tibial growth plates the individual's age was estimated.

The epiphyseal union of distal femur and proximal tibia of five stages with estimation of age described by O'Connor et al [2] is given in **table no. 1**.

Table no. 1: Five stages of the epiphyseal union of distal femur and proximal tibia.

Stage 0	Non-union	Age between 10 – 12 years
Stage 1	Beginning union	Age between 12 – 14 years
Stage 2	Active union	Age between 14 – 16 years
Stage 3	Recent union	Age between 16 – 18 years
Stage 4	Complete union	Age above 18 years

Using X-ray film, age is estimated according to the above grading and the individual's age is identified.

3. Results:

Findings of femur bone (distal end of femur) are tabulated in **table no. 2**.

Table 2: Number of male & female subjects according to stages.

Male		Female	
Stages	**Subjects(n=54)**	**Stages**	**Subjects(n=46)**
Stage 0	15	Stage 0	8
Stage 1	10	Stage 1	6
Stage 2	9	Stage 2	10
Stage 3	11	Stage 3	12
Stage 4	9	Stage 4	10

Age groups for both males and females were

categorized into three ranges: 10-13, 14-17, and 18-20. A grade system was employed to predict age using data from the distal femur (**table 3**). Validation of the estimated ages was conducted through separate chi-square tests for males and females, utilizing distal femur data. In both genders, the estimated age derived from the distal femur yielded a p-value of 0.000, which was statistically significant.

Table 3: Age prediction from distal end of femur

Gender	Group (estimated age in yrs)	Stages					sig. (p <0.05)
		Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	
Male	1 (10 – 13)	8	5	2	0	0	
	2 (14 – 17)	0	1	8	10	0	
	3 (18 – 20)	0	0	0	2	10	
	Total	8	6	10	12	10	0.000
Female	1 (10 – 13)	15	10	1	0	0	
	2 (14 – 17)	0	0	8	8	0	
	3 (18 – 20)	0	0	0	3	9	
	Total	15	10	9	11	9	
Total	(0 to 4)	23	16	19	23	19	

Table 4: Comparison of femur distal ages with between groups and within groups.

Between groups	Within groups	Sig. (p < 0.05)
1 (10 – 13)	2 (14 – 17) 3 (18 – 20)	0.000
2 (14 – 17)	1 (10 – 13) 3 (18 – 20)	0.000
3 (18 – 20)	1 (10 – 13) 2 (14 – 17)	0.000

In order to assess statistical significance, an ANOVA test was used to compare femur distal ages with between groups and within groups. It was statistically significant for both groups with a p-value of 0.000 (**table 4**).

Findings of tibia bone (proximal end of tibia) are tabulated in **table no. 5**.

Table 5: Number of female & Male subjects according to stages.

Female		Male	
Stages	Subjects (n=46)	Stages	Subjects (n=54)
Stage 0	8	Stage 0	15
Stage 1	6	Stage 1	10
Stage 2	9	Stage 2	9
Stage 3	13	Stage 3	8
Stage 4	10	Stage 4	12

Table 6: Age prediction from proximal end of tibia.

Gender	Group (estimated age in yrs)	Stages					Sig. (p <0.05)
		Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	
Male	1 (10 – 13)	8	5	2	0	0	
	2 (14 – 17)	0	1	7	8	0	
	3 (18 – 20)	0	0	0	5	10	
	Total	8	6	9	13	10	0.000
Female	1 (10 – 13)	15	10	2	0	0	
	2 (14 – 17)	0	0	7	4	0	
	3 (18 – 20)	0	0	0	4	12	
	Total	15	10	9	8	12	
Total	0 to 4	23	16	18	21	22	

The age groups for both males and females were divided into three distinct ranges: 10-13, 14-17, and 18- 20 years (**table 6**). Employing a grade system, age prediction was based on information extracted from the proximal tibia. To validate the accuracy of the estimated ages, chi-square tests were performed for males and females, utilizing data from the proximal tibia. Remarkably, in both genders, the estimated age obtained from the proximal tibia yielded a p-value of 0.000, which was statistically significant.

Table 7: Comparison of tibia proximal ages between groups and within groups.

Between groups	Within groups	Sig. (p < 0.05)
1 (10 – 13)	2 (14 – 17) 3 (18 – 20)	0.000
2 (14 – 17)	1 (10 – 13) 3 (18 – 20)	0.000
3 (18 – 20)	1 (10 – 13) 2 (14 – 17)	0.000

The ANOVA test demonstrated statistical significance in comparing proximal tibia ages both betweengroups and within groups, with a remarkably

low p-value of 0.000 (**Table 7**).

4. Discussion

Age estimation using X-rays of the distal femur (the lower part of the thigh bone) and proximal tibia (the upper part of the shinbone) is a commonly employed method in forensic anthropology and skeletal age assessment. The development and fusion of specific ossification centers in these bones can provide valuable information about a person's age. Ossification centers are areas of bone formation that appear as radiolucent regions on X-rays.[13] The X-ray images of these bones can provide valuable information about the skeletal development and fusion of specific growth centers, which can be used to estimate a person's age.[14] Age estimation using X-rays of the distal femur and proximal tibia is typically performed by comparing the findings with established reference standards or age estimation charts.[15]

Aly SM et al. reviewed retrospectively a total of 479 anteroposterior and lateral radiographs of the knee in subjects aged between 10 and 20 years old; 255 males and 224 females. Epiphyseal union was scored as stage 0 (non-union), stage 1 (beginning union), stage 2 (active union), stage 3 (recent union) or stage 4 (complete union). It has been noted that union occurs at an earlier age in the Chinese population. As expected, epiphyseal union in females occurred earlier than males.[16]

In the current study, Age estimation can be made by assessing the fusion stages of the epiphysis at the distal end of the femurusing a 5-stage scale. The analysis of the samples showed that among females, there were 8 cases in stage 0, 6 cases in stage 1, 10 cases in stage 2, 12 cases in stage 3, and 10 cases in stage 4 and among males, there were 15 cases in stage 0, 10 cases in stage 1, 9 cases in stage 2, 11 cases in stage 3, and 9 cases in stage 4.

Age estimation can be made by assessing the fusion stages of the epiphysis at the proximal tibia using 5-stages. The analysis of the samples showed that among females, there were 8 cases in stage 0, 6 cases in stage 1, 9 cases in stage 2, 13 cases in stage 3, and 10 cases in stage 4 and among males, there were 15 cases in stage 0, 10 cases in stage 1, 9 cases in stage 2, 8 cases in stage 3, and 12 cases in stage 4.

Anil Aggrawal et al. has stated that the lower end of femur and upper end of tibia unites with the shaft at 18 years.[17] Other textbook authors have also stated the same but various stages of union of long bones have not been completely studied further in Indian population.

The results using X-rays is a valid method of estimating age and is consistent with the following studies. The Suchey-Brooks Atlas named after the researchers, George R. Suchey and Stanley Rhine Brooks involves the examination of several features on X-ray images, including the appearance of the medial clavicle, the proximal tibial epiphysis, and the distal femoral epiphysis. Each feature is scored based on its developmental stage, and the scores from different features are combined to estimate the individual's age.[18]

The Ubelaker Method, developed by Douglas H. Ubelaker, for age estimation using X-ray images of the distal femur and proximal tibia compared the data to estimate the age from sub adults and young adults. This method utilizes the X-ray data from the distal femur, the proximal tibia, and the medial clavicle. It is based on a regression formula that combines the age-related changes observed in these bones to estimate age.[19]

O'Connor et al. described the epiphyseal union method to estimate age using X-ray based on the observation of the fusion or closure of epiphyseal growth plates in the distal femur and proximal tibia. The study included 200 subjects 108 were males and 22 were females aged between 10 to 20 years, the findings revealed that a significant majority of cases exhibit complete fusion of the lower end of the femur at approximately 19- 20 years for males and 17-18 years for females. Notably, females tend to achieve fusion earlier than males.[4]

MK Meena et al. carried out a study to determine age by epiphyses fusion at knee joint by X-Ray in age group of 14 to 21 years. 100 subjects (64 males, 36 females) were selected randomly from various schools and neighborhood. The age was verified by checking the date of birth from school admission records. Anteroposterior & lateral views of knee joint was taken for fusion of ossification centre. Maximum number of cases belongs to 17-18 years of age group in both genders. Complete fusion of epiphysis and diaphysis in lower end of femur was observed at 18-19 years of age in male and 17-18 years of age in females.[20]

The current study findings indicate that a significant majority of cases exhibit complete fusion of the lower end of the femur and proximal tibia at around 19-20 years for males and at 17-18 years for females. Nermeen N. Welson et al (2019) conducted a study and estimated maturation of the knee joint

starts from the age of 10 and ends at 20 years. The epiphyseal unions were higher in females than males from the distal femur and proximal tibia and their score was statistically significant.[21]

Galic I et al. analyzed a sample of anteroposterior x-rays of the knee joints from 446 living individuals from Umbria, Italy (234 males and 212 females), aged between 12 and 26 years and evaluated the ossification of the distal femoral (DF), proximal tibial (PT), and proximal fibular (PF) epiphyses. They took into account possible persistence of the epiphyseal scars in the ossified epiphyses by the adopted stages of those previously introduced by Cameriere et al. (2012) and also used measurements from all three epiphyses to calculate the total score of maturation for the knee joint (SKJ). These results indicate that the SKJ method may give valuable supporting information in forensic procedures for discriminating individuals of legal adult age of 18 years. [22, 23]

The results of the current study also demonstrate that skeletal maturation fusion happens earlier in females than in males, with a significant mean difference of 19 years for males and 17 years for females and is a potential site for age estimation in late adolescence.

5. Limitations

For age estimation from the proximal tibia and distal femur using X-ray technique, several limitations have to be considered when interpreting the results like Population Variation, Individual Variation, Age Range Limitations, Sex Differences, Postmortem changes and also a much larger sample size.

6. Conclusion

The X-ray technique is utilized for age estimation in subadults and adolescents, as well as in unidentified decayed and missing individuals, to narrow down potential matches. Age indicators such as dental development or long bone lengths are commonly employed in such cases. This study presents alternative techniques for age estimation of fragmentary remains, demonstrating that the size of the metaphyses and epiphyses at the knee exhibits a remarkably strong correlation with chronological age.

A grading score system can be used with a higher degree of accuracy and reliability in estimating age based on these measurements. The study findings indicate that a significant majority of cases exhibit complete fusion of the lower end of the femur and proximal tibia at around 19-20 years for males and at 17-18 years for females, with females generally completing fusion earlier than males. Also, the results are significant in concluding that if the union of distal femur and proximal tibia are in stage 0 and 1, the age of the individual is less than 13 years, if in stage 2 and 3, the age is between 14-17 years and if in stage 3 and 4, the age is more than 18 years. So, observing the various stages of union from long bones from x-rays will be useful to estimate the age in different ranges with precision.

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Original Research Article

Profile of Deaths due to Poisoning, Autopsied in Chennai – A Cross Sectional Study

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Poisoning, Autopsy, Hydrochloric acid, Suicide.

Abstract

Introduction: Poisoning is an important health problem in every country of the world and it is a known fact that the incidence of poisoning in India is the highest and is estimated that more than 50,000 people die every year from poisoning. Poisoning affects all age groups generally due to easy accessibility of poisons and lack of awareness. **Objectives:** To find out epidemiological factors, pattern and other significant features of poisoning. **Methods:** The present study was conducted in the Department of Forensic Medicine & Toxicology attached to Medical College for a period of 2 years. Detailed and complete Post – Mortem Examination of the dead bodies were done including Chemical Analysis of Viscera. A proforma was prepared to fill up details of the parameters used in this study, data was compiled and analysed statistically. **Results:** Out of 5438 cases autopsied in the year 2020 & 2021 only 114 cases were confined to poisoning which constitutes 2.09% on a whole. Males (68.42%) outnumbered females. The most predominant age group of poisoning is between 31-40 Years. Maximum cases were brought dead to the hospital (80.70%). Maximum cases of consumption of poisoning were confined with Hydrochloric Acid Poisoning (28.07%). Maximum cases of poisoning related deaths were suicidal in nature (85.96%). **Conclusion:** In order to minimize the deaths due to poisoning, awareness need to be created among the public about the seriousness of poisoning. Government can take initiation to set up a poison information centre in all the tertiary care hospitals which can provide information about the type of toxic compound, antidote.

1. Introduction

Paracelsus (1493 – 1545) defined poison as all substances are poison; there is none which is not a poison. The right dose differentiates a poison and a remedy.[1] Till today poisoning remains one of the commonest causes of unnatural death. With the development of science and technology poisonous substances are used in house holding works, paintings, grain preservatives, agriculture

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and industries etc. Even though the advanced medical treatment and awareness, the poisoning cases are increasing day by day. Annually it has been estimated that the health hazards are directly or indirectly due to poisons is for more than 1 million illnesses worldwide, and this could be just the tip of the iceberg as most of the cases of poisoning actually go unreported and untreated especially in the developing and underdeveloped countries.[2]

WHO estimated that approximately 3 million pesticide poisoning cases occurs worldwide and cause more than 22,000 deaths per year.[3] This happened probably because of easy availability of these substances, less price and peaceful death on behalf of some social causes, emotional causes, less education and far away from tertiary hospital.

Poisoning being invariably medico legal in nature among fatal cases, post mortem examination is done to establish the exact cause of death. Manner of death in these cases is predominantly suicidal because of the general belief that it terminates life with minimal sufferings. Even accidental or homicidal cases are also reported and alleged which was more prevalent in the past as there were no well-established means of detecting poison from viscera etc and it was believed that if dead body was black, blue or spotted in places or smelled bad, the cause of death was a poison. Poisons are subtle and silent weapons, which can be easily used without violence and often without arousing suspicion.

At present due to vast development in all fields of life like industries, medicine and agriculture a significant number of new compounds have appeared as new poisonous substances, which lead to more number of poisoning cases.[4,5]

Even though the advanced medical treatment and awareness, the deaths due to poisoning are increasing day by day. As various chemicals are in use in modern era, they are very handy for misuse or accidental calamity. With the advent of modern techniques of chemical analysis, this method of committing homicide has lost its grounds.[2]

2. Aims and Objectives:

- To find out epidemiological factors, pattern and other significant features of poisoning.
- To know the predominant age, sex, and occupation involved in consumption of poison.
- To know the most common type of poison& the common manner of death encountered.

3. Materials and Methods:

The present study was conducted in the Department of Forensic Medicine & Toxicology attached to Medical College & Hospital for a period of 2 years from 01-01-2020 to 31-12-2021. During this period a total of 5438 Post Mortem cases were conducted, out of these 114 cases contributed to poisoning. Detailed and complete Post – Mortem Examination of the dead bodies were done including Chemical Analysis of Viscera, which was done at Forensic Science Laboratory. A proforma was prepared to fill up details of the parameters used in this study, data was compiled and analysed statistically.

Inclusion Criteria: All cases of poisoning autopsied at Government Medical College & Hospital, for the year 2020 & 2021 from 01-01-2020 to 31-12-2021.

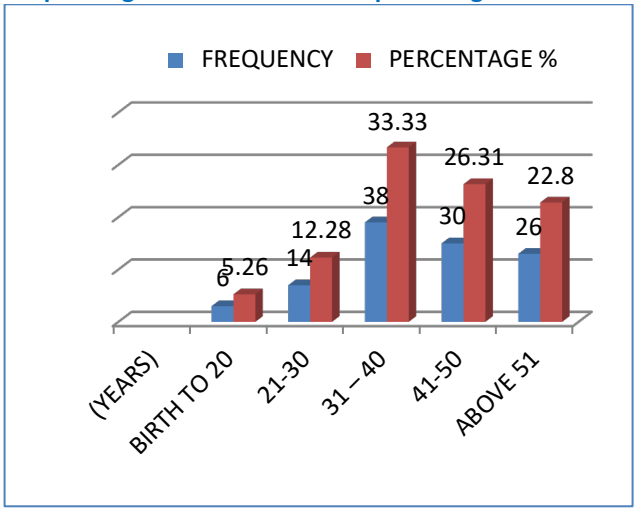
Exclusion Criteria: All snake bite cases, scorpion sting, bees sting cases and where the diagnosis of poisoning was doubtful (Unconscious patient without proper history and signs of poisoning).

4. Observations:

Sex wise distribution of poisoning: Maximum cases of Poisoning were seen in males which constitutes to 68.42% of the cases where as females were 31.57%.

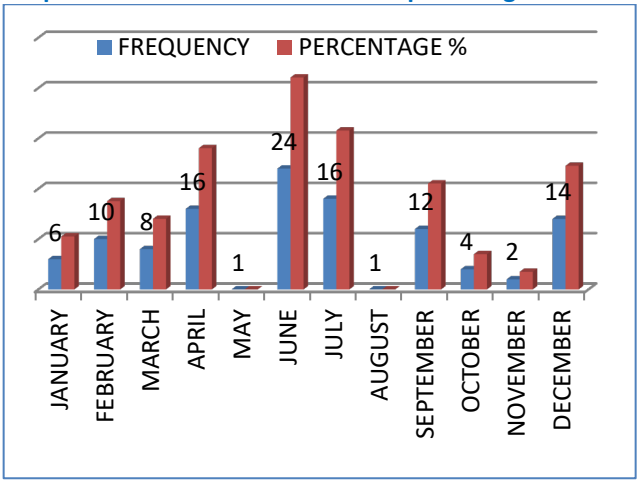
Age wise distribution of poisoning: Maximum cases of poisoning were seen in the age group of 31-40 Years (33.33%) followed by 41-50 Years (26.31%) and above 51 Years (22.80%). The most predominant age group of poisoning was between 31-40 Years (33.33%) (**Graph 1**).

Graph 1: Age wise distribution of poisoning.



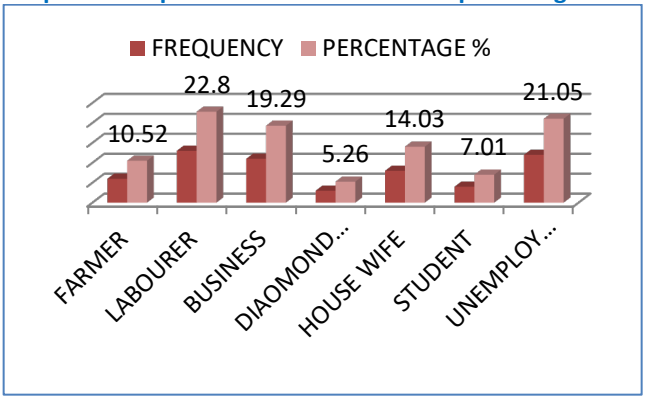
Month wise distribution of poisoning: Maximum number of poisoning cases were seen in the month of June (21.05%) followed by July (15.78%) and April (14.03%). Predominant month of poisoning is June (21.05%) (**Graph 2**).

Graph 2: Month wise distribution of poisoning.



Occupation wise distribution of poisoning: Cases of poisoning based on occupation was relatively high in labourers (22.80%) followed by business individuals (19.29%) and unemployed individuals (21.05%). Maximum cases of poisoning were noticed in laborers (22.80%) (**Graph 3**).

Graph 3: Occupation wise distribution of poisoning.



Religion wise distribution of poisoning: Cases of poisoning were more in Hindus (57.89%) followed by Christians (28.07%) and Muslims (14.03%).

Table 1: Distribution of poisoning cases according to educational status.

Educational status	Frequency	Percentage %
Illiterate	**34**	**29.82**
Graduate	22	19.29
Post graduate	26	22.80
Upto school	14	12.28
College drop outs	18	15.78
Total	114	100

Most of the individuals who consumed poison and died were Illiterates (29.82%) followed by Post Graduate's (22.80%) and College Dropouts (15.78%) (**Table 1**).

Distribution of poisoning cases according to marital status: Maximum number of poisoning cases was seen in married males (57.14%) followed by unmarried males (86.36%).

Distribution of poisoning cases according to socio economic status: Maximum number of poisoning cases was seen in Middle socio-economic status (56.14%) followed by lower socio-economic status (35.08%) and Upper socio-economic status (8.77%).

Distribution of cases based on treated and died, brought dead to the hospital: Maximum cases were brought dead to the hospital (80.70%).

Table 2: Distribution of poison detected by chemical analysis.

Chemical analysis (FSL)	Frequency	Percentage %
Organophosphorus	10	8.77
Crane poison	04	3.50
Carbamate	04	3.50
Pyrethroid	04	3.50
Paraquat	04	3.50
Zinc phosphide	14	12.28
Hydrochloric acid	**32**	**28.07**
Nitric acid	02	1.75
Sulphuric acid	08	7.01
Cyanide	06	5.26
Benzodiazipine	06	5.26
Thinner	02	1.75
Alcohol	04	3.50
Super Vasmol – 33	04	3.50
Medicinal tablets	04	3.50
Unknown compounds / Not detected	06	5.26
Total	114	100

Maximum cases of consumption of poison were confined with hydrochloric acid poisoning (28.07%) followed by zinc phosphide (12.28%) and organophosphorus poisoning (8.77%) (**table 2**).

Manner of death: Maximum cases of poisoning deaths were suicidal in nature (85.96%) followed by accidental (7.01%) and manner of death not known contributed to (5.26%).

5. Discussion:

Total 5438 autopsies were carried out during the study period and out of them 114 cases of deaths due to poisoning were observed which constitutes 2.09% of deaths on a whole. Maximum cases of Poisoning were seen in males which constitutes to 68.42% of the cases where as females were 31.57%. (Males outnumbered females), which is in concurrence with the study conducted by PC Vaghela et al, Rajesh et al, S Chaudhry et al & Sasikumar et al.[6,7,8,9] Though all the studies were conducted in different parts of India, male predominance was a common and constant feature. Maximum cases of poisoning were seen in the age group of 31-40 Years (33.33%) followed by 41-50 Years (26.31%) and above 51 Years (22.80%). Almost similar statistics were observed in studies conducted by Navin Varma et al,

AK Kapoor, Dalal et al, Sanjay Gupta et al, Sharma BR et al, Rajesh et al.[3,10,11,12,13] It could be explained by the facts that the persons of this young age group are suffering from stress of the modern life style, family problems, financial problems and failure in the exams.

Maximum number of poisoning cases were seen in the month of June (21.05%) followed by July (15.78%) and April (14.03%) which was not consistent with the studies done by Navin Varma et al, PC Vaghela et al, Dhattarwal S.K et al where maximum number of poisoning cases were observed in the monsoon months of August, September and October.[3,6,14] Cases of poisoning based on occupation was relatively high in labourers (22.80%) followed by business individuals (19.29%) and unemployed individuals (21.05%).This is in contrast to the studies conducted by Rajani V. Bhagora et al, and Anand Patil et al. Farmers consuming poison was high in the study conducted by Bhuyyar Chandrasekhar et al followed by housewives.[15,16,17] In our study labourers consuming poison were high, this is because Chennai being a cosmopolitan city, many labourers from other parts of the country reach here for various job opportunities.

Cases of poisoning were more in Hindus (57.89%) followed by Christians (28.07%) and Muslims (14.03%).This is similar to the studies conducted by B.D.Gupta et al and Bhuyyar Chandrasekhar et al.[6,17] This increase in Hindus consuming poisons could be confined to majority of population with Hindus in India. Most of the individuals who consumed poison and died were Illiterates (29.82%) followed by Post Graduates (22.80%) and College Dropouts (15.78%).This is in contrast to many studies, including the study conducted by Bhuyyar Chandrashekar et al were literates outnumbered illiterates in consumption of poisoning.[17] In our study illiterates were more because most of them were labourers and daily wages. Economic stress could be the reason for them to commit suicide.

Maximum number of poisoning cases was seen in married males (57.14%) followed by unmarried males (86.36%).This is almost similar to the studies conducted by Bhuyyar Chandrashekar et al and B.D.Gupta et al were married people where high in committing suicide by poisoning.[6,17] This is related to financial stress and emotional stress related to bonding. In the study conducted by B.D.Gupta et al, married females were found to be high in number in consuming poison and die whereas in our study married males were high in consuming poison and die. This could be explained as most of the men are the persons who go to work to run the family and could have consumed poison because of financial stress.[6]

Maximum number of poisoning cases was seen in middle socio economic status (56.14%) followed by lower socio economic status group (35.08%) and upper socio economic status (8.77%) which is in contrast to the studies conducted by B.D.Gupta et al and Anand Patil et al, people with lower socio economic status were high in consuming poison and die out of it.[6,16] This could be clearly explained that the expectations of individuals in middle Socio Economic Status could not be satisfied and subsequently due to social, emotional and financial stress they commit suicide.

Maximum cases were brought dead to the hospital (80.70%).This is similar to almost all the studies.[18-21] This indicates people are so determined and prefixed and have enough knowledge about consumption of more toxic products so that they will not survive. Maximum cases of consumption of poison were confined with hydrochloric acid poisoning (28.07%) followed by zinc phosphide (12.28%) and organophosphorus poisoning (8.77%). This is in contrast to the studies conducted by B.D.Gupta et al and Bhuyyar Chandrashekar et al where most of the cases of poisoning where confined to consumption of organophosphorus poison.[6,17]

In our study hydrochloric acid consumption was high as it is an easily available as a domestic product to clean the bathrooms and Chennai being a cosmopolitan city, sale of agricultural products are less. Most of who consumed organophosphorus poison could have got the insecticide from the outer rural areas which are in close proximity to Chennai and would have consumed it. Maximum cases of poisoning deaths were suicidal in nature (85.96%) followed by accidental (7.01%) and manner of death not known contributed to (5.26%) which is similar to the studies conducted by B. D. Gupta et al, Rajesh et al & many other studies as various chemicals are in use in modern era, they are very handy for misuse or accidental calamity as well.[6,13,22-24] Most of the people prefer them for the purpose of suicide, as poisons leads to peaceful death.[25]

6. Conclusion:

In India, prevention of poisoning deaths poses a difficult task, as the cause of poisoning is

multifaceted. Chances of suicide is more prevalent of various reasons like poverty, unemployment, socio economic problems, divorce, dowry, love affairs, illegitimate pregnancy, extra marital affairs and conflicts relating to the issues of marriage, play an important role, particularly in the suicide of women in India.

In order to minimize the deaths due to poisoning, awareness need to be created among the public about the seriousness of poisoning, implementing the measure to uplift the socio – economic status and to solve unemployment and last but not the least, the law has to be strengthened towards the sale and distribution of pesticides& other harmful chemicals. Establishing poison control centre in every treating hospital may decrease the deaths due to poisoning.

7. Recommendations:

Government can take initiation to set up a poison information centre in all the tertiary care hospitals which can provide information about the type of toxic compound, antidote, toxicity assessment and treatment recommendations over phone / e-mail round the clock for all kinds of poisons.

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Contributor ship of Author: All authors equally contributed.

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Original Research Article

Profile of Medico Legal Autopsies Conducted at a Tertiary Care Centre in Indore (M.P)

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Autopsy,
Road Traffic Accident,
Poisoning,
Asphyxia.

Abstract

Introduction: Death is defined as the irreversible cessation of all biological functions sustaining a living organism, resulting from natural or unnatural causes. Determining the cause of death is crucial for law enforcement and health professionals to understand mortality patterns. **Aim:** To determine the demographic profile and causes of death in autopsy cases brought to the Department of Forensic Medicine and Toxicology, MGM Medical College, Indore (M.P), over a one-year period (January 1, 2023, to December 31, 2023). **Methodology:** This retrospective study analysed autopsies performed from January 1, 2023, to December 31, 2023, at the Department of Forensic Medicine and Toxicology, MGM Medical College, Indore (Madhya Pradesh). **Results:** Out of 2778 cases brought for post-mortem examination, males predominated (2250, 81%). The majority (753, 27.1%) belonged to the 21-30 years age group. Road traffic accidents were the most common cause of death (1045, 37.6%). **Conclusion**: This study highlights the significance of determining the cause of death, particularly in cases of unnatural deaths. These results can inform preventive measures and policy decisions to reduce mortality rates, particularly among young males.

1. Introduction

'Necropsy' is semantically the most accurate description of the investigative dissection of a dead body, the word 'autopsy' is used so extensively that there is now no ambiguity about its meaning.[1] In general terms, autopsies can be performed for two reasons: clinical interest and medico-legal purposes.

Theoretically any registered doctor can perform autopsy but ideally it should be performed by a forensic pathologist or forensic expert.[2] Objective of doing autopsy is to find out cause of death, manner of death, how the injuries were caused, type of object involved and preservation of relevant organs as evidence.[3] In cases of new born infants the question of live birth and viability and live birth assumes importance and should be determined.[4,5] Manner of death is either natural or unnatural. Natural deaths are mainly due to pathological cause and Unnatural deaths could be Accidental, Suicidal and Homicidal.

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Unnatural deaths include road traffic accidents, railway accidents, mechanical asphyxia, drowning, accidental fire, electrocution, assaults, poisoning, firearms, fall from heights, killed by animals, illicit liquor, snake bites, and food poisoning.[6] Manner of death is usually deciphered by circumstantial evidences but the cause of death in most of the cases is determined by the autopsy finding.[7,8,9,10,11] According to NCRB 2022 data, During 2022, total of 4,46,768 cases of Road Accidents were reported which rendered 4,23,158 persons injured and 1,71,100 deaths. 45.5% victims of road accidents were riders of 'two wheelers' followed by cars, trucks / lorries and three wheeler/auto rickshaw have accounted for 14.1%, 8.8% and 4.5% respectively of road accidental deaths. Majority (62.6%) of road accidents were due to over speeding accounting for 1, 00,726 deaths and 2, 71,661 persons injured. Dangerous/careless driving or overtaking contributed to 24.7% road accidents which rendered 45,161 deaths and 1, 00,901 persons injured and 2.2% of road accidents were due to poor weather conditions. 59.7% and 40.3% of road accidents were reported in rural areas (2, 66,707 cases) and urban areas (1, 80,061 cases) respectively. 29.5% (1, 31,793 cases out of 4, 46,768 cases) of total road accidents were reported near residential areas. Most number of deaths were seen in Maharashtra (66656 cases) followed by Madhya Pradesh (43726 cases) and the least reported in Lakshadweep (8 cases) followed by Nagaland (55 cases).[12]

Total number of Road Accidents registered an increase by 11.9% in 2022 compared to the previous year 2021. The number of persons killed and the number of persons injured had also increased by 9.4% and 15.3% respectively in 2022 as compared to the year 2021.[13] The aim of our study is to analyse the cause of death, age, sex, month & religion wise distribution among 2778 cases taken in our study over a period of one year duration.

2. Material and methods

The present study is a retrospective study performed in the Department of Forensic Medicine and Toxicology at Medical College in Central India from January 2023 to December 2023 and a total no. of 2778 cases were analysed. Information regarding deceased age, sex, religion, incident duration (month wise) and cause of death were collected from the department records, police Inquest papers and Post mortem reports. A Proforma has been formed to collect data, complied the collected data on excel sheet, observed it and the results has been drawn.

3. Result

The present study is a retrospective study performed in the Department of Forensic Medicine and Toxicology at Medical College in Central India.

A total of 2778 medico legal autopsies were conducted during the study period of 01 year from January 2023 to December 2023, out of which 2250 cases (81%) were males and 528 cases (19%) were females **(Table-1).**

Taking age group into consideration, the maximum number of male cases are 621 (22.3%) in the age group of 21-30 years, followed by 31-40 years age group with 501 cases (81.3%). In females, 21-30 years age group has maximum number of cases i.e. 132 (4.7%) followed by the 31-40 years age group with 115 cases (4.1%). The least number of cases in males are 57 (2.0%) belongs to the age group of >70 years and least number of female cases are 07 (0.2%) belong to the similar age group as male. Taking overall population into consideration 21-30 years age group has maximum number of cases i.e. 753(27.1%) and the least number of cases were 64 cases (2.3%) in the age group of >70 years **(Table-1).**

Table 1. Age and Sex wise distribution of cases (n-2778).

Age	Sex	No. of cases (%)	Total cases (%)
0-10	Male	85(3.1)	115(4.1)
	Female	30(1.0)	
11-20	Male	243(8.7)	312(11.2)
	Female	69(2.4)	
21-30	Male	621(22.3)	753(27.1)
	Female	132(4.7)	
31-40	Male	501(18.0)	616(22.2)
	Female	115(4.1)	
41-50	Male	381(13.7)	445(16)
	Female	64(2.3)	
51-60	Male	237(8.5)	314(11.3)
	Female	77(2.7)	
61-70	Male	125(4.5)	159(5.7)
	Female	34(1.2)	
>70	Male	57(2.0)	64(2.3)
	Female	07(0.2)	
Total		2778	2778

On the basis of Month wise distribution of case in the present study, the maximum number of

autopsies was conducted in the month of March that is 276 cases (7.9%) followed by in month of May that is 270 cases (9.7%). Month of September showed least number of cases i.e. 186 (6.7%) **(Table-2).**

In the present study, Hindu deceased's were majority in number with 2334 cases (84.04%) followed by Muslims with 154 cases (5.5%) followed by Sikh with 93 cases (3.3%) and the least number of deceased were belongs to Jain community that is 7 cases (0.25%). In our study, unknown cases were 179 in number that is 6.4%**.**

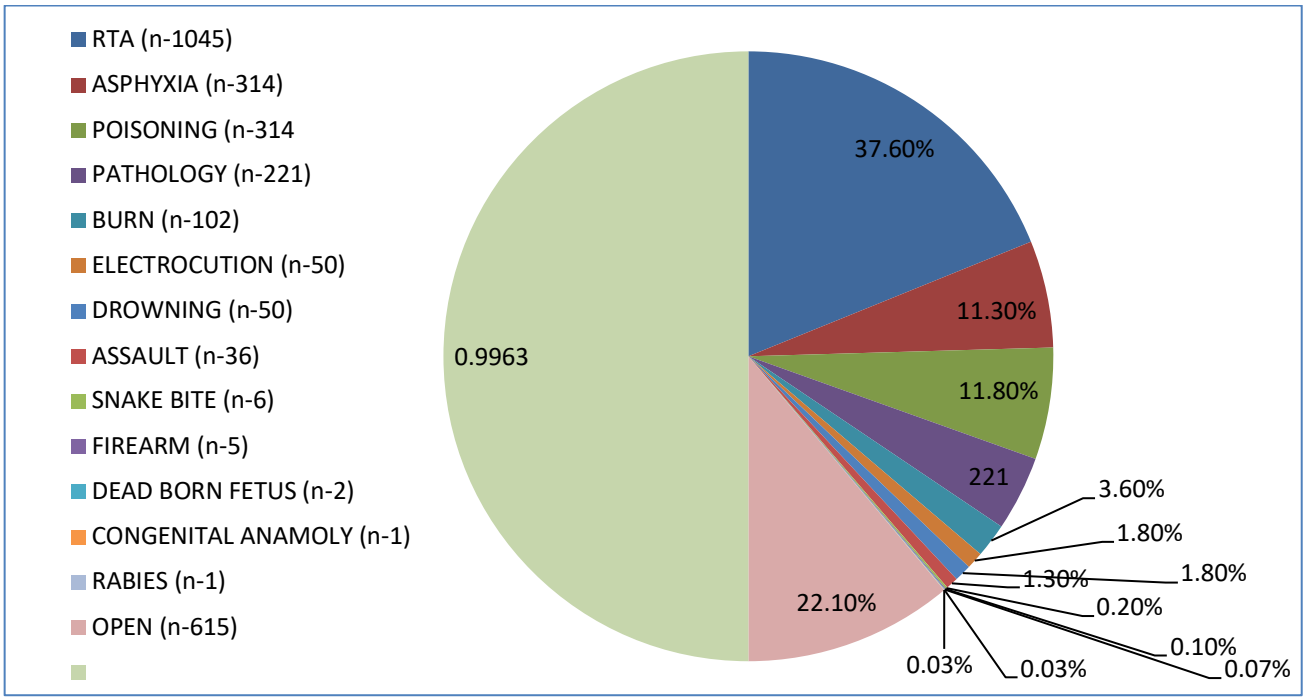
In our study, out of 2778 cases, the cause of death was determined in 2163 cases (77.7%). Out of these 2163 cases, in 221 cases (10.1%) death was due to natural causes, whereas in 1942 cases (89.9%) it was unnatural. In 615 cases (22.1%) cause of death could not be ascertained.

It was observed that death due to road traffic accident was most common cause of death involving 1045 cases (37.6%), followed by poisoning 330 cases (11.8%), followed by asphyxia 314 cases (11.3%) (In this study asphyxia includes death by hanging, smothering, strangulation and suffocation). Death due to pathological cause seen in 221 cases (7.9%) including cardiac pathology, lung pathology, liver pathology or brain pathology. Death due to burn seen in 102 cases (3.6%) including thermal burn and scald burn. Death due to electrocution and Drowning includes 50 cases (1.8%) each. Violent Death due to Assault seen in 36 cases (1.3%) including stab injury, blunt trauma to head, abdomen and other part of body.

Table 2. Month & Sex wise distribution of cases (n-2778)

Gender	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Total
Male	160	178	207	204	219	186	176	189	151	204	174	202	2250(81%)
Female	49	41	69	30	51	39	45	45	35	29	44	51	528(19%)
Total cases	209 (7.4)	219 (7.8)	276 (7.9)	234 (8.4)	270 (9.7)	225 (8.1)	221 (7.9)	234 (8.4)	186 (6.7)	233 (8.3)	218 (7.8)	253 (9.1)	2778 (100%)

Graph 1 - Distribution of cases on the basis of cause of death (n-2778)



In our study, there were also 06 cases (0.2%) cases of death due to snakebite and 05 cases (0.1%) of death due to firearm injury. In our study, we also found rare cause of death i.e. rabies and congenital anomaly including 01 case each. **(Table-3) (Graph 1).**

In males major cause of death was road traffic accident 901 cases (32.4%) followed by asphyxia 240 cases (8.6%) and in female major cause of death was 144 cases (5.1%) followed by poisoning 100 cases (3.5%). Least common cause of death in males was

rabies with 01 case (0.03%) and in females the least common cause of death was snake bite having 02 cases (0.06%) .

Table 3. Distribution of Cases on the bases of Cause of Death (n-2778).

Cause of Death	No. of Male	No. of Female	Total (%)
RTA	901(32.4)	144(5.1)	1045(37.6)
Poisoning	230(8.2)	100(3.5)	330(11.8)
Asphyxia	240(8.6)	74(2.6)	314(11.3)
Pathology	184(6.6)	37(1.33)	221(7.9)
Burn	60(2.15)	42(1.5)	102(3.6)
Electrocution	34(1.2)	16(0.5)	50(1.8)
Drowning	27(0.9)	23(0.8)	50(1.8)
Assault	27(0.9)	09(0.3)	36(1.3)
Snake Bite	04(0.1)	02(0.07)	6(0.2)
Firearm	05(0.1)	00	5(0.1)
Dead Born Fetus	02(0.07)	00	2(0.07)
Congenital Anomaly	01(0.03)	00	1(0.03)
Rabies	01(0.03)	00	1(0.03)
Open	534(19.2)	81(2.9)	615(22.1)
Total	**2250 (81.0)**	**528 (19.0)**	**2778**

(RTA- Road Traffic Accident).

4. Discussion

During the study period of one year, a total of 2778 cases of medico legal autopsies were performed at Department of Forensic Medicine and Toxicology. Out of 2778 cases 2250 (81%) were males and 528 (19%) were females showing male predominance and this finding of male predominance was consistent with studies done by Jain.A.P et al[14] in which out of 2447 cases, maximum number were of Male cases that is 1826 (74.6%) predominated over the female cases. This similar findings is also consistent with study done by Venkatesulu B[6] et al, Narendra Singh et al[15] and Pramod kumar et al.[16] Male predominance can be explained by males being more exposed to the external environment than females because of their more involvement in many sectors like in Government or private services, in sports, in army etc. In our present study, The most common age group involved in both male and female was 21-30 years having 753 cases (27.1%), this finding is consistent with the study conducted by Venkatesulu B[6] et al, Jain.A.P et al[14], Narendra Singh et al[15] and Pramod Kumar et al[16] in which 21-30 years of age group involves 458 (34.2%), 690 cases (28.2%), 119 cases (36.06%) and 260 cases (32.1%) respectively. This age group of 21-30 years belong to young adults who are active, energetic, mobile and impetuous which results in violence and wrong doing.

In our study population, 2334 cases (84.04%) were of Hindus followed by 154 cases (5.5%) were Muslims. Similar findings were observed by Venkatesulu B[6] et al, in which 1257 cases (67.69%) were Hindus followed by 419 cases (22.56%) were Muslims and in study done by M.E. Bansude et al[17] in which 630 cases (87.26%) were Hindus followed by 92 cases (12.74%) were Muslims. In contrast to our study, Gurmanjit Rai Mann et al[18] study shows common population involved were also belong to hindu religion that is 660 cases (83.22 %) but second most common was Sikh 83(10.48%). Hindu being predominant because in India majority of population were of Hindus. In our study, Religion was not known in 179 cases (6.4) as their identity is not known.

In the present study the maximum number of deaths were due to road traffic accident seen in 1045 cases (37.6%), followed by poisoning 330 cases (11.8%) and asphyxia 314 cases (11.3%) etc, similarly in the study conducted by Venkatesulu B[6] et al death due to road traffic accident was most common cause of death account for 45.07% followed by poisoning that is 15.67%. Similar finding of most common cause of death being road traffic accident followed by poisoning were observed in study conducted by Narendra Singh et al[15] in which death due to road traffic accident were present in 142 cases (43%) followed by poisoning in 98 cases (29.69%) and Pramod kumar et al[16] in which death due to road traffic accident were present in 313 cases (38.6%) followed by poisoning in 140 cases (17.2%). In study conducted by Jain A.P. et al.[14] The major cause of death was same as our study that is road traffic accident seen in 42.5% but second most common was differ from our study that is Pathological death seen in 16.5 % of cases. In study conducted by M.E. Bansude et al[17] **also** major cause of death was road traffic accident seen in 246(34.07%) cases and second most common was differ from our study that is thermal injuries in 193(26.73%) cases. Road traffic accident is major cause of death due to non-

adherence and unawareness of traffic rules, violating traffic rules, over speeding, poor condition of roads and overcrowding etc.

This finding of road traffic accident being most common cause of death in our study was found inconsistent with the study done by Mitra S. et al[19] who found death due to poisoning as a major cause of death in 36.6% cases followed by burn in 24.8% cases. In a study by Bhoi et al[20] poisoning deaths are observed more in young age group. Infant deaths are less.[21] There are very less number of assault cases as compare to other region.[22] Also in study conducted by Mugadlimath A. et al[23] major cause of death was burn seen in 37.5% cases followed by road traffic accident in 22% cases. This inconsistence in cause of death is may be due to different geographical area and less traffic movement in that area.

5. Conclusion

This study helps to understand pattern of medico legal autopsy conducted at the mortuary of Medical College in Central India. Road traffic accident was the most common cause of death in either gender of age group 21-30 years. In females second most common cause of death was poisoning whereas in males it was Hanging (Asphyxia). Accidental deaths can be prevented by encouraging people about use of helmets and seat belt, strict implementation of traffic rules and awareness about road safety measures. In today's world of artificial intelligence we should adopt GPS system and alarming system in all the vehicles which during the time of accident should alarm the nearest police station and hospitals resulting in timely hospitalization and early management which will reduce accident related mortality.

Since suicide is conglomerate, there is a need to spread awareness among people including children's, parents and young adults about mental health, communication and importance of meditation. Homicidal deaths can be reduced by increasing literacy rate, job opportunity and strict implementation of law and order.

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Original Research Article

Death due to Cardiac Tamponade: An Autopsy-Based Study at a Tertiary Care Facility in India

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Abstract

Introduction: Cardiac tamponade is a condition produced by a sudden increase in intra-pericardial pressure above the venous pressure due to fluid, which impairs diastolic filling by compressing the heart and leads to cardiac dysfunction and potentially cardiac collapse. Given its potential for sudden death, medico-legal autopsies are essential for accurate diagnosis. **Aim:** This study aims to analyse the incidence, prevalence, demographics, mechanism and manner of death due to cardiac tamponade based on autopsy findings at a tertiary care centre in western Maharashtra, India over six years. **Materials and Methods:** A retrospective study was conducted from 2018 to 2023 on deaths due to cardiac tamponade autopsied at a tertiary care facility in western Maharashtra, India. Data were extracted from inquest and admission papers and analysed for incidence, demographics, cause of death, mechanism and manner of incident. **Results:** Out of 5751 medicolegal autopsies, 36 cases (0.62%) were due to cardiac tamponade. The majority of cases occurred in males (74.3%), with the highest incidence in the 51-60 age group (41.66%). Non-traumatic origins accounted for 33 cases, primarily due to left ventricular wall rupture associated with post-myocardial infarction and involving rare case of pseudoaneurysm rupture of left ventricle, and one case was traumatic cardiac tamponade involving a child. **Conclusion:** Cardiac tamponade, often undiagnosed in emergency situations, emerges as a significant contributor to sudden cardiac deaths. Recognizing spontaneous cardiac tamponade promptly in the emergency department has the potential to save lives through timely interventions in this life-threatening condition.

1. Introduction

'Cardiac tamponade is a condition produced by a sudden increase in intra-pericardial pressure above the venous pressure due to fluid, which impairs diastolic filling by compressing the heart and leads to cardiac dysfunction and potentially cardiac collapse.[1-3]

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Cardiac tamponade results from the accumulation of pericardial fluid—whether exudate, transudate, or blood—leading to compression of the heart. Its causes broadly include pericardial effusion and hemopericardium. Pericardial effusion may arise from malignancy, myocarditis, bacterial or tuberculous pericarditis, rheumatologic diseases, or conditions such as myxoedema, hypothyroidism, and radiation therapy. Hemopericardium, the presence of blood within the pericardial cavity, can occur due to trauma, surgical procedures, myocardial infarction, rupture of intrapericardial vessels, or spontaneously. Non-traumatic cases most often involve rupture of the ventricular wall following myocardial infarction or spontaneous aortic rupture, commonly at the lateral wall of the left ventricle, whereas traumatic causes include road traffic accidents, falls from height, and penetrating chest injuries.[4-8]

Most cases of cardiac tamponade present as sudden and unexpected fatalities. Such sudden deaths hold considerable medico legal importance, as they commonly arouse suspicion of foul play, while cardiovascular pathology being the predominant underlying contributor.[9,10, 11] The unexpected death of an apparently healthy individual without significant medical history often raises suspicion, thereby necessitating a meticulous post-mortem examination to establish the precise cause of death.

2. Material and method

The study protocol was reviewed and approved by the Institutional Clinical Ethics Committee (ICEC). A six-year retrospective study was conducted on deaths due to cardiac tamponade in medico-legal autopsies performed between 2018 and 2023 at a tertiary care centre in the western Maharashtra region. The study included all medico-legal autopsies conducted during the study period in which the cause of death was solely attributed to cardiac tamponade, irrespective of age, gender, or traumatic/non-traumatic origin, while cases with other conditions contributing to the immediate cause of death in additional to cardiac tamponade were excluded. Data collection involved a detailed analysis of postmortem reports, along with a review of inquest papers, relevant medical history or past clinical records provided by relatives prior to postmortem as recorded by the autopsy surgeon and histopathology reports. Relevant parameters such as incidence, age and gender distribution, cause of death, mechanism of fluid accumulation, and manner of incident were systematically evaluated.

3. Results

During the study period, of the 5,751 medicolegal autopsies conducted, cardiac tamponade accounted for 0.62% (36 cases) (**Table 1**). All individuals were either brought dead to the hospital or succumbed within a few minutes of arrival in casualty. Of these, 26 were males (74.3%) and 10 were females (25.7%), yielding a male-to-female ratio of 2.88:1. The mean age for males was 54.57 +/- 5.67, whereas the mean age for females was 67.33 +/- 11.79. (**Table 2**). Out of 36 cases of cardiac tamponade, two cases were attributed to non-hemorrhagic pericardial effusion while the remaining 34 cases were associated with hemopericardium or hemorrhagic cardiac tamponade.

Table 1: Year wise data for the total number of medico legal autopsies conducted and cases of cardiac tamponade.

Year	Total No. Of Medicolegal Autopsies	Cardiac Tamponade
2018	839	5
2019	977	3
2020	767	4
2021	850	3
2022	998	7
2023	1320	14
Total	5751	36

Table 2: Age and sex wise distribution of cases of death due to cardiac tamponade.

Age in years	Male	Female	Total
<10	0	1	1
11 - 20	0	0	0
21- 30	2	0	2
31 - 40	1	1	2
41 -50	4	0	4
51 - 60	**15**	**0**	**15**
61 - 70	2	4	6
71 - 80	1	3	4
81 - 90	1	1	2
91-100	0	0	0
Total	26	10	36

Notably, out of the 34 cases of haemorrhagic cardiac tamponade, only one had a history of trauma, involving a female child aged 1.5 years. In the remaining 33 non-traumatic haemorrhagic cardiac tamponade cases, rupture of the left ventricle was identified in 31 cases, including pseudoaneurysm

Figure 1(a) and (b): (1a) Characteristic tense pericardium with bluish-black discoloration. (1b) Cut section of pericardial sac reveals the presence of a frank blood and clot on opening pericardium.

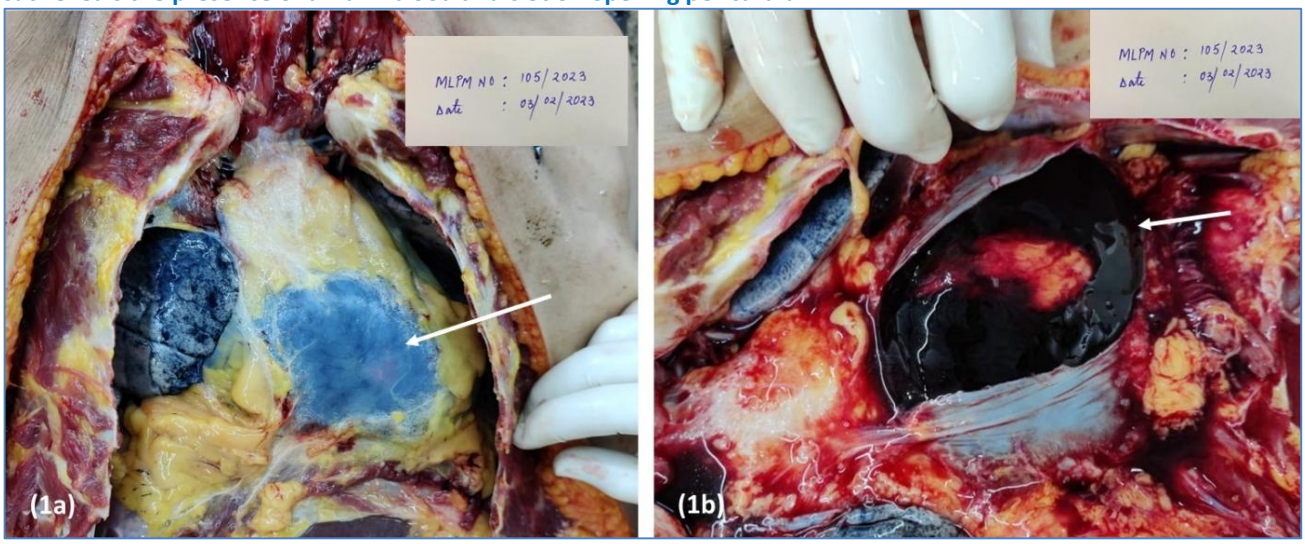


Figure 2(a) and (b): (2a) Rupture site of left ventricular wall (2b) Transmural rupture of left ventricular wall

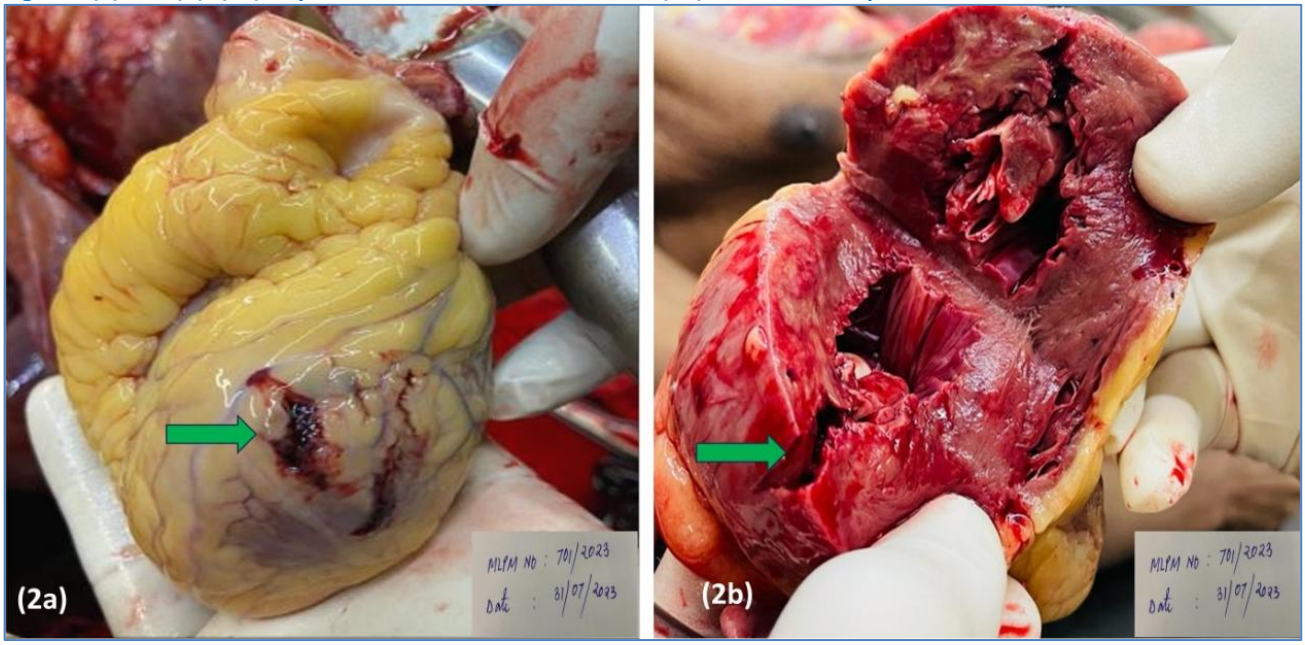


Figure 3 (a), (b) and (c): (3a) and (3b)- showing intrapericardial rupture of dissecting aneurysm of ascending aorta. (3c) Haemorrhagic area over base of aorta close to its origin.

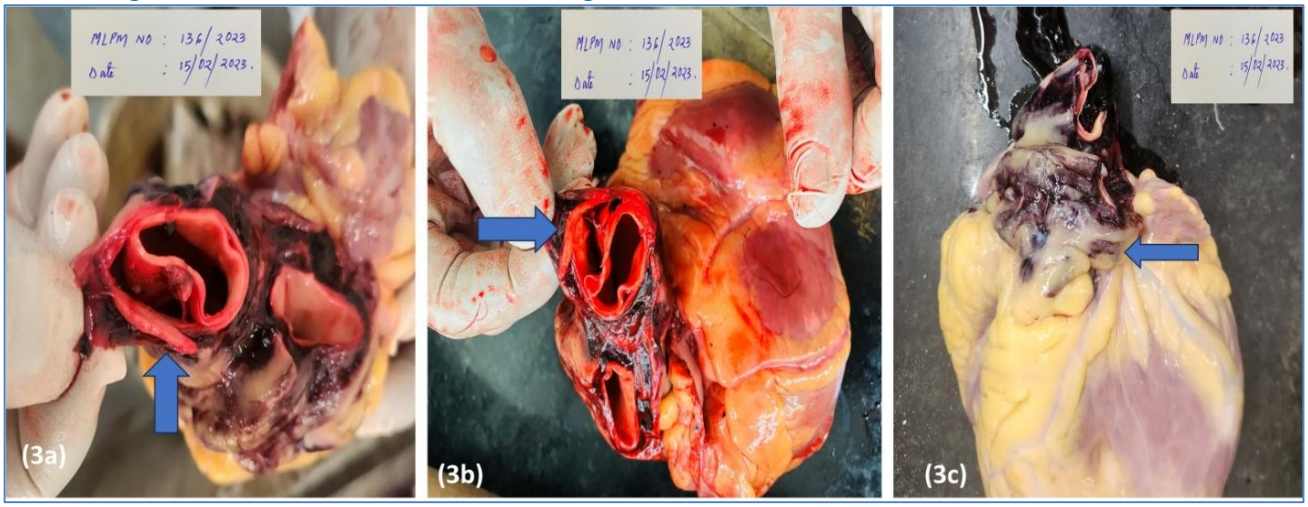
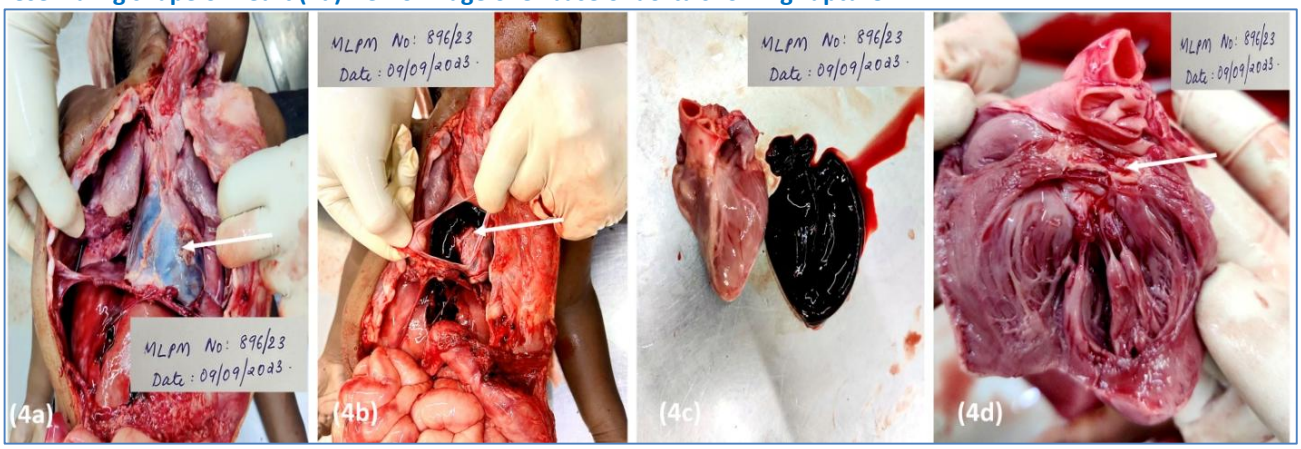


Figure 4(a), (b) , (c) and (d): Traumatic cardiac tamponade in a case of 1.5-year-old child : (4a) Tense bluish-black appearance of pericardium (4b) blood and blood clots inside pericardial cavity (4c) Blood clot from pericardial cavity resembling shape of heart (4d) Hemorrhage over base of aorta showing rupture



rupture of left ventricle, while 2 cases were attributed to rupture of a dissecting aortic aneurysm. Among the 31 cases of left ventricular wall ruptures, 17 cases showed an evident fibrous scar, indicating rupture of a weakened wall as a complication of old myocardial ischemia. The gender distribution of left ventricular rupture secondary to old myocardial infarction comprised 11 males and 6 females.

4. Discussions.

Understanding the physiological changes in tamponade is critical for diagnosis and treatment. It primarily includes the heart chambers being compressed as a result of increased pressure surrounding the heart. As the pressure rises, the heart's ability to expand inside the limited space of the pericardium diminishes, affecting cardiac function. The normal pericardial fluid volume (30 to 50 ml) displays a balance between production and reabsorption. The risk of death due to cardiac tamponade is higher in cases of rapidly accumulating hemopericardium (200 to 300 ml) compared to the slower accumulation of pericardial fluid (500 to 2000 ml), which can accommodate greater volumes due to gradual distension of the pericardial sac. The rate of fluid accumulation and the effectiveness of compensatory mechanisms are key factors, as rapid hemorrhage can quickly reach the pericardium's limit, leading to tamponade, while slower fluid accumulation, such as from inflammation, can tolerate a larger volume before becoming life-threatening.[1,5,6]

In order to ascertain the precise pathophysiological mechanism of cardiac tamponade, an extensive post-mortem examination is essential. On autopsy, hemorrhagic cardiac tamponade is characterized by a tense pericardium with a purplish or bluish-black discoloration. On opening, the pericardial sac typically contains frank blood and clots [Figure 1(a) and (b)].

In the study conducted by Raoof A et al., [4] over a period of 8 years, a pronounced male preponderance was evident in cardiac tamponade-related fatalities, with a male-to-female ratio of 4.6:1. Similarly, in our study, a notable male preponderance was observed with a male-to-female ratio of 2.88:1, which may reflect regional demographic and cardiovascular risk variations. The highest incidence of cases in Raoof A et al., [4] was within the 41–50 years age group, representing 29.41% of all cases. In contrast, our study revealed the highest incidence among individuals aged 51 to 60 years corresponding to 41.66%, likely due to differences in population age distribution and cardiovascular morbidity across the populations studied. The majority of cardiac tamponade cases in both studies were of spontaneous or non-traumatic origin, with only a small fraction being attributed to trauma. In the study conducted by Raoof A et al., [4] left ventricular rupture was identified as the most frequently reported cause, accounting for 73.53% of cases. Similarly, in our study, left ventricular rupture was also recognized as the predominant aetiology with 86.11% of cases, followed by rupture of the dissecting aortic aneurysm. Cardiac tamponade due to non-traumatic pulmonary artery rupture was observed in a single case in Raoof A et al., [4] study but no incidence in current study, probably due to its rare presentation.

Rupture of the left ventricular wall is a complication of myocardial infarction, affecting around 4% of infarct patients and approximately 23%

of those with fatal infarctions. Rarely, this wall rupture is contained by the surrounding pericardium, leading to left ventricular pseudoaneurysm. True ventricular aneurysm develops as a gradual outpouching involving the full myocardial wall, with fibrous replacement and a wide communication to the ventricular cavity. In contrast, a pseudoaneurysm of ventricle results from ventricular wall rupture contained by pericardium and fibrous tissue, shows no myocardial elements, and has a narrow communication neck with ventricular cavity. Unlike true ventricular aneurysms, which usually rupture in the peri-infarct period, pseudoaneurysms of ventricle can rupture immediately or even years later, often resulting in sudden death from cardiac tamponade.[12-16] In 2013, Dogan et al., [13] reported a 55-year-old woman who died suddenly 11 months after myocardial infarction, with autopsy revealing a large left ventricular pseudoaneurysm showing pericardial adhesions and organized thrombus with absence of myocardium. In comparison, our study describes two undiagnosed post-infarction cases in female patients, where rupture occurred in the lateral wall with thin fibrous tissue and organized thrombus between epicardial and pericardial adhesions. Similarities include female predominance and delayed or absent medical evaluation after infarction, while differences arise from pathological features where case report of Dogan et al.,[13] involved a single large pseudoaneurysm resulting in heart failure, whereas our study observed smaller lesion that progressed to rupture resulting in cardiac tamponade.

Swaminathan et al., [17] reported that males are more susceptible to myocardial infarction and aortic dissection at a younger age. They found that ventricular wall rupture, primarily due to acute myocardial infarction, was the primary cause of hemopericardium with a male-to-female ratio of 1:1.6. In cases of intrapericardial rupture of dissecting ascending aortic aneurysms, although affecting a smaller group, the male-to-female ratio was 1:1.2 while our study confirms male predominance in both post-myocardial infarction and aortic dissection rupture, accounting for 6.25% of cases.[18] Our autopsy findings revealed a distinctive double lumen appearance in instances of dissecting aortic aneurysm rupture, caused by an intimal tear extending from the ascending aorta. [Figure 3 (a), (b) and (c)]. Notably, the ventricular wall was the most common site of rupture in our study of the Indian population, emphasizing a higher incidence of atherosclerotic occlusive coronary artery disease and its related complications among males. Swaminathan et al., [17] reported that 69% of 458 cases of haemorrhagic pericardial effusion were associated with post-myocardial infarction. In comparison, our study documented 34 cases of haemorrhagic cardiac tamponade, of which 54.83% were attributed to left ventricular wall rupture with a demonstrable fibrous scar indicative of post-myocardial infarction.

Murillo et al., [19] Pooniya et al., [20] and Kanchan et al.[21]documented cases of traumatic cardiac tamponade resulting from blunt chest trauma. In each of these cases, the left ventricular wall sustained rupture, emphasizing the left ventricle as the most frequently affected site in cases of traumatic rupture. In the present study, the case was involved a 1.5-year-old girl child who had been thrown from a height by her father, resulting in a traumatic rupture of the base of the aorta [Figure 4(a), (b), (c) and (d)].

5. Conclusion.

In the current study, haemorrhagic non-traumatic cardiac tamponade predominated, with rupture of the left ventricular wall as the fundamental cause. Males were more affected, likely due to their higher burden of cardiovascular risk factors such as smoking, hypertension, and dyslipidaemia. The 51–60-year age group showed the highest incidence, reflecting the cumulative impact of atherosclerosis and age-related risk exposure. Notably, most of these cases had non-traumatic origins in contrast to the limited instances of traumatic cardiac tamponade Most cases were non-traumatic, while traumatic tamponade was rare. Left ventricular wall rupture, often following myocardial infarction, emerged as the primary aetiology, as infarcted myocardium is structurally weakened and prone to rupture, with subsequent fibrous scarring in longer survivors.

Cardiac tamponade, often undiagnosed in emergency situations, emerges as a significant contributor to sudden cardiac deaths. Recognizing spontaneous cardiac tamponade promptly in the emergency department has the potential to save lives through timely interventions in this life-threatening condition.

Limitation of the study: Post-mortem examinations of individuals who had myocardial infarction offer limited information due to a lack of detailed medical history and record availability.

Ethics approval: The study protocol was reviewed and ethically approved by the Institutional Clinical Ethics Committees (ICEC) of the study institute.

Availability of data and materials: The datasets generated and/or analyzed during our study are not publicly available since they are owned by the study institute. They can be made available from the corresponding author on reasonable request.

Competing interest: The authors declare no competing interests.

Funding: There was no financial burden on the institute or the subjects. The funding body has no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Authors' contributions: A.N, R.P & M.G identified the problem, designed the study, interpreted data and drafted the manuscript; All authors critically reviewed the draft and approved the final manuscript.

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Original Research Article

Frontal Bone Morphometry: A Standardized Protocol in Dry Skulls

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Abstract

Introduction: Frontal bone is a crucial component of facial architecture. It has evolved and changed in modern humans, modifying the skeletal phenotype. This makes the bone a key structure for human body morphological analysis. **Aims:** To establish a replicable frontal bone morphometry and to compare these dimensions with those from other populations. **Material and methods:** Fifty adult dry frontal bones were measured using anatomical landmarks and four measuring tools. One angular and eight linear measurements were used to determine bone sex and assess its morphometry. **Results:** Twenty-six bones were male and twenty-four were female. Average length of 12.5±0.6 centimeters. Supraorbital foramen height right side 1.8±0.3 millimeters and left side 1.7±0.3 millimeters. Supraorbital foramen width 3.5±1 millimeters for right side and 3.7±1.3 millimeters for left side. Orbits distance 26.6±2.6 millimeters. Right zygomatic process width 7.1±1.2 millimeters and left side 7.1±1.1 millimeters. The right zygomatic process width differs between male and women ($p \leq 0.0068$). **Conclusion:** A standardized morphometric protocol for dry human skulls' frontal bone was established. Results were compared with individuals of both sexes and different populations.

1. Introduction

The frontal bone is a key component of facial architecture, playing a crucial role in the transition between the facial skeleton and the skull.[1] These bone has evolved with changes in brain size, cranial base flexion, and facial retraction, making it essential for morphological and functional balance in modern humans.[1-2] Disciplines such as anatomy, anthropology, forensics and clinical sciences (orthodontics, ophthalmology, orthopedics, radiology, neurosurgery, etc.) rely heavily on understanding the development and growth of individual skull bones. For example, gender determination often involves analyzing skull´s sexually dimorphic features, such as mastoid triangle, foramen magnum, internal acoustic meatus, temporal zygomatic, and frontal bone, especially when pelvic bones are unavailable.[3] Studies have demonstrated the utility of craniometric analysis for sex determination, with the frontal bone's morphology

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being particularly informative. Other studies have shown that osteological features, dimensional parameters, and specific angular measurements are useful for sex estimation. A more gracile and less sloped frontal bone may suggest a female skull, whereas a more sloped frontal bone likely indicates a male skull.[4,-7] The aim of this study was to establish a replicable frontal bone morphometry and to compare these dimensions with those from other populations.

2. Materials and methods

Fifty adult dry frontal bones unknown sex/age were measured for this descriptive observational cross-sectional study. These bones were obtained as convenience samples from the Anatomy Laboratory of tertiary healthcare centre, Colombia. According to the Institutional Ethical Committee, this was classified as exempt from ethical review under institutional guidelines. Measurements were taken using the following tools: a digital caliper (Ubermann, Chile) for recording breadth, height, and length in millimeters (mm); a measuring tape (Stanley Black & Decker, Inc., Seattle, USA) to obtain length in centimeters (cm); a protractor and ruler (Faber-Castell, Guanajuato, México) to collect angular measurements in degrees (°); and a digital camera was used to document the bones photographically. All data were recorded in Microsoft Excel® (version 2205).

Sex classification followed the criteria described by Perlaza (2014) ,[8] where the frontal bone is convex in males and flat in females, see **Figure 1A and 1B**. Consistent with Koelzer et al. (2019) ,[3] frontal bone inclination was also used to determine sex, see **Figure 1C.** Morphometric analysis included frontal length measured with a tape, and supraorbital foramen height and width, orbital distance, and zygomatic process width measured with a digital caliper, see **Figure 2**.

Figure 1. Morphological features of the frontal bone. A. Female morphology. B. Male morphology. C. Frontal angle measurement.

Figure 2. Frontal bone morphometric parameters. A. Frontal length (red), supraorbital foramen height (purple), width (green), orbital distance (yellow), and zygomatic process width (blue). B. Supraorbital foramen height (yellow) and width (red). C. Orbital distance (red). D. Zygomatic process width (red).

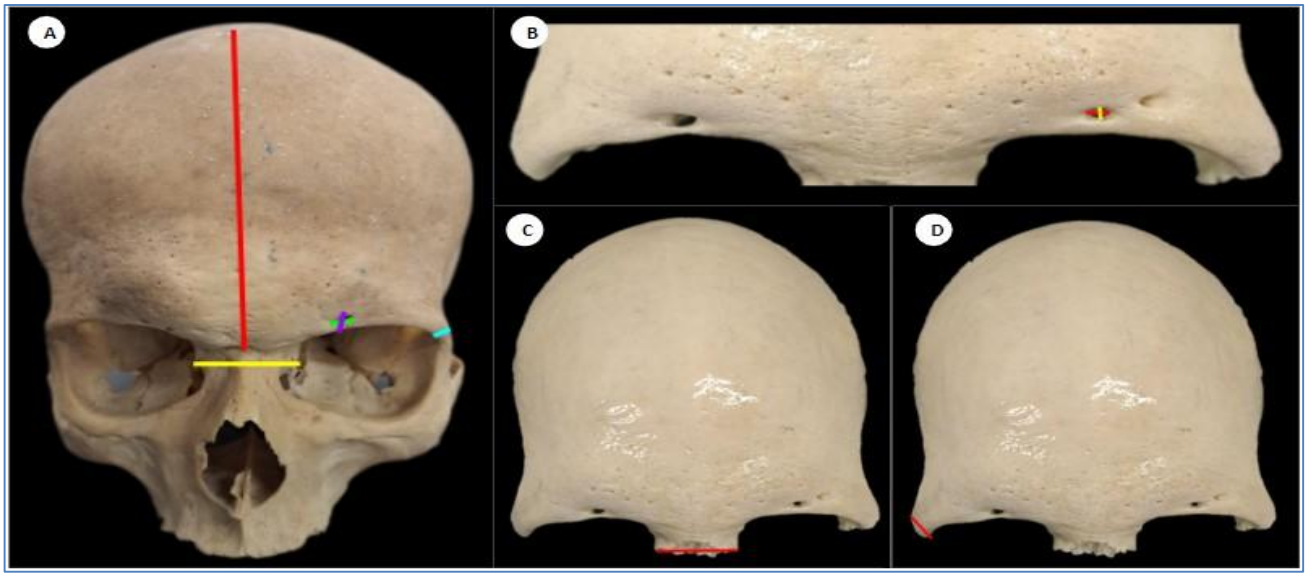

Table 1. Frontal bone morphometry results

Sample	Frontal angle (°)	Frontal length (cm)	Supraorbital foramen height (mm)		Supraorbital foramen width (mm)		Orbits distance (mm)	Zygomatic process width (mm)	
			Right	Left	Right	Left		Right	Left
ALL	90.97 ± 3.01	12.59 ± 0.61	1.85 ± 0.3	1.71 ± 0.3	3.53 ± 1.05	3.78 ± 1.31	26.64 ± 2.69	7.19 ± 1.27	7.17 ± 1.17
n	*43*	*29*	*12*	*13*	*34*	*36*	*50*	*47*	*47*
MALE	90.56 ± 2.86	12.62 ± 0.51	1.88 ± 0.28	1.73 ± 0.21	3.33 ± 0.94	3.44 ± 0.95	26.95 ± 2.86	7.58 ± 1.09	7.41 ± 1
n	*22*	*14*	*8*	*9*	*17*	*19*	*26*	*24*	*25*
FEMALE	91.40 ± 3.17	12.56 ± 0.71	1.79 ± 0.38	1.65 ± 0.48	3.72 ± 1.14	4.16 ± 1.56	26.31 ± 2.51	6.38 ± 1.75	6.89 ± 1.30
n	21	15	4	4	17	17	24	23	22

Measurements in degrees (°), centimeters (cm) and millimeters (mm).

Results are presented in **Table 1**. Data were expressed as mean ± standard deviation (SD). Student's t-test was used to compare mean values of supraorbital foramen height and width, as well as zygomatic process width, between both sides of the body; and to compare all measurements between sexes. A p-value ≤ 0.05 was considered statistically significant. Statistical analyses were performed with Jamovi Cloud, online statistical software.

3. Results

Among the analyzed frontal bones, twenty-six were classified as male bones, and twenty-four as female bones. The frontal angle was greater in females bones than in males; however, the difference was not statistically significant. Frontal length was greater in male bones, with values exceeding the overall sample mean. For supraorbital foramen height, male bones showed higher values than the sample mean, with the right side being larger than the left in both sexes. Supraorbital foramen width was greater in female bones, with values exceeding the overall sample mean. Results were not statistically significant.

The orbital distance measurement indicated that male bones had a slightly larger distance than females, the difference was not statistically significant. Males' right zygomatic process was significantly wider than the females' (p≤0.0068) while left differences were not significant.

4. Discussion

Frontal bone angle

Significant sexual dimorphism is expressed in the face upper third. Frontal bone proportions contribute to these findings with its external surface and craniometric landmarks.[9] A key measurement used to estimate sex from remaining bone was the frontal angle described by Schwalbe, which provided an accuracy rate of 75.4%.[10] To form the frontal bone inclination angle, and parallel to the Frankfurt plane, a line is placed from the craniometric point glabellae, and another line is drawn tangential to the frontal bone.[9] A threshold value of ≥ 88.6° suggests female sex, while smaller angles indicate male sex.[10] Additionally, a recent study with two hundred and eleven volume-rendered 3D cranial images, reported that this was the best frontal angle among ten, to estimate gender from the frontal bone inclination.[3]

Regarding this angle a research paper compared three different populations, sample size four-hundred-and-thirteen. A value of 78.2° or under expresses that the bones were from male, and above this angle value samples belong to females from North American and Portugal populations. However, an angle accuracy of 66% in the Chinese population, was not a satisfactory measurement on these digital 3D models.[11]Another research with seventy-seven 3D images of the Netherlands, estimated that ≤ 80.9° corresponds to male samples and ≥ 96.5° to females.[10]In the present study, the mean angle in the Colombian sample aligned more closely with female values reported in the first study, which may be related to the ethnic mix of native Colombians and migrants from the north of the continent and the European region.

Another study made in Colombia established two functional tools for sexual diagnosis: the size and the shape of the frontal region. The study relies on identifying four key anatomical points visible on seventy lateral radiographs of the glabellar region. An accuracy of 84.31% was reported.[11] Using that technique, the present results samples were classified according to their gender. When analyzed,

the frontal angle between sexes was pretty close between the used samples.

Frontal bone length

In the skull, there are external landmarks that can be important guides in several neurosurgical procedures and can lead to the measurement of the bone length. The Colombian frontal bone length values were similar to the Turkish population. One study quantified the distance between the nasion and the coronal sutures using measurements obtained from thirty dry skulls and thirty dry frontal bones.[12] A second report examined the nasion and the bregma landmark, in seventy-two dry skulls.[13] Both studies measurements were obtained with a measuring tape like in these results. The above may be due to the Christian migration of Turks to Colombia at the beginning of the nineteenth century.

Supraorbital foramen height and width

The supraorbital foramen (SOF) is a significant anatomical structure, with several digital radiography studies highlighting dimensional differences across populations, though not consistently by sex.[14] In the Thai population, gender variations in the mean horizontal widths of the SOF were found to be not significant, with an average of 2.81 ± 0.62 mm, measured with a caliper on one hundred and six dry skulls.[15] In a sample of eighty-three adult South Indian human skulls, results showed a mean height of 3.5 mm for the right SOF and 3.04 mm for the left SOF.[16] A study of the Pakistani population analyzed thirty-two dry human adult skulls, revealing that the mean height of the right side supraorbital foramen was 3.649 ± 0.687 mm, while the left side foramen measured 3.489 ± 0.651 mm.[14] On the other hand, males a study conducted in Southeast Europe on sixty dry skulls indicates that males exhibit higher values of SOF dimensions compared to females. The measurements for SOF width were 3.75 ± 1.36 mm in males and 3.58 ± 1.04 mm in females, while the SOF height was 1.98 ± 0.76 mm in males and 1.83 ± 0.73 mm in females. Additionally, on the right side they obtained results of 2.09 ± 0.74 mm for height and 3.66 ± 1.44 mm for width, indicating that these were higher values compared to the left side, which had a height of 1.89 ± 0.64 mm and a width of 3.63 ± 1.25 mm.[17]

As for the Colombian sample, the SOF exhibited a mean width of 3.65 ± 1.18 mm which is a higher value than the first and second Thai studies. Regarding the laterality, the Colombian samples on both sides were smaller than SOF dimensions made in India, and similar to the Southeast Europe population. In relation to this last study the male SOF width was higher than the Colombian sample 3.29 ± 0.9 mm, and the female width was lower than the ones in the present results, 3.94 ± 1.35 mm. Regarding SOF height, the Colombian samples showed lower values than those reported in South Indian and Pakistani studies, and a similar result than the Indian mean and the Southeast Europe population mean by laterality. This last study revealed that according to the gender, the Colombian sample displayed similar results, being 1.8 ± 0.24 mm for male and 1.72 ± 0.43 mm for female. The similarity of results between the Southeastern Europe population and the Colombian population could be due to the European ancestry that was present in the colonization of the South American country.

Orbits distance

Morphological variations of the orbital width can be used in forensic medicine to determine sex or ethnicity. Comparing the Colombian sample with an Indian study used the radiographs of fifty males and fifty-one females. It showed similar male results and lower female results.[18] A Thailand investigation and a second Indian paper showed lower male and female results. The Turkish population with a paper on sixty skulls of unknown gender, also exhibited a lower mean than the Colombian sample, while the Canadian skulls displayed a similar result. The latter could be due to migration within the American continent.[19]

Zygomatic frontal process width

The Colombian zygomatic frontal process width values were similar to an European country population. These results were recorded in a Bulgarian study on one hundred and twenty-five dry skulls.[20] However, no further studies were found to compare this measurement with other populations, which leaves no room for conjecture.

5. Conclusion

Frontal bone craniometry provides valuable insights for multiple disciplines, including anatomy and forensic science. This study established a standardized protocol for measuring the frontal bone in dry skulls, emphasizing angular and linear parameters for sex estimation and morphometric analysis. Findings were consistent with results from European and North American male populations, highlighting morphological similarities with Colombian remains and contrasts with South Asian skulls across specific dimensions.

6. Recommendations / suggestions

Future studies should include a larger sample size, including bones from other ethnicities and continents such as Oceania, Central America, and Africa. This would enhance the contrast and analysis of the results and allow a more comprehensive bone variation understanding. The bones for this study were obtained from the University Laboratory which might be from donors in the Andean region of the country. Integration with radiological studies and 3D imaging is recommended for future comparative research.

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Original Research Article

Morphological and Histopathological Changes in the Structure of the Neck in Cases of Hanging: A Comprehensive Review

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Histopathology,
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Abstract

Background: Hanging is a leading mode of suicide in India. While diagnosis is usually aided by a well-defined ligature mark, cases of partial hanging or faint marks make reliance on external findings alone difficult. Examination of internal neck structures and histopathology can provide vital supportive evidence. **Aim:** To assess the socio-demographic profile and gross as well as histopathological changes in the neck structures of deaths due to hanging. **Materials and Methods:** An observational cross-sectional study was conducted in the Department of Forensic Medicine, Rajiv Gandhi Medical College, Thane, from January 2021 to June 2022. Out of 1247 autopsies, 115 cases of hanging were included. Detailed demographic data were obtained, and bloodless neck dissection for clarity was performed. Tissue samples from skin, subcutaneous tissue, muscles, and carotid arteries were examined grossly and histologically using H&E stain. **Results:** Most cases were males (67.8%), with a male-to-female ratio of 2:1, predominantly in the 21–30 year age group (39.2%). Complete hanging (80.9%) was more common than partial hanging (19.1%). Gross soft tissue injuries were seen in 62.6% of cases, while histopathological changes were observed in 89.6%. Carotid intimal tears were noted grossly in 12.2% but histologically in 68.7% of cases. **Conclusion:** Histopathology consistently demonstrated ante-mortem changes in the examined neck structures, thereby reinforcing its importance in forensic practice. These findings support its role as an essential adjunct to gross examination, as it provides reliable microscopic evidence that strengthens the medico-legal opinion, particularly in cases where the external or gross findings are doubtful or inconclusive.

1. Introduction

'Hanging is that form of asphyxia which is caused by suspension of the body by a ligature which encircles the neck, the constricting force being the weight of the body.[1] Hanging is one of

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the most common forms of suicide in India. According to a survey by National Crime Records Bureau in 2023, suicide by 'Hanging' (58.2%) followed by consuming 'Poison' (25.4%) were the prominent means of committing suicides.[2] Various structures are damaged in death due hanging which include the soft tissues like skin, subcutaneous tissue, neck muscles, blood vessels and the bony and cartilaginous tissues like the hyoid bone, thyroid cartilages and larynx.[3-6] In cases of suspected hanging, the post-mortem examination is not limited to the identification of the external ligature mark alone. When the classical mark is absent or poorly defined, additional parameters become critical for diagnosis. A systematic bloodless neck dissection of the neck structures helps in detecting deep tissue injuries that may not be apparent externally. Complementing this, histopathological examination of skin and soft tissues from the site of suspected compression can reveal evidence of vital reaction, which continues to be considered the benchmark in establishing ante-mortem injury.

The present study was done to examine both the external and internal changes in the neck structures in cases of hanging. In most cases, the ligature mark is clearly seen and helps in confirming the diagnosis. However, in some situations, such as partial hanging or when the ligature mark is faint, it becomes difficult to rely only on external findings. In such cases, looking at the tissues of the neck under the microscope can give useful information. Histopathology can show changes that prove the injury happened before death and can support the diagnosis of hanging. By studying both the gross appearance and the microscopic findings, this research aims to make the cause of death more certain, especially in cases where the external signs are unclear.

2. Aims and Objectives:

The aim of the present study was to evaluate the socio-demographic, gross morphological, and histopathological profile of neck structures, including the skin, subcutaneous tissue, neck muscles, and carotid arteries, in cases of death due to hanging. The objectives were to analyze the socio-demographic characteristics of the deceased, to document the gross and microscopic morphological changes in the neck structures and to assess the histopathological alterations in tissues at the ligature site,

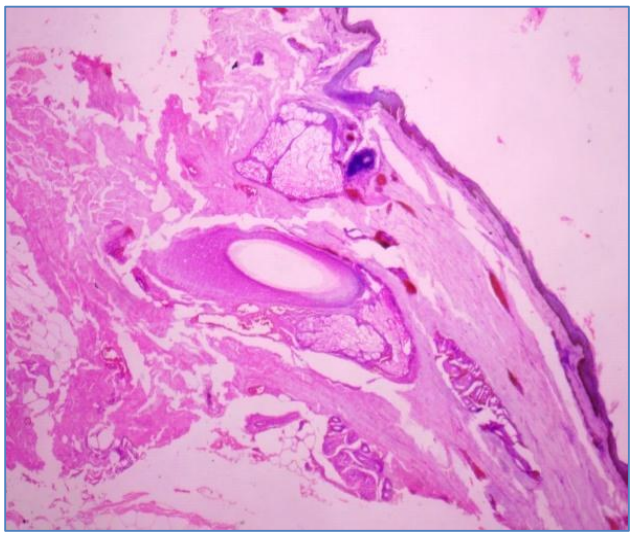
3. Materials and Methods:

This observational cross-sectional study was conducted in the Department of Forensic Medicine at a tertiary healthcare center between January 2021 and June 2022. The study population comprised all cases of hanging deaths brought for medico-legal autopsy during the study period. A total enumeration method was employed, yielding 115 cases of hanging deaths out of 1247 autopsies. Decomposed and burned bodies, as well as cases of alleged fatal neck compression due to causes other than hanging, were excluded. Detailed information on the demographic profile of the deceased, circumstances of death, type of ligature material, and classification as complete or partial hanging was obtained from inquest reports and relatives. In certain cases, supplementary information was collected through visits to the scene of occurrence or from photographs taken at the scene.

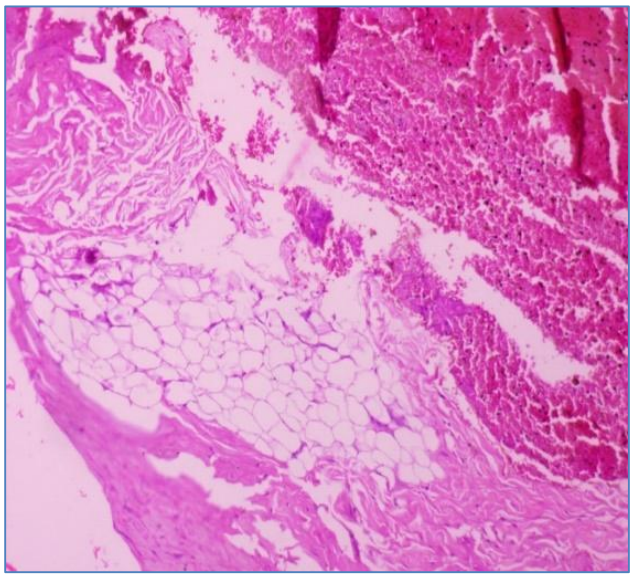
All autopsies were performed according to the standard autopsy protocol, beginning with a general and local external examination and concluding with a general and local internal examination. For neck dissection, a bloodless technique was followed: thoraco-abdominal contents and the brain were removed prior to the procedure. A block measuring 12–20 cm was placed beneath the shoulders to provide slight neck extension, thereby facilitating dissection. Neck dissection was performed according to the method described by Prinsloo and Gordon, layer by layer. The skin below the ligature mark, subcutaneous tissue, neck muscles, and carotid arteries were carefully examined. Special attention was given to the detection of Amussat's sign (longitudinal tears of the carotid artery). Representative samples of skin, subcutaneous tissue, muscles, and carotid artery were preserved in 10% formalin.

The preserved tissues were processed and stained with hematoxylin and eosin (H&E) stain for histopathological examination. Slides were prepared and examined in collaboration with the Department of Pathology, and gross as well as microscopic findings were documented. Photographic documentation of gross and histological changes was also carried out in selected cases. All collected data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 20.0. The objective of the methodology was to identify and document histopathological changes in the skin, subcutaneous tissue, muscles, and carotid arteries at the ligature site in deaths due to hanging.

Picture 1: Photomicrograph of skin showing epidermal compression and condensation of collagen fibers in the dermis, H&E, 40X



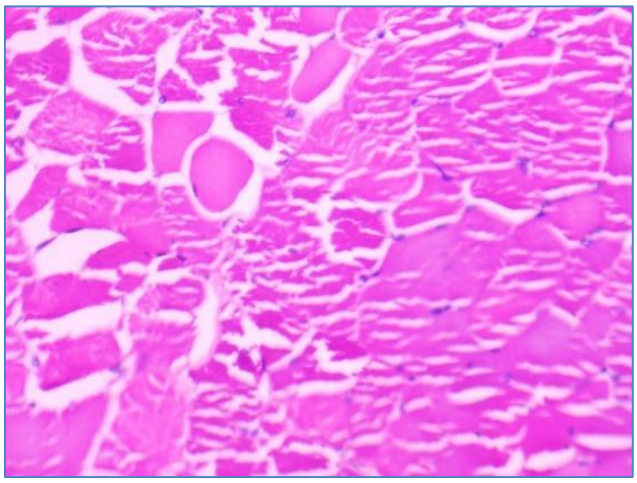
Picture 2: Photomicrograph of subcutaneous tissue showing hemorrhages and intervening fibrous septa, H&E, 100X



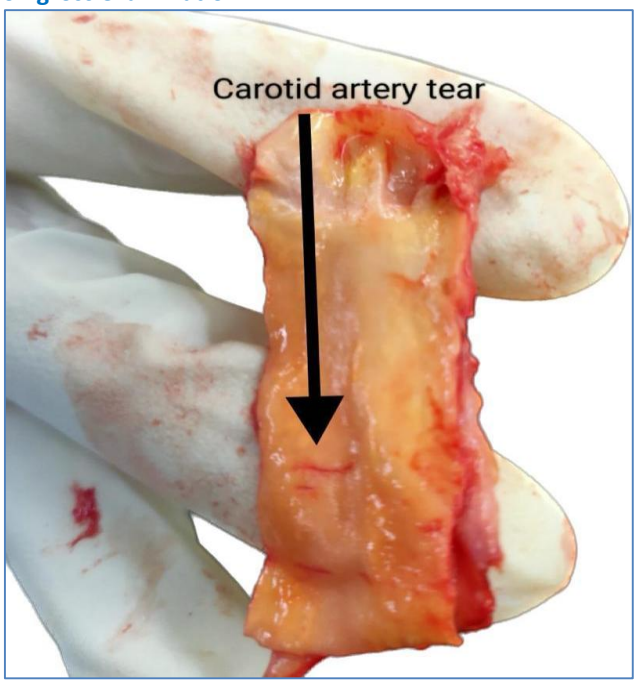
4. Observations & Results:

Out of 115 cases of hanging, 37 were females and 78 were males, which gives male: female ration of around 2:1. Males are twice as prone as females to hang themselves. The age group from 21-30 years had the most cases - 39.2%, followed by 31-40 years age group - 23.4%. 10.4% were aged 20 years or below. 18.3% were 41-50 years old, while 9.1% individuals were over 50 years old. Out of 115 cases of hanging 66.1% (n=76) were married individuals and 33.9% (n=39) were unmarried individuals. Incidence of hanging is more in married cases compared to unmarried cases with ratio of 2:1. The reasons may be stress due to marital problems, financial instability, dowry deaths, extra-marital affairs etc.

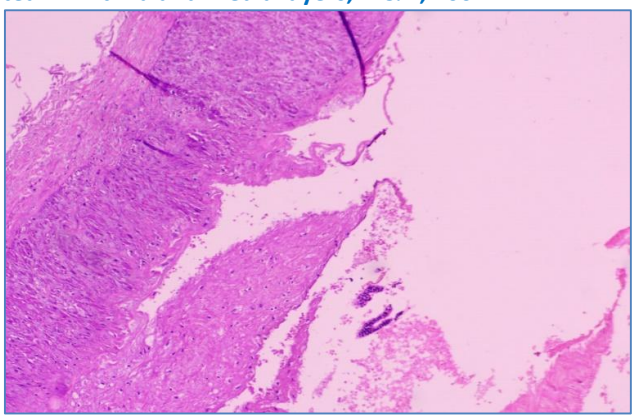
Picture 3: Photomicrograph of muscles showing opaque fibers with loss of cross striations, H&E, 400X.



Picture 4 : Photograph showing carotid artery intimal tear on gross examination.



Picture 5: Photomicrograph showing carotid artery with tear in intima and media layers, H & E, 100X.



Out of 115 cases of hanging, there were 93 (80.9%) cases of complete hanging and 22 (19.1%)

cases of partial hanging. Therefore, the frequency of complete hanging is four times as that of partial hanging. The most used materials for the purpose of hanging were odhni (n=43; 37.4%), nylon rope (36; 31.3%) and saree (n=20; 17.4%). Dupatta (n=5; 4.3%), Gamcha (n=4; 3.5%), bedsheet (n=2; 1.8%), blanket, electric cable, nylon belt, polypropylene strap, towel (each 1 case) was the other ligature materials used in cases of hanging. Therefore, the most widely used ligature materials are the readily available materials at home such as nylon rope, odhni and sarees.

In 72 cases (62.6%) the knot was seen posteriorly, while in 25 cases (22.3%) knot was seen in left lateral position, whereas in 11 (9.6%) cases knot was seen in right lateral position. There were only 7 (6.1%) cases with knot in anterior position. Depending upon the position of knot it was inferred that, 72 (62.6%) cases were typical hanging, and 43 (37.4%) cases were atypical hanging. In this study, changes in various neck structures were observed both grossly and histopathologically in cases of complete and partial hanging. In complete hanging (n=93), skin and subcutaneous tissue changes were seen grossly in 64.5% of cases and histopathologically in 93.5% of cases, while in partial hanging (n=22), these were observed grossly in 54.5% and histopathologically in 72.7% of cases.

The alterations in the skin and subcutaneous tissue included abrasion, congestion, breaking, disruption, necrosis, haemorrhage, and condensation of collagen fibres. Hemorrhages in neck muscles were noted grossly in 44.1% and histopathologically in 62.4% of complete hanging cases, whereas in partial hanging, they were present in 36.4% of cases both grossly and histopathologically. Carotid artery intimal tear was identified grossly in 15.1% and histopathologically in 76.4% of complete hanging cases, while in partial hanging, no gross tear was found, but 36.4% showed histopathological evidence of intimal tear.

5. Discussion:

In present study, out of total 115 cases of hanging, incidence of soft tissue injury on gross was seen in 72 (62.6%) cases. This is higher than studies by Luke et al [7] and Arumalla VK et al [8] which show pale, white and glistening structures with focal engorged capillaries and small areas of haemorrhagic collections in the muscle plane and fibro fatty tissue.
In present study, out of total 115 cases of hanging, histopathological changes in soft tissues in the form of congestion, condensation of collagen fibers, intervening fibrous septa etc. were seen in 103 (89.6%) cases. It was similar to studies conducted by Mukesh Prasad et al [9] and Perju-Dumbravă D. et al.[10] A much lower incidence is found in studies conducted by Arumalla VK et al [8] and Navneet et al.[11] In present study, out of total 115 cases of hanging, hemorrhages in neck muscles on gross were seen in 49 (42.6%) cases. This is similar to study done by B R Sharma et al [12], Azmak [13] and Suarez-Penaranda et al.[14]A much lower incidence is found in Indian studies by Jayaprakash and Sreekumari[15] and Ambade et al.[16] Study by Hejna and Zátopková [17] showed an higher incidence of haemorrhage in sternocleidomastoid muscle.

In present study, out of total 115 cases of hanging, histopathological changes in neck muscles were seen in 66 (57.4%) cases. It was much higher compared to studies by Arumalla VK et al [5] and Navneet et al. [11] Only 14 cases (12.2%) out of 115 cases showed transverse intimal tears (Amussat's sign) in the carotid arteries on gross, in the present study. It was comparable to studies conducted by Suarez-Penaranda et al [14], Petr Hejna[17]and S. Balusubramanian et al.[18] However, study conducted by Jayaprakash and Sreekumari [15] showed lower incidence of carotid intimal tears. Studies done by Jani and Gupta [19], Meera and Singh [20] and Rao D [21] show higher incidence of carotid intimal tears on gross examination. In this present study, Amussat's sign on histopathology was seen in 68.7% cases. It was higher compared to studies done by S. Balusubramanian et al[18] and Ghodake et al[22].

6. Conclusion:

The present study underlines the critical role of histopathology in the forensic evaluation of hanging. While gross examination of neck structures can provide important clues, it is often limited by variability in external findings, particularly in cases of partial hanging, faint ligature marks, or atypical presentations. Histopathological changes, on the other hand, are more consistent and sensitive, offering microscopic evidence of vital reactions such as haemorrhage, vascular congestion, intimal tears, and tissue disruptions that may not be apparent on gross inspection.

These findings reinforce that histopathology is indispensable in strengthening the medico-legal opinion, especially when gross findings are equivocal or absent. Incorporating histopathological evaluation not only improves the accuracy of diagnosing hanging as the cause of death but also reduces the possibility

of misinterpretation in suspicious or doubtful cases. This, in turn, enhances the reliability of forensic investigations, supports judicial processes, and contributes to upholding justice in society.

In essence, the study concludes that histopathological examination should be regarded as an essential adjunct to gross examination in all cases of suspected hanging, ensuring a more comprehensive autopsy examination.

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Contributor ship of Author: All authors equally contributed.

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Original Research Article

Neuroscientific Evidence in Court: Evaluating Brain Fingerprinting in Indian Judiciary

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Brain fingerprinting, Forensic Ethical implications, Legal admissibility, Neuroscientific evidence.

Abstract

Introduction: Brain fingerprinting, a neurotechnology, determines whether a person knows the relevant facts by examining their brainwave patterns. This novel technique is increasingly being dealt with discussions on its possible application in forensic analysis, criminal investigations, and Court proceedings. **Objective:** The article analyses the scientific, legal, and ethical aspects of brain fingerprinting in India, including its admissibility as evidence, compatibility with constitutional rights, and its judicial perspective. **Methodology:** This review study critically appraises available neuroscientific literature, legal precedents and ethical theories to determine the possibility and limitations of using brain fingerprint evidence within the Courtroom. **Results & Discussion:** Although brain fingerprinting appears to be a promising tool for improving the accuracy in forensic cases, it poses significant concerns related to privacy, self-incrimination, due process and false conviction rates. Judicial review, constitutional protections and scientific validation will remain the primary considerations in determining its admissibility. **Conclusion:** Brain fingerprint analysis may transform crime solving under proper regulation, but its application must balance scientific possibilities and constitutionally protected freedoms to prevent it from being misused, coerced, or subjected to surveillance. India should be careful in embracing this technology and establish strong legal and ethical controls over its use.

1. Introduction

Imagine a reality in which the human brain has become the ultimate witness, wherein investigators no longer depend on confessions, eyewitness testimony or circumstantial evidence but instead peer directly into a suspect's mind to ascertain guilt or innocence. This formerly unimaginable situation is now a topic of serious legal and scientific debate, courtesy of brain

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fingerprinting, a forensic technique that purports to reveal whether or not an individual's brain recognises information related to a crime or crime scene.[1] Unlike most traditional lie detectors, which measure physiological changes like heart rate or sweating, this technique looks at involuntary electrical impulses in the film of the brain, with the theory that it is more objective and harder to manipulate.[2]

However, the technology's use in criminal trials poses difficult questions despite its potential for forensic scrutiny. Does brain fingerprinting really expose concealed information, or do experts merely suggest that knowledge of specific facts simply exists? Are Courts right to consider brainwave responses as working evidence, or does this cross an ethical line into thought policing? Second, is the compelled brain fingerprinting of an accused violative of his most basic rights, such as the protection against self-incrimination and right to privacy under the provisions of the Indian Constitution? The justice system has always been reticent about incorporating new methods of science, especially ones that delve into personal autonomy and cognitive freedom. History has shown that excessive reliance on forensic techniques, such as unreliable lie detector tests, flawed interpretations of DNA or forensic hypnosis, has occasionally resulted in wrongful convictions.[3] Even brain fingerprinting, with its technological promise, is not free from similar scorn.

Brain fingerprinting was introduced in the U.S. in the 1990s by Dr Lawrence Farwell and subsequently in India in high-profile criminal investigations in the early 2000s. In India, the judiciary has wrestled with the admissibility of neuroscience-based forensic tools. The landmark ruling in Selvi v. State of Karnataka (2010) 7 SCC 263, had declared narcoanalysis, polygraph tests and brain-mapping unconstitutional if carried out without the consent of the accused. This ruling established the principle that mental privacy is at least as sacred as physical privacy.[4] Yet, brain fingerprinting poses a specific problem as the test is passive (as opposed to a suspect's active participation); should it still be perceived as a fundamental infringement? Is it possible to treat it as forensic evidence, or does it fall instead into the category of unreliable, pseudo-scientific techniques? Brain fingerprinting, in this scenario, is one of the most disputable forensic tools in India While traditional forensic techniques, such as examining the body or the crime scene, work on the physical level, brain fingerprinting gets hold of the mind itself, thus not only questioning the guarantees under Article 20(3) against self-incrimination and Article 21 on privacy and dignity, but also changing the paradigm. The present article is, therefore, committed to three things in particular: the first one is to check the legal position of brain fingerprinting as evidence in Indian criminal trials; the second is to analyse the compatibility of brain fingerprinting technology with the Indian constitution; and, finally, the third one is to unveil the inherent ethical issues of using the human brain as forensic evidence by critically assessing the same.

2. Literature & Background

One aspect of the story about the different ways the brain fingerprinting debate has been handled is the mention of different countries and their judicial systems. It has been observed that Courts in the United States have been quite conservative when it comes to the acceptance of lie detection evidence from neuroscience-technological sources. The case of United States v. Semrau is a good example, where functional MRI-based testimony was given no credit due to failure to meet Daubert standards of reliability.[5] On the other hand, in the European Union, the right to privacy and proportionality have been the main points of focus in the debate. At the same time, the scholars regard the issue as one of "cognitive liberty."[6]

The Indian judicial system which is based on the Supreme Court's decision in Selvi v. State of Karnataka (2010) 7 SCC 263, has always been very strict in opposing the forced use of neuroscience-based forensic methods; it has also categorically stated that the logic behind it is Article 20(3) and Article 21 of the Constitution. The Law Commission of India in its 185th Report on the Indian Evidence Act (2003)[7], while emphasising the need for careful scrutiny of novel scientific techniques when admitting them, in its 277th Report on Wrongful Prosecution (Miscarriage of Justice): Legal Remedies (2018)[8] has been much more explicit about how an over-reliance on invalidated forensic methods might lead to wrongful prosecutions. It also recommended establishing statutory frameworks for compensation and judicial safeguards. Then, there is the research in the field of neuroscience, which is clearly a source of great ambiguity. Thus, for instance, P300/MERMER-based methods may just show that a subject has recognised a particular stimulus to which researchers like Rosenfeld and Meijer et al. refer, stating that

these results do not allow for a clear differentiation of the guilty knowledge from the innocently familiar grounds.[9] A comparative engagement with U.S. and EU perspectives outlines the differences and emphasises the necessity of understanding India's position on the same issue. India needs to mentally map its own debate on brain fingerprinting by tracing its route through the global discourse on the topics of experimental reliability, human rights, and constitutional safeguards for the same.

3. Legal Admissibility and Judicial Approach in India

The admissibility of brain fingerprinting as per the Indian legal framework is a question of the technology itself and a holistic assessment with constitutional guarantees, laws, and changing judicial decisions regarding forensic science. The issue is not just about the technology being scientifically valid, but that the use of such neurotechnology is in accordance with the fundamental principles of voluntariness, scientific reliability, corroboration and proportionality.

a. Voluntariness and the Right against Self-Incrimination

A constitutional barrier is, firstly, a leading element. Article 20(3) of the Constitution is the most explicit provision which protects the accused from any compulsion to give a statement against themselves. In Selvi v. State of Karnataka (2010) 7 SCC 263, the Supreme Court decided that interventions like narcoanalysis, polygraphy, and brain-mapping can only take place with the patient's voluntary consent. The ground for the decision was not only to restrict physical coercion, but also to ensure that the person's mental operations were left untouched by force. The Court furthered the concept of "cognitive privacy" in that judgment, acknowledging that forced revealing of the subconscious or unintentional brain reactions is a similar form of coercion as the one where a person is extracted a confession by the use of force. Hence, brain fingerprinting without informed consent would violate the provisions of the constitution. However, even with consent, it raises the question of whether such "consent" can ever be genuine in the case of custodial settings where the presence of psychological pressure is felt. So, voluntariness still remains a debated, weak and insecure guard in reality.

b. Scientific Reliability and Evidentiary Standards

Sections 3 to 9 of the Bharatiya Sakshya Adhiniyam, 2023 lay down the criteria that evidence must have relevance and probative value to be admissible, while under Section 39, expert opinion is welcomed. Nevertheless, the decision to accept is significantly harmed by the reliability of the underlying science, as brain fingerprinting has not by any means reached a standard of scientific acceptance. The main arguments of the opponents of the technique are mainly related to the risk of false positives, in which innocents may recognise crime details as a result of media exposure, and false negatives, in which the guilty are not able to register due to trauma, stress, or memory suppression. The judiciary is also reflecting these concerns.

In, Santokben Sharmanbhai Jadeja v. State of Gujarat (2007)[10], the Gujarat High Court allowed the administration of the narco-analysis, polygraph, and brain-mapping experiments during the inquiry, but definitely stated that the results of such interventions could not be considered as primary or final evidence at trial. The Court had established a distinction between the utility of the investigation and suitability for evidence, arguing that while such methods might be helpful in guiding the detectives, their scientific reliability was not enough to warrant independent probative value in the Court. Since the demand for reliability is not solely related to evidence, it is also associated with the constitutional right to a fair trial under Article 21. A way of working that is uncertain about accuracy cannot be accepted as proof without jeopardising procedural fairness.

c. Corroboration as a Structural Safeguard

One more judicially recognised principle is corroboration. In Dinesh Dalmia v. State (2006)[11], the Madras High Court clarified that neuroscientific methods could help an investigation but could not make a presumption of guilt. It manifests the wider Indian Court philosophy that no matter how good a forensic innovation is, it cannot replace the traditional safeguards of cross-examination, corroboration by physical evidence, and testing under adversarial scrutiny. That is to say, practically, if brain fingerprinting were allowed, it would just work as partnering evidence, not as standalone proof.

d. Proportionality and Privacy Concerns

The principle of proportionality is perhaps the least mentioned but the most important one that comes into play over time. In the landmark case, Justice K.S. Puttaswamy (Retd.) and Anr. vs. Union of India and Ors., (2017) 10 SCC 1, the Supreme Court declared the right to privacy as a fundamental right under Article 21 and acknowledged the right to mental privacy. Brain fingerprinting is a method of

investigation that requires one's brain to give a response to questions, which is a direct interference with cognitive liberty. From a standpoint of proportionality, the State should provide a case that such a breach is essential, a minimally restrictive way of achieving the purpose is used, and a substantial public interest justifies the interest. Given the errors in scientific accuracy and the availability of more straightforward forms of investigation, the use of brain fingerprinting will not be the method that reflects this test of the first principle. The opponents, too, are of the opinion that if the Courts were to accept it early, such a decision would be setting a precedent which would lead to broader state access to the private neural processes of individuals, thereby making neuro-surveillance a norm appearing under the cloak of law enforcement.

4. Synthesis of Judicial Approach

When these strands of the synthesis are done, Indian Courts are showing a consistent, albeit very cautious, philosophy towards brain fingerprinting and similar neuroscientific tools:

- Voluntariness is the main issue - There is no room for negotiation. Evidence, which is obtained without real consent, is illegal under the Constitution.
- The scientific reliability is non-negotiable – If invalidated technologies are allowed, they cannot be given without reinstating the integrity of the evidence.
- Corroboration is a condition – If no independent proof supports the neuro evidence, it is not admissible.
- Privacy and proportionality are the main factors – The intrusion into cognitive liberty is the highest constitutional cost that only the most reliable and necessary technologies can justify.

5. Operational Risks: False Positives, False Negatives and Countermeasures

The law not only needs to look at average accuracy claims, but it also needs to consider the error distribution and the practical situations that cause misclassification. A false positive is an error that can occur if an innocent person is unintentionally implicated with crime-relevant information (media reports, casual conversation). In this case, the recognition signal is generated; however, a false negative may be the situation when a guilty person does not register recognition due to factors such as stress, trauma, medication, or intentional countermeasures. Besides, deliberate countermeasures (mental distraction, rehearsed responses) make the test less valid. Since criminal adjudication requires proof beyond a reasonable doubt, methods that are vulnerable to errors must not be allowed as the decisive link in a chain of evidence.[12] Empirical reviews suggest reining in expectations with regard to the present brain-based memory detection for legal purposes.[13] This tiered strategy is the reason why the Indian judiciary has been consistent in clearly stating that brain fingerprinting shall not be treated as conclusive evidence. This line of thought is actually far from their position. Such judicial caution is their principled commitment to due process over technological expediency. Brain fingerprinting will only be used as an investigative aid until the science matures and the legal framework explicitly regulates its scope, not as a determinative evidentiary tool.

6. Ethical and Social Concerns

The controversy surrounding the use of brain fingerprinting requires us to consider its potential for good and the very real ethical and social dangers it entails. The supporters refer to pilot studies under control, like those in New Zealand, which indicate the possible employment of brain fingerprinting in investigations if used as a corroborative tool.[14] At the same time, well-known bioethicists such as Prof. Nita Farahany go to the length of asserting that the right to cognitive liberty is indeed their core, and hence, people have to be the ones who decide if their minds are accessed.[15] This area of human rights is just opening up, and if forced neurotechnology becomes normal, we will face a new challenge.[16]

Nevertheless, the science behind the technology is still not conclusive. Some sceptics, who are neuroprivacy contributors, maintain that brain fingerprinting continues to be a highly disputable scientific method. It is still quite open to errors of false positives (i.e., the recognition of a fact resulting from reading the media) and false negatives (due to stress, trauma, or when applying countermeasures) that can easily creep into the experiment.[17] In the case of Rojo George v. Deputy Superintendent of Police (2006)[18], the High Court ruled that the use of narco-analysis and similar neuroscience tests for the investigation is allowed, if the administration of such tests is done correctly, they do not violate the accused's constitutional rights against self-incrimination and personal liberty. The Court reiterated that these tests' results cannot be used as substantive evidence in a trial only if the role of

investigative aids and their admissibility in the Court are correctly distinguished.[19] At this moment, those worries about the broader misuse of these technologies, the area outside of the criminal justice system, are now a reality. Thus, the main problems with these technologies are the new laws being developed and implemented. For example, in Chile, a significant step has been taken toward ensuring the protection of neuro rights, and the country's Supreme Court recently made a decision that set a precedent regarding the use of neurotechnology devices by removing the commercial aspect from the Emotiv Insight case because it violated these rights.[20]

These events show a serious challenge at the core of brain fingerprinting. This technology can greatly help the police in cases where people consent and the tests have been reliably carried out.[21] The biggest issue here is technology, which is dangerous for human dignity and privacy, if no strict legal regulations protect citizens and their rights, including cognitive liberty, privacy laws, and empirical rigour or at least part of these. If such protections are not in place, it is not difficult to envision a future in which the mind becomes a data bank and the justice system is akin to a police force monitoring people's thoughts.[22]

7. Recommendations for Legal and Scientific Regulation

Considering constitutional protection, ethical boundaries, and accuracy, brain fingerprinting in India requires constitutional law the most. The admissibility of such evidence should be written down in the law through changes in the Bharatiya Sakshya Adhiniyam, 2023, that limit the use of neuroscientific evidence only to cases where the evidence has been subjected to a rigorous peer review validation process consistent with the U.S. Daubert standard[23] or U.K. guidelines[24] and is even allowed as secondary evidence after independent experts evaluate it.[25] With the implementation of Article 20(3), there must be no exceptions regarding voluntariness and informed consent, and the Courts must disregard any evidence obtained under coercion, custody, or any form of undue pressure.[26] A Statutory Board on Neuroscientific Evidence operating under the Ministry of Law & Justice should verify the technologies beforehand, distribute the corresponding regulations, conduct the necessary annual auditing, and submit their reports to Parliament. It must be emphasised here that scientific confirmation must come first before proceeding with the use of such technologies.[27]

This confirmation will come through studies on specific populations, with contributions from NLUs, AIIMS, and IITs, and the establishment of a repository designed in compliance with privacy regulations, which will also be instrumental in monitoring error rates. The judicial academies should incorporate neuroscience and forensic psychology courses into their curricula, and a National Judicial Academy handbook should be published, so that judges know the advantages and challenges of this technology. Finally, public awareness and legal safeguards must complement judicial and scientific reforms. National campaigns should inform citizens about the risks, limitations, and legal boundaries of brain fingerprinting, mirroring existing efforts on DNA profiling.[28] Simultaneously, privacy laws should be amended to prohibit their use in non-forensic domains such as employment screening, political vetting, or consumer profiling, while introducing criminal penalties for misuse outside regulated legal contexts.[29] Collectively, these measures would embed brain fingerprinting within a constitutional, ethical, and scientifically credible framework, ensuring its role remains one of justice delivery rather than social control.

8. Conclusion

Brain fingerprinting exists in the nexus of neuroscience and the law, with much promise for investigation but profound scientific, ethical and social issues to confront. Though its advocates promote it as a potentially helpful tool in complex cases involving terrorism and sexual offences, the unresolved debate about reliability, risk of error and potential selective misuse still leaves this application in the category of highly disputable. Science should never be taken as final proof, but only as a supplement to be bolstered by other evidence. Key in the future is to engage in a two-pronged approach, i.e. establishing rigorous admissibility criteria, statutory oversight and enforceable safeguards and investment in independent validation studies, neuroscience and law partnerships, and judicial education. Further studies should look beyond accuracy analysis and investigate cultural and linguistic factors, long-term reliability, and issues of cognitive privacy. The only way the technology can positively contribute to justice is through a careful, evidence-based and rights-sensitive deployment,

rather than a coercive tool or a mechanism of social harm.

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Review Article

Social Criticism and its Impact on Law-Making Activities in Vietnam: A Critical Analysis

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Abstract

Introduction: Social criticism, rooted in public discourse, scholarly research, and activism, serves as a mechanism to address systemic challenges, promotes equity, and advocates for legal reforms that align laws with the needs and aspirations of the public. **Methods:** This study examined the critical role of social criticism in shaping Vietnam's law-making process, emphasizing its influence on creating inclusive and effective legislation. A qualitative analytical, systematic review was employed to analyze secondary resources, including scholarly articles, reports, and case studies. **Results and Discussion**: Results reveal that social criticism influences this process through public consultations and structured legislative processes, allowing social criticism to inform and revise laws. However, challenges persist, such as political constraints, cultural resistance, and limited accessibility for marginalized groups, which hinder the full integration of social criticism into legal reforms. **Conclusions:** The study recommends enhancing public involvement, promoting open media and civic education, and leveraging technology for broader engagement. Overcoming political and cultural barriers is essential to creating an inclusive environment for constructive dialogue. Ultimately, integrating social criticism strengthens Vietnam's legal system by ensuring laws dealing with societal needs, enhancing transparency, fostering civic trust, and contributing to a more equitable and sustainable legal system.

1. Introduction

Social criticism is a systematic practice of interrogating societal structures, norms, and practices to expose contradictions and injustices that impede progress, equality, and justice. Emerging from philosophy, sociology, and political theory, it aims to bridge the gap between normative ideals and social realities by identifying systemic flaws and proposing pathways for reform.

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Philosophers like Karl Marx, Michel Foucault, and Jürgen Habermas[1] laid much of the theoretical groundwork, critiquing economic inequality, institutionalized power, and the conditions necessary for rational democratic discourse.[2] Social criticism thus functions as both a diagnostic and normative tool, fostering accountability, transparency, and moral responsibility in society. The concept of social criticism is often defined broadly, at times overlapping with public opinion, activism, and civil society engagement.[3] Yet conflating these categories risks conceptual dilution. Public opinion refers to the aggregated attitudes and preferences of citizens, often measured or expressed through media, but lacking the systematic analysis of criticism.[4] Activism, while frequently informed by critique, emphasizes mobilization and direct action rather than reflective evaluation. Civil society engagement encompasses the participatory role of associations and non-state actors in governance processes, which may or may not involve critical interrogation.[5] By contrast, social criticism is distinguished by its systematic, reflective, and normatively grounded character. Recognizing these distinctions is crucial to preserving its analytical precision.

Within this framework, social criticism can be further classified into academic, public, and political forms.[5] Academic criticism is rooted in scholarly research and critical theory, offering sustained analyses of social, economic, and political structures and challenging dominant ideologies. Public criticism is articulated through mass communication, cultural discourse, or literature, channeling collective concerns and mobilizing awareness.[6] Political criticism originates from political actors or institutions and evaluates government policies, legislative processes, or institutional shortcomings, seeking alignment with constitutional principles and democratic legitimacy.[7] Although these forms often intersect, maintaining conceptual boundaries clarifies their specific contributions to social reform. Social criticism serves as an instrument for identifying and addressing systemic dysfunctions, including poverty, inequality, environmental degradation, corruption, and discrimination.[8] By amplifying marginalized voices, it exposes structural barriers and empowers demands for justice. It also educates the public, cultivating civic engagement and critical consciousness. Most significantly, social criticism shapes legal and policy reform by illuminating inconsistencies, exposing blind spots, and promoting legislative outcomes grounded in equity and justice.

In Vietnam, social criticism plays a vital role in the formulation of law. Consultative mechanisms allow citizens, experts, and social groups to engage with draft legislation, providing lawmakers with valuable insight into societal needs and perspectives.[9] This process strengthens the social relevance and legal soundness of legislation, while enhancing transparency and accountability in governance.[10] In a rapidly transforming context marked by economic growth, technological change, and evolving social expectations, social criticism ensures that law-making remains responsive rather than rigid.[11] Laws enacted without sufficient critical input risk marginalizing vulnerable groups or producing ineffective governance outcomes. Conversely, when social criticism is integrated into legislative deliberations, public trust in institutions is reinforced, compliance with laws is enhanced, and the legitimacy of the legal system is deepened.[12] By anchoring law-making in societal realities and moral accountability, social criticism contributes not only to more effective legislation but also to broader civic trust, social cohesion, and democratic development.

2. Methods

This study utilized a qualitative systematic review to analyze the secondary resources based on the research model of Sutehall et al.,[13] and Ke's principles[14] to highlight the distinctive characteristics of social criticism in law-making process. Secondary resources, such as scholarly articles, books, reviews, and reports, provide a comprehensive overview of existing knowledge, enabling researchers to build upon existing findings. They offer diverse perspectives, critical analyses, and help identify gaps in current literature. Besides, they save time, verify facts, and establish context, enhance the credibility and reliability of research.

3. Results and Discussion

Brief comparative overview: Social criticism in law-making frameworks in developing countries

Vietnam's legal framework reflects its socialist orientation, where the Communist Party of Vietnam (CPV) provides overarching ideological guidance. The Constitution is the supreme legal source, and the civil law system ensures that legislation is the primary basis of governance. Drafting responsibilities usually fall to ministries or specialized committees, followed by rounds of public consultation, review in the National Assembly, and final promulgation by the

State President. Social criticism has increasingly been institutionalized through public consultations, workshops, and expert input, although challenges such as limited civic awareness and bureaucratic inefficiencies remain.[15] The system combines centralized party leadership with a growing but still constrained role for participatory feedback.

Like Vietnam, China operates under a socialist system in which the Communist Party maintains strict ideological leadership over legislative processes.[16] The National People's Congress (NPC) and its standing committees are central to law-making, but consultation with the public and civil society remains more limited and controlled compared to Vietnam. While China has mechanisms for soliciting public opinion on draft laws, the process is tightly managed, and social criticism rarely functions as an independent force. Compared with Vietnam, China places greater emphasis on top-down policy direction, with narrower opportunities for bottom-up criticism to shape legislative outcomes. Indonesia, a developing democracy, [17] offers a sharp contrast with its decentralized, multi-party governance model. Law-making involves the national legislature (DPR), regional parliaments, and strong civil society engagement. Public hearings, lobbying, and protests are common forms of social criticism that influence legislative debates.[9] While institutional inefficiencies and corruption remain challenges, Indonesia demonstrates a more pluralistic environment in which competing political actors and social groups can directly influence law-making. Compared to Vietnam, social criticism in Indonesia is less constrained by centralized authority and more closely linked to democratic contestation. India's legal framework, rooted in a common law tradition, is characterized by parliamentary sovereignty and a robust judiciary.[18] Parliamentary committees routinely invite civil society organizations, academics, and experts to provide input into draft legislation. Media scrutiny and public opinion exert significant influence, while judicial review often acts as a corrective mechanism when laws face criticism for violating constitutional principles. In contrast to Vietnam's centralized party-led framework, India demonstrates how social criticism can be institutionalized within a pluralist system, with multiple avenues for contesting and reshaping laws.

A comparative perspective underscores Vietnam's intermediate position between highly centralized socialist models, such as China, and more pluralist democratic systems, such as Indonesia and India. Like China, Vietnam maintains the ideological leadership of a ruling party and a legislative process guided by centralized authority.[19] However, unlike China's more tightly controlled framework, Vietnam has increasingly institutionalized consultative mechanisms, including public hearings, academic workshops, and opportunities for expert input on draft laws. These innovations create limited but meaningful channels for social criticism to influence legislation. At the same time, Vietnam's model contrasts with the decentralized and competitive environments of Indonesia and India, where multiple political parties, civil society organizations, and judicial institutions interact in shaping legal outcomes.[6] In those contexts, social criticism often operates independently of the state and can exert significant influence through lobbying, public campaigns, or judicial review. Vietnam remains less pluralistic: participation is encouraged but ultimately bounded by the political authority of the Communist Party.[8] This intermediate position highlights both the strengths and constraints of Vietnam's legal framework. On the one hand, it ensures coherence, stability, and alignment with national development goals. On the other hand, it limits the depth of critical engagement, leaving social criticism structured but carefully managed.

The influential role of social criticism in shaping laws in Vietnam

Social criticism has been a significant force in shaping laws and legal reforms in Vietnam,[2] as the country faces challenges in aligning its legal framework with its evolving needs and aspirations. This criticism, originating from various sources such as public discourse, academic inquiry, non-governmental organizations (NGOs), and grassroots movements, has acted as a driving force in addressing systemic issues, raising awareness, and advocating for reform.[7] Public social criticism in Vietnam is often expressed through media platforms, including newspapers, television, and social media, where citizens, journalists, and independent commentators have used these platforms to highlight issues such as environmental degradation, corruption, and labor rights abuses.[6] Besides, academic social criticism has also exerted a powerful influence on shaping Vietnam's legal framework. Researchers and scholars provide evidence-based analyses of societal issues, offering insights that inform legislative reforms.[12] In areas such as land use rights and rural development,

academic studies have highlighted systemic inefficiencies and inequities, influencing key legislative changes.[6] In the realm of labor rights, academic research has shed light on the challenges faced by workers in Vietnam's rapidly industrializing economy, leading to the development of labor laws to improve workplace conditions and protect workers' rights.[2] Non-governmental organizations (NGOs) in Vietnam have emerged as key actors in advocating for legal reforms through social criticism. They often work at the intersection of public and academic discourse, translating research findings and public concerns into actionable policy recommendations. At present, NGOs specializing in human rights and social justice have demonstrated their liabilities in shaping laws related to gender equality and child protection.[1] Advocacy campaigns by women's rights organizations have resulted in significant legal reforms, including the adoption of the 2006 Law on Gender Equality[20] and amendments to the 2022 Law on Domestic Violence Prevention and Control.[21] Furthermore, grassroots movements represent another powerful form of social criticism that has shaped Vietnam's legal framework. These movements often arise in response to specific grievances, mobilizing collective action to demand legal and policy changes. As Vietnam integrates into the global economy and joins international agreements, social criticism has highlighted the need to align domestic laws with global norms.[11]

Despite its significant impact, social criticism in Vietnam faces several challenges. The country's political system, which prioritizes stability and control, places constraints on freedom of expression and limits the space for dissent.[13] Journalists, activists, and organizations engaging in social criticism may encounter censorship, legal restrictions, or other forms of repression. These challenges underscore the need for a more open and inclusive environment that allows social criticism to thrive and contribute to societal progress.[3] Another challenge is the accessibility of platforms for marginalized groups to voice their concerns. While social media has democratized public discourse to some extent, systemic barriers, such as economic inequality and limited internet access in rural areas, can hinder the participation of disadvantaged communities in social criticism.[2]

Challenges in incorporating social criticism into legal reforms

Incorporating social criticism into legal reforms is crucial for creating laws that reflect societal needs and aspirations. However, this process is influenced by political, cultural, and institutional barriers, especially in developing countries like Vietnam, where the government serves as a central role in governance and law-making, these challenges are clearly pronounced.[12] Factors such as the balancing act between state interests and public demands, deeply rooted cultural norms, and power dynamics within institutional frameworks can significantly influence the extent to which social criticism is integrated into legal reforms.[9] Political barriers are among the most significant challenges to incorporating social criticism into legal reforms. In many political systems, remarkably in those with strong centralized governments like Vietnam, the state prioritizes maintaining stability and control.[1] Social criticism, particularly when it challenges authority or highlights systemic flaws, can be perceived as a threat to political legitimacy, leading to restrictions on freedom of expression and limited tolerance for dissent.[8] Activists, journalists, and NGOs attempting to critique laws or advocate for legal changes may face censorship, legal repercussions, or even persecution. The political environment can also shape the way social criticism is filtered.[6] For example, criticism that aligns with government priorities, such as economic growth or anti-corruption efforts, is more likely to be acknowledged and acted upon. Whereas, criticism that raises sensitive issues, such as human rights or political freedoms, is often sidelined, undermining the inclusivity and effectiveness of social criticism.[5] Cultural norms and societal values have a great impact on shaping attitudes toward criticism in many societies, including Vietnam.[7] These cultural factors can create resistance to change and discourage individuals from openly challenging existing norms and institutions. Furthermore, the interplay between cultural values and social criticism is greatly evident in discussions of gender equality and LGBTQ+ rights.[8] Efforts to incorporate social criticism into these reforms require careful navigation of cultural sensitivities and the development of strategies to build public support for change.

Solutions to enhance the role of social criticism in law-making activities in Viet Nam

The role of social criticism in Vietnam's law-making process is essential for ensuring that laws are more reflective of public needs, responsive to societal

changes, and inclusive of diverse viewpoints. To achieve this, Vietnam must institutionalize public participation in the law-making process, create formalized and transparent channels for citizen engagement, and strengthen legal protections for freedom of expression.[3] This includes expanding public consultations to engage every segment of society, including marginalized and vulnerable groups, and ensuring they are conducted at various stages of law-making.[11] Supporting free and open media is essential for fostering public opinion, debates, and criticisms. In practice, civil society organizations are necessary for mobilizing public opinion and conducting research that highlights areas of the law that need reform.[9] They should be given legal protections, funding, and institutional support to facilitate their role in amplifying social criticism and advocating for meaningful legal reforms.

Technological integration can also be a transformative factor in enhancing the role of social criticism in Vietnam's law-making process.[12] The Vietnamese government can utilize existing e-government platforms to allow citizens to provide feedback on draft laws and propose new ideas or solutions for legal challenges.[4] Social media platforms like Facebook, Twitter, and YouTube can be used to gather real-time social criticism and build public awareness on legislative matters.[6] However, it is important for the government to adopt a balanced approach to these technologies, ensuring they do not become tools for state surveillance or censorship but promote transparency and open dialogue.[2] Education and awareness campaigns can make more efforts to promote the transformative role of social criticism. Civic education programs should be introduced into school curricula at all levels to help young people understand their rights, the importance of social criticism, and how to engage meaningfully in public discourse.[16] Public campaigns to raise awareness about the role of social criticism in legal reforms can help citizens understand the process by which their input can influence policy decisions.[7] Educational efforts should target policymakers and public servants, providing them with the tools to engage with social criticism productively. Addressing political and cultural barriers to social criticism is crucial. In Vietnam, where the government places high value on political stability and social harmony, there is a tendency to suppress open criticism that could be perceived as destabilizing.[1] Cultural norms that emphasize respect for authority and social unity can sometimes stifle the willingness of citizens to engage in public critique. Therefore, a critical solution lies in favoring a culture of constructive criticism that emphasizes its role in strengthening the state. The government could encourage more open debate within the media, academic institutions, and even within the Communist Party itself.[6] Promoting dialogues between state authorities and civil society can help dispel the perception that social criticism is inherently antagonistic. Gradual and deliberate steps should be taken to foster an environment where citizens feel comfortable voicing dissenting opinions, framing this as an essential part of a healthy democracy.[8] Lastly, recognizing and rewarding constructive criticism can incentivize more people to engage in the law-making process. Public acknowledgment of individuals, organizations, or communities whose social criticisms have led to positive changes in the law can motivate others to become active participants in shaping the legal system.[2]

4. Conclusion

Social criticism is a crucial tool in shaping Vietnam's law-making process, ensuring that legislation aligns with the needs and realities of its citizens. It is rooted in philosophy, sociology, and political science and offers a framework for addressing societal disparities, systemic flaws, and injustices. In Vietnam, where rapid economic, social, and technological transformations present new challenges, integrating social criticism into the legislative framework is vital for ensuring inclusivity, transparency, and effectiveness. Public social criticism highlights societal concerns through mass communication platforms, mobilizing collective action on pressing issues like corruption and environmental degradation. Academic social criticism provides evidence-based analyses that inform legislative reforms, particularly in areas like labor rights and land use.

NGOs and grassroots movements further amplify these critiques, advocating for reforms addressing gender equality, environmental protection, and social justice. However, incorporating social criticism in Vietnam faces numerous challenges, including political barriers, cultural norms, and systemic barriers. To enhance the role of social criticism in Vietnam's legislative process, several strategies are essential. Expanding public consultations, creating transparent channels for citizen engagement, supporting free and open media,

and leveraging technology can facilitate real-time feedback on draft laws. Educational campaigns targeting both citizens and policymakers are also crucial. Balancing the government's stability priorities with open dialogue is essential. Promoting a culture of constructive criticism, where dissent is framed as an essential component of societal progress, encourages open debate within media, academia, and political institutions. Recognizing and rewarding constructive contributions motivates individuals and organizations to actively engage in shaping legislation.

Ultimately, social criticism enhances the legitimacy and effectiveness of Vietnam's laws by ensuring they are rooted in the real needs of its people. By fostering trust, civic duty, and national unity, it contributes to a stronger, more equitable society. Embracing and institutionalizing social criticism will enable Vietnam to navigate its development trajectory while maintaining the values of inclusivity, justice, and sustainability.

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Review Article

Forensic Nursing: A Review of its Evolution and Scope with Special Reference to India

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Abstract

Background: Forensic nursing is an evolving specialty that bridges healthcare and the justice system by integrating clinical expertise with medico-legal responsibilities. While the specialty has achieved global recognition through structured training programs such as Sexual Assault Nurse Examiner (SANE), India is still at a nascent stage in formally adopting forensic nursing. **Objectives:** This review explores the historical evolution of forensic nursing globally, highlights its roles and competencies, critically analyses its status in India, and identifies challenges and opportunities for strengthening the discipline within the national healthcare and judicial systems. **Discussion:** Globally, forensic nursing has developed into a structured profession supported by associations, postgraduate training, and legal empowerment. In India, however, forensic nursing remains under-recognized due to limited legal authority, lack of standardized curricula, insufficient infrastructure, and cultural barriers. Recent initiatives by the National Forensic Sciences University (NFSU) and Indian Nursing Council (INC) indicate progress. Opportunities include adaptation of global SANE models, integration into One Stop Crisis Centres (OSCCs), policy reforms, and generation of India-specific research. **Conclusion:** Forensic nursing has the potential to transform India's medico-legal framework by improving victim-centered care and strengthening judicial outcomes. Standardized training, legal empowerment, infrastructural support, and academic research are essential for its sustainable development.

1. Introduction

'Hanging Nursing has transitioned from a passive role under medical authority to an autonomous profession involving independent decision-making and critical thinking.[1] This evolution has allowed nurses to develop specialized roles, with clear implications for patient outcomes, professional satisfaction, and system efficiency. The development of advanced nursing roles—ranging from nurse practitioners to nurse educators—has demonstrated a positive impact on healthcare delivery, underscoring the importance of expanding nurses' responsibilities in emerging fields.[2] To assume such advanced responsibilities, nurses must not only possess clinical expertise but

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also understand medico-legal and ethical frameworks.[3] This integration becomes particularly crucial in cases of trauma, violence, and medico-legal incidents, where healthcare professionals interact with both survivors and offenders.[4]

In India, nurses are often the first point of contact for survivors of assault, sexual violence, domestic abuse, and trauma.[5] This frontline role places them in a privileged position to ensure victim-centered care while also contributing to the preservation, collection, and documentation of medico-legal evidence. However, despite this potential, their contribution has historically remained under-recognized, largely due to systemic, legal, and academic barriers.[6]

Forensic nursing as a specialty was conceptualized to address this gap, combining clinical expertise with medico-legal competencies. The International Association of Forensic Nurses (IAFN) defines forensic nursing as the "application of nursing practice to public or legal proceedings, and the application of forensic healthcare in the scientific investigation of trauma and death related to violence, criminal activity, and liability".[7] Globally, forensic nursing is regarded as a critical component of victim-centered healthcare, whereas in India it is still emerging as a defined specialty.[6]

This review provides a comprehensive overview of the historical evolution of forensic nursing, its core roles and competencies, global training models, and its current scope in India. Challenges and opportunities are analysed to highlight the potential of forensic nursing as a transformative specialty within the Indian healthcare and legal systems.

2. Historical Evolution and Global Development

The roots of forensic nursing can be traced to the late 20th century. The most significant milestone was the establishment of Sexual Assault Nurse Examiner (SANE) programs in the United States during the 1980s.[8] These programs trained nurses to conduct sexual assault examinations, preserve forensic evidence, and provide expert testimony in courts. The creation of the International Association of Forensic Nurses (IAFN) in 1992 marked another landmark, offering global recognition to the specialty and structured training frameworks.[7] Since then, forensic nursing has diversified into subspecialties including child abuse nursing, elder abuse nursing, correctional nursing, death investigation nursing, and disaster response nursing.[1, 2] These developments demonstrate how the field has matured into a structured discipline integrated into both healthcare and judicial systems.

Internationally, forensic nurses now play critical roles in evidence-based practice, patient advocacy, and policy formulation.[3] Their contributions have been linked to improved survivor outcomes, better quality of forensic evidence, and stronger judicial results.[9, 10]

3. Core Roles and Competencies

Forensic nurses function at the intersection of clinical care and legal responsibility. Their key roles include:

1. Clinical care: Providing acute medical treatment, crisis intervention, and psychological support to survivors and offenders.[2]
2. Evidence collection: Obtaining DNA swabs, collecting trace evidence, photographing injuries, and maintaining chain of custody.[8]
3. Documentation and testimony: Preparing medico-legal reports and providing expert testimony in courts.[9]
4. Public health contribution: Participation in surveillance of violence, injury prevention programs, and advocacy for vulnerable groups.[11]
5. Disaster response: Supporting triage, body identification, and mass casualty management.[12]

Core competencies include trauma-informed care, medico-legal literacy, meticulous documentation, cultural sensitivity, and interprofessional collaboration.[13, 14]

4. Education and Training Models (International)

Training in forensic nursing varies internationally, ranging from short-term certificate programs to full postgraduate degrees. The SANE model in the U.S. remains the most widely replicated, offering structured training in clinical forensic examination, communication skills, medico-legal documentation, and ethical principles.[8] Programs emphasize simulation-based learning, clinical placements in medico-legal settings, and competency-based assessments.[3]

Many universities in North America, Europe, and Australia offer MSc and postgraduate diploma programs in forensic nursing. Training models emphasize simulation-based learning, clinical placements in medico-legal settings, and competency-based assessments. These programs highlight the necessity of a multidisciplinary approach, involving collaboration with forensic medicine, law, law enforcement, and psychology.[2]

5. Forensic Nursing in India

Unlike global counterparts, forensic nursing in India remains underdeveloped.[6] Medico-legal responsibilities such as sexual assault examinations and autopsies are typically assigned to physicians, especially forensic medicine specialists. Traditionally, medico-legal responsibilities such as conducting sexual assault examinations and autopsies have been assigned to physicians, particularly forensic medicine specialists. Nurses' roles have been largely confined to providing bedside clinical care[5]. Some progressive work done at certain places towards developing this field.

1. Academic progress: A turning point came with the establishment of postgraduate programs at the National Forensic Sciences University (NFSU), which began offering M.Sc. Forensic Nursing and short-term certificate courses.[4] In addition, the Indian Nursing Council (INC) recently announced the introduction of M.Sc. Nursing in Forensic Nursing as a recognized specialty course (October 2024). This program is designed to equip nurses with a broad understanding of medico-legal concepts, legal procedures, and trauma management, while also enabling them to assist forensic medical experts in assessments.[15]

2. Practice settings: Some tertiary hospitals in India have initiated pilot SANE-style programs within One Stop Crisis Centres (OSCCs), but systematic implementation remains absent. The integration of forensic nurses into emergency departments for domestic violence deaths, sexual assault response teams, and medico-legal units is still limited.[16, 17, 18]

3. Literature base: Indian academic publications on forensic nursing remain sparse. The few existing studies consistently emphasize deficits in training, recognition, and institutional infrastructure. The lack of indigenous research significantly restricts policy advocacy.[5, 6, 17]

6. Critical Analysis: Challenges and Opportunities in India

Forensic nursing in India is still in its **formative stage**, and its trajectory is shaped by complex systemic, legal, cultural, and academic factors.

Challenges

1. Absence of standardized curricula**:** The lack of uniform training leads to inconsistent skill development and undermines professional recognition.[4]
2. Limited legal authority**:** Nurses are not legally empowered to conduct medico-legal examinations or testify as expert witnesses, restricting their contribution.[5, 6]
3. Resource deficits**:** Many hospitals lack forensic kits, private examination rooms, or funding for specialized staff.[8]
4. Shortage of professionals**:** Undefined career pathways and limited institutional recognition discourage nurses from pursuing this specialty.[2]
5. Cultural stigma: Survivors of sexual violence often avoid medico-legal care due to victim-blaming, lack of confidentiality, or social ostracism.[3,18]
6. Limited research base**:** Sparse India-specific studies weaken the evidence needed to support policy reforms.[6]

Opportunities

1. Expansion of academic programs**:** NFSU and INC initiatives can standardize education and create a pool of trained professionals.[4, 15]
2. Adaptation of global SANE models**:** Local adaptation can help India establish evidence-based, survivor-centered care pathways.[10]
3. Integration with OSCCs and health schemes**:** Embedding forensic nurses in OSCCs and government initiatives like Ayushman Bharat can improve access to medico-legal care.[16,19]
4. Policy reforms**:** Legal endorsement empowering nurses to collect medico-legal evidence can strengthen both healthcare and judicial outcomes.[17]
5. Research opportunities**:** Generating India-specific outcome data on evidence quality, survivor care, and trial outcomes will build local credibility.[9,20]

7. Discussion

Globally, forensic nursing has evolved into a structured discipline, enriched by specialized education, professional associations, and evidence-based practice guidelines. India, however, is still navigating the early phases of this professional evolution.[2,3,7] In India, however, the field is still emerging.

To bridge the gap, a **tiered training model** could be implemented:

- Basic forensic awareness for all nursing undergraduates.
- Certificate-level training (SANE-equivalent) for nurses in emergency and obstetric settings.
- Postgraduate specialization (M.Sc. Forensic Nursing) for advanced practitioners.[4,15]

Legal recognition is equally essential. Empowering forensic nurses to conduct medico-legal examinations, provide testimony, and certify

documentation would reduce physician workload, particularly in rural and resource-limited areas, and accelerate justice delivery.[5, 6, 17]

Infrastructure investments, such as dedicated forensic examination units, standardized evidence kits, and digital documentation tools, are critical for improving the quality of medico-legal evidence. In parallel, research must be prioritized. Outcome studies evaluating the impact of forensic nurses on survivor satisfaction, quality of evidence, and conviction rates will provide the data necessary for long-term policy reform.[8, 12] Research must be prioritized to evaluate forensic nurses' impact on survivor care, evidence quality, and conviction rates.[9,20] Finally, integration into multidisciplinary teams—including law enforcement, forensic medicine, psychology, and social work—will ensure that forensic nursing not only enhances survivor care but also strengthens India's medico-legal system.[11, 13]

8. Conclusion

Forensic nursing, though globally recognized, is still in its infancy in India. The specialty holds significant promise for bridging healthcare and justice, particularly in addressing gender-based violence and trauma care. Current initiatives such as postgraduate programs at NFSU and the INC's new specialty course mark important progress. However, challenges relating to curricula, legal authority, infrastructure, and social acceptance persist.

Advancing forensic nursing in India will require standardized training curricula, legal reforms, infrastructural support, and research evidence. If these steps are pursued, forensic nursing can transform India's medico-legal landscape, delivering both improved patient care and stronger judicial outcomes.

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Short Communication

Comparing the Inking Method and the Dusting-Lifting Method for Recording Exemplar Fingerprints

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Abstract

Background: Fingerprints are scientifically sound and reliable means of human identification. Exemplar fingerprints can be recorded from dead bodies. Two current and widespread methods are the inking method and the dusting-lifting method for recording exemplar prints from dead bodies. **Objective**: To measure the speed and the quality of the results of the two methods, conducted by less experienced and more experienced participants. **Methods**: This paper proposes an experiment where less-experienced and higher-experienced participants tried the two different methods on the same hand, while the time was measured, and the resulting exemplar prints were evaluated. **Results and discussion**: Despite the Author's null hypothesis, the inking method was not slower than the dusting-lifting method, and from a living human's hand, it yielded acceptable results. **Conclusion**: the fastest and most effective operation for fingerprinting was teamwork, where two experienced participants worked together on the same hand. The dusting-lifting method is recommended for casework, especially in teamwork, although the inking method is also acceptable.

1. Introduction

The volar skin of the palmar and plantar surface of the human skin has friction ridges, which form the fingerprints, palm prints, and sole prints.[1] The function of these ridges is not entirely clear, but they probably increase sensitivity to touch, the strong attachment of the skin layers, and the anti-slip of the grasping and stepping surfaces of the body.[2] Fingerprints are scientifically based and reliable means of personal identification, and have been used for one hundred and thirty years in forensic science.[3]

The fingerprint features can be divided into three levels: Level 1, Level 2, and Level 3.[4-6] Level 1 details are the basic patterns that can be used for classification, sorting the fingerprints into a database efficiently. By the Level 1 details, the fingerprints can be sorted into three general categories based on their pattern type: loop, arch, and whorl. All three can have sub-categories as well, forming nine basic types,[7] or even ninety-five.[8] The ridges are not continuous; they can end, diverge, or converge. Many small details can be observed in the ridge flow; these are called "minutiae". Minutiae can also be called Level 2 detail, a continuation of the nomenclature from the Level 1 general patterns. Genetics plays a role

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in the formation of the Level 1 details, but the exact Level 2 details are mostly based on environmental conditions.[9] In this connection, studies have been carried out to identify dermatoglyphic traits that can be associated with different types of diseases and conditions.[10-11] However, the basic whorl, arch, and loop patterns may be similar between siblings; the Level 2 details of the pattern are practically unique to everyone, even between monozygotic twins.[12-13] The Level 3 details are the dimensional attributes of the ridges, which can only be used to support identifying individuals.

Ridgeology is also suitable for the identification of dead bodies since ridge details can persist after the individual's death. As long as the body has its skin, the ridge details can be recorded. Putrified cadavers can lose the epidermis and dermis in days, but for mummified bodies, the skin can last for years or even decades. Researchers could obtain fingerprints from a 2,500-year-old Egyptian mummy.[14,15] After a mass fatality incident, the victims have to be identified by scientifically sound means. The international police organization, Interpol, has a Disaster Victim Identification (DVI) Working Group, which issues and regularly reviews the Interpol DVI Guide.[16,17,18,19,20]

Fingerprints can be utilized for victim identification after mass fatality incidents as well. Interpol accepts ridgeology as a primary identifier, along with odontology and genetics. During a victim identification after a mass fatality incident, the speed of the fingerprinting process and the quality of the resulting exemplar prints are crucial. From a disaster victim identification perspective, PM (*post-mortem*, after death) prints need to be obtained from the dead body: as many fingers as possible, both palms, sometimes the soles and toes as well. The post-mortem samples from a dead body are needed to compare with the ante-mortem (AM) fingerprints, gathered from databases or the missing person's belongings and environment.

This paper covers a short experiment, which aimed to compare the inking method and the dusting-lifting method from a disaster victim identification point of view, however, focusing only on the PM fingerprinting techniques.

2. Materials and methods

Post-mortem fingerprinting has some different methods, like the inking method, described by F. Galton himself, in the very first scientific book, Finger Prints" from 1892. The equipment that is needed to record prints by inking includes a rubber roller, an inking plate made of glass or smooth metal, such as stainless steel or spelter, paper cards for recording the inked prints, and a quality black ink formulated for this purpose.[21] Recently, forensic suppliers have offered many different types of fingerprinting inks.

Another well-known method is the so-called dusting-lifting method, when regular fingerprint powders are used, and the dusted fingertip is covered with a regular latent fingermark lifting tape. Powdering is the most common, easy-to-use, and oldest method to develop latent fingerprints from crime scenes.[22] After the dusting, the lifting adhesive side of the tape will yield the dusted friction.[21] For this purpose, almost every type of latent print powder can be used, but usually, black powders with transparent lifters are the best. The transparent lifter should be attached to a white background card or directly to the fingerprint card. It is worth noting that in this case, the prints would be a mirrored image of the original patterns.

The right hand of a living human (Author 1) was printed, five fingers only, but not the palm. Time was measured with a stopwatch for the inking method, and, similarly, time was measured for the dusting-lifting method too. Two people experimented; the first one was a newbie for crime scene investigation, just after the cadet years, without any real experience in post-mortem fingerprinting. The second one (Author 2) has 18 years of experience in crime scene investigation and 6 years of experience in disaster victim identification and post-mortem fingerprinting.

After the sets of different methods, Author 2 and Author 3 together conducted a dusting-lifting method in teamwork. Author 3 is a qualified fingerprint expert with sound and comprehensive experience in post-mortem fingerprinting. For the inking method, the Disposable Inked Strips (Sirchie, Youngsville, NC, US; catalog number: SIS610C) were used, where the ink is sandwiched between two thin sheets of plastic film. Each finger was printed to Printover Tabs (Sirchie, Youngsville, NC, US; catalog number: FPT108R), making the preparation much faster. Using Printover Tabs, it was not necessary to cut a fingerprint card into pieces, which is perhaps the most time-consuming part of the method (**Fig. 1**).

For the dusting-lifting method, black fingerprint powder (Regular Silk Black Fingerprint Powder; Sirchie, Youngsville, NC, US; catalog number:

BPP0916) was used with „SEARCH Regular Powder Brush" (Sirchie, Youngsville, NC, US; catalog number: 118L). Prints from the fingertip were lifted with 1.5-inch wide Sirchie fingerprint lifting tape (Fig. 2).

Fig. 1: The inking method with the inked strips and the paper tab. A thin layer of ink is applied to the finger from a plastic film. A self-adhesive piece of paper is used to transfer the fingerprint. The piece of paper is later to stick on a regular fingerprint card.

Fig.2: The dusting-lifting method, fingerprint powder, and brush. A thin layer of latent print development powder is applied to the finger by a crime scene brush. A latent print lifter is used to transfer the fingerprint. The lifter is later to stick on a regular fingerprint card.

3. Results

Results are summarized in Table 1-2.

Table 1. Comparing the less experienced participants and the more experienced participants in applying the inking method. Results are in seconds.

Attempts	Less experienced participant (seconds)	More experienced participant (seconds)
1	530	125
2	514	123
3	522	118
4	527	121
5	524	124

Mean and standard deviation for the less experienced participants: 523.4 ± 5.7 s

Mean and standard deviation for the more experienced participants: 122.2 ± 2.5 s

Table 2: Comparing the less experienced participants and the more experienced participants in applying the dusting-lifting method. Results are in seconds.

Attempts	Less experienced participant (seconds)	More experienced participant (seconds)
1	405	343
2	399	321
3	392	326
4	402	332
5	395	340

Mean and standard deviation for the less experienced participants: 398.6 ± 4.7 s

Mean and standard deviation for the more experienced participants: 332.4 ± 8.9 s

The dusting-lifting method in teamwork took 3 minutes and 12 seconds the first time, and 3 minutes and 16 seconds the second time. The quality of the exemplar prints can be measured by the clarity of the print, the sharpness of the ridge details, the blurred parts of the prints, or, conversely, the lack of blurred parts. From this point of view, the dusting-lifting method yielded a slightly better result, while the inking method was also suitable, and had far enough clear details for identification (Fig. 3).

In order to objectively determine the quality, the prints were loaded into AFIS, where the automatic marking of minutiae was chosen. In each case, the dusting-lifting method proved to be better. Fig. 4 shows that the number of minutiae automatically found by AFIS is 108 for the inking and 135 for the dusting-lifting method. Since all results were above 100 minutiae, and in practical work, a value around 20 is considered perfectly acceptable, we did not consider the qualitative differences to be significant.

Fig. 3: Right thumbprint with the inking method (on the left) and with the dusting-lifting method (on the right. It is a reversed image of the fingerprint.)

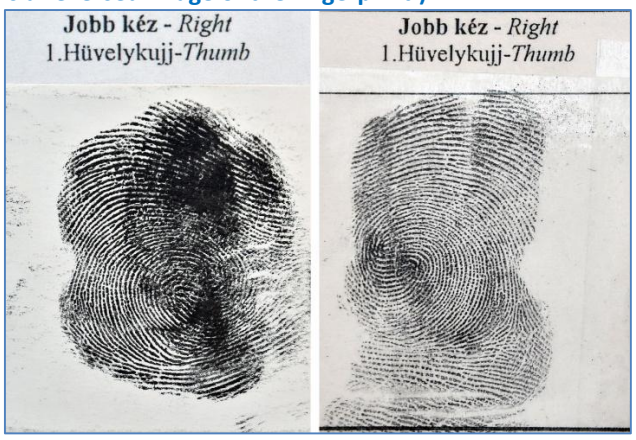
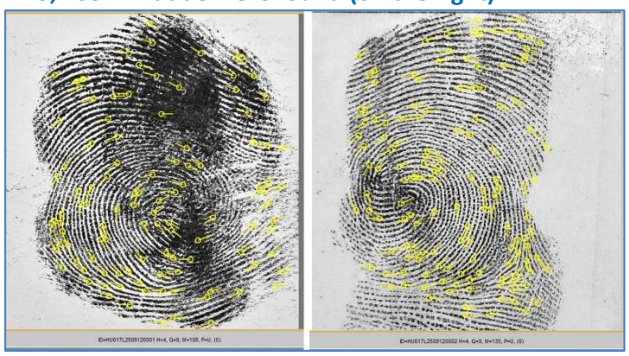


Fig. (4). Right thumbprint with the inking method uploaded to the AFIS, 108 minutiae were found (on the

left), and with the dusting-lifting method, uploaded to the AFIS, 135 minutiae were found (on the right).



4. Discussion

Anecdotal evidence claims that the dusting-lifting method is faster, cleaner, and yields better quality than the inking method. Knowing this, it was surprising that the experienced participant was much faster, almost three times faster with the inking method than with the dusting-lifting method. This was probably due to the use of the Printover Pads, instead of cutting off the fingerprint card and attaching the paper pieces to another card, which is a time and energy-consuming process.

The difference between the speed of the two participants was something foreseen and expected. The result is that even a less experienced person can easily be taught the methods, and after that, would be able to apply them, with acceptable results, despite the slight slowness. The so-called teamwork, when author 2 and author 3 conducted the dusting-lifting method together, sharing the tasks, was the fastest. Approximately two times faster than the less experienced participant, and more than one and a half times faster than author 2 alone.

Regarding the quality, the living human as the donor of the exemplar can be considered the most significant limitation of the experiment. Not only anecdotal evidence but also comprehensive practical experiences prove that on dead bodies, especially the not very fresh ones, the dusting-lifting method yields much better results.[23-24] After some days, despite the refrigeration, the body starts to lose water, which would make the fingertips wrinkled or the skin flaccid. Another factor behind the surprisingly good results may be the usage of the inked strips, instead of the rubber roller and the inking plate. The inked thin films evenly distribute just the right amount of ink on the fingertip.

5. Conclusion

The main conclusions are about the speed, the training, the material, and the operation. For a well-trained and experienced person, the inking method is not slow. Surprisingly, it was faster than the dusting-lifting method. Being so fast, however, required the ink strips rather than the rubber roller, and the sticky tabs rather than the cutting of the fingerprint cards. Without these comfortable solutions, the inking method would be much slower. Even a less experienced crime scene investigator can be taught both fingerprinting methods very quickly. The more the experience, however, the faster the fingerprinting, and the better the quality of the results.

The teamwork, when two participants worked together, was the fastest. It is recommended to form postmortem fingerprinting teams, instead of single fingerprinting individuals. Usually, during postmortem investigations, there is more than one crime scene investigator or fingerprint specialist, so this cannot be an obstacle. Concluding this experiment, the dusting-lifting method should be preferred during casework, but in teamwork. The inking method, however, can also be suitable for fresh bodies or living people, with the preparation of adequate hand-cleaning.

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Author's contribution:

Author 1: Conceptualization, designed and performed the experiment, supervision, writing – review & editing.

Author 2: Designed and performed the experiment, photo documentation & visualization, and data collection.

Author 3: Conceptualization, data evaluation, validation, writing – original manuscript.

Abbreviations

Interpol: International Police Organization.

DVI: disaster victim identification

AM: Ante mortem, before death

PM: Post mortem, after death

AFIS: Automated Fingerprint Identification System

Ethics Approval: Ethics approval was not relevant to this study because there were no human subjects involved. To experiment, Author 1 was a donor for fingerprinting, which is not invasive, dangerous, or poses any health risk.

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Short Communication

Insoluble Challenges of Prosecuting Transnational Cybercrime: A Case in a Developing Country

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Abstract

Introduction: Transnational cybercrime includes hacking, phishing, identity theft, ransomware, and cyber espionage conducted across national borders. Its borderless nature complicates jurisdiction, investigation, and prosecution, particularly in developing countries such as Vietnam, where legal and institutional gaps remain acute. **Methods:** This qualitative, descriptive study employed secondary sources to analyze the multifaceted challenges of prosecuting and preventing cybercrime in developing contexts, with Vietnam as a case study. **Results:** Findings reveal that limited resources, outdated laws, weak forensic capacity, and corruption hinder effective enforcement. Jurisdictional ambiguity and technological deficits further constrain prosecutions. The medicolegal dimension heightens risks: breaches of healthcare systems and electronic health records compromise privacy, patient safety, and evidentiary integrity, engaging both civil liability and professional accountability. **Conclusion:** Addressing these challenges requires harmonized legislation aligned with international standards, specialized cybercrime units, medicolegal safeguards, and robust international cooperation. Public awareness and societal resilience remain critical to securing the digital environment.

1. Introduction

The Transnational cybercrime refers to criminal activity conducted through digital networks that transcend national borders, complicating investigation and prosecution due to divergent laws, priorities, and resources.[1] Such offences are often perpetrated by organized networks exploiting jurisdictional fragmentation to evade liability. Developing countries encounter heightened vulnerability, given resource constraints, infrastructural deficits, and legal lacunae.[2] As Clough[3] notes that the borderless nature of the Internet enables cybercriminals to target regions with weak cybersecurity regimes, confident that enforcement capacity is limited.

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Cybersecurity infrastructure in these jurisdictions is further undermined by shortages of skilled professionals, inconsistent regulations, and competing political priorities. Corruption within enforcement agencies exacerbates this deficit, while low public awareness and poor cyber hygiene among citizens make individuals and enterprises particularly susceptible to phishing, ransomware, and identity theft.[4] Natarajan and Androulaki[5] emphasize that political instability or competing national interests often result in cybersecurity being deprioritized, creating fertile ground for exploitation.

The medicolegal dimension raises distinctive concerns. Breaches of healthcare databases, telemedicine platforms, and hospital systems jeopardize not only informational privacy but also patient safety. Unlawful access may facilitate insurance fraud, manipulation of medical histories, or disruption of clinical care, thereby implicating both civil liability and professional accountability.[6] Developing countries must, therefore, embed medicolegal safeguards into their frameworks, including statutory duties of confidentiality, malpractice-style liability standards for cybersecurity lapses in medical institutions, and formal recognition of electronic health data as a protected evidentiary category.[7] Vietnam illustrates both progress and persistent gaps. Legislative developments such as the 2018 Cybersecurity Law[8] and Decree No. 53/2022/ND-CP,[9] alongside partnerships with INTERPOL, ASEAN, and UNODC, reflect a commitment to transnational collaboration. Nevertheless, limited resources, a cybersecurity skills gap, and inadequate public awareness continue to impede effective prevention.[10] A multi-faceted approach, such as legal reform, professional training, infrastructural investment, medicolegal integration, and sustained international cooperation, remains indispensable. This paper aimed to answer the following questions:

1. What laws and regulations has Vietnam implemented to combat transnational cybercrime?
2. What challenges does Vietnam face in implementing and enforcing transnational cybersecurity regulations?

2. Methods

This study employed a structural review research design based on a qualitative analytical approach proposed by Linos and Carlson[11] for law writing review methods. It also examined secondary sources and emphasized systematic data collection, transparency, and ethical considerations to contribute to rich, contextually grounded insights into the challenges of imposing legal sanctions on transborder criminality in developing countries like Vietnam.

3. Discussion

3.1. Challenges in prosecuting transnational cybercrime in Vietnam

Transnational cybercrime prosecution is inherently complex because of the borderless nature of the Internet, divergent legal regimes, and the increasing sophistication of offenders' methods. In developing countries like Vietnam, the challenges of such an approach are exacerbated by jurisdictional ambiguity, technological deficits, and limited institutional capacity.[10] The lack of explicit statutory provisions on extraterritorial jurisdiction frequently impedes prosecutorial authority, especially in cases that offend multiple sovereigns. Effective prosecution thus necessitates legal reform alongside active participation in bilateral and multilateral instruments, extradition, and cross-border exchange of evidence.[12] Resource constraints further weaken enforcement capabilities because offenders use anonymization, encryption and darknets beyond the current forensic and investigative capabilities. Insufficient budgets limit investment in digital forensic laboratories, advanced surveillance technologies, and judicial training in cyberlaw.[13] Without such assistance, law enforcement agencies lack the tools to even identify, retain, and present intricate electronic evidence. Parallel efforts in public awareness campaigns are also crucial to encourage early reporting and prevention.[7]

From a medicolegal standpoint, issues of evidentiary integrity and procedural compliance are critical. Digital evidence must satisfy chain-of-custody requirements and admissibility standards consistent with both domestic law and international privacy regimes, such as GDPR-inspired frameworks.[14] Accordingly, courts must consider the extent to which collected evidence extraterritorially complies with Vietnamese rules of procedure and evidence, as any failure to meet this will likely lead to exclusion and consequent collapse of prosecutions. Forensic practitioners, moreover, bear ethical and legal duties to ensure impartiality, accuracy, and confidentiality, thereby protecting the rights of the accused while upholding prosecutorial legitimacy.[15] There are also political and institutional obstacles, such as corruption, bureaucratic inefficiency, and insufficient

judicial independence that make it difficult to apply regulations effectively. Strengthening governance, transparency and accountability of investigative and prosecuting authorities is still essential.[4] Ultimately, the effective prosecution of transnational cybercrime in Vietnam requires a holistic strategy combining legislative harmonization, forensic preparedness, international cooperation, and medicolegal safeguards, thereby enhancing prosecutorial efficacy and digital security resilience.

3.2. Implications for combating and preventing transnational cybercrime in Vietnam

It is necessary to have a harmonised and practical instrument to combat and prevent transnational cybercrime in developing countries, including Vietnam. In today's digital age, cybercrime routinely transcends territorial boundaries, rendering traditional jurisdictional doctrines inadequate absent meaningful reform.[7] From the perspective of substantive criminal law, Vietnam's existing provisions regulate certain cyber-offences but fail to capture the expanding spectrum of digital threats, including ransomware schemes and intrusions into critical infrastructure. As Roscini explains, the lack of clearly defined terms, proportionate penalties, and uniform procedural protections undermines deterrence and compromises justice.[2] Consequently, harmonisation with foreign legal frameworks, particularly the Budapest Convention on Cybercrime, would increase both the jurisdictional reach, admissibility of digital evidence and compliance with internationally recognised due process principles. The medicolegal aspect emphasizes further vulnerabilities.[15] Cyberattacks against healthcare systems, telemedicine platforms, and repositories of electronic health records are related to privacy, patient safety, and public health. Violations may enable identity theft, insurance fraud, and manipulation of medical histories, so these breaches implicate civil liability and professional responsibility.[16,17] In contrast, a combined medicolegal approach is needed to be instituted as a matter of law in Vietnam. This would involve statutory duties of confidentiality for healthcare institutions, liability standards analogous to medical malpractice for cybersecurity lapses, and recognition of digital health records as a protected evidentiary category in judicial proceedings.

In terms of institutional capacity, enforcement remains constrained by deficits in forensic expertise and limited technological resources. Establishing specialized cybercrime units, which are supported by sustained investment in forensic technologies and professional training, is indispensable.[18] The incorporation of forensic medicine and health-law experts into investigative processes would further strengthen the State's capacity to address crimes targeting medical infrastructure and patient data. Because of the transnational character of cybercrime, unilateral domestic action is insufficient. It is necessary for Vietnam to participate in multilateral processes, including INTERPOL, UNODC, and ASEAN cyber initiatives, for the purposes of intelligence exchange, mutual legal assistance, and extradition.[5] As a result, harmonized standards on evidence preservation and medicolegal certification will strengthen cross-border enforcement.[13] Finally, it is important to emphasize the role of societal resilience. As reported by the Ministry of Public Security, public unawareness of cyber risks increases susceptibility to fraud, identity theft, and medical data misuse.[10] Besides, nationwide educational initiatives, which are integrated into curricula and reinforced by campaigns, are therefore critical. Public confidence in reporting mechanisms also promotes incident detection and strengthens prosecutorial outcomes.[15] Overall, a comprehensive strategy combining legal reform, medicolegal accountability, institutional strengthening, and international cooperation is essential for developing states confronting transnational cybercrime.

4. Conclusion

Transnational cybercrime poses profound challenges for developing countries such as Vietnam, where legal gaps, resource limitations, and jurisdictional fragmentation undermine effective enforcement. While Vietnam has advanced through its Cybersecurity Law, Decree No. 53/2022/ND-CP, and collaboration with INTERPOL, ASEAN, and UNODC, significant obstacles remain, including limited forensic capacity, a shortage of skilled professionals, and low public awareness. The medicolegal dimension illustrates the heightened risks to healthcare systems, telemedicine, and electronic health records, where breaches compromise privacy, patient safety, and evidentiary integrity. To address these risks, statutory duties of confidentiality, malpractice-style liability standards, and recognition of digital health data as protected evidence must be integrated into the legal framework. Sustainable progress requires a comprehensive approach: harmonized legislation,

specialized enforcement units, forensic preparedness, public education, and cross-border cooperation. Only by embedding medicolegal safeguards within a broader cybersecurity strategy can Vietnam enhance resilience and ensure justice in the face of evolving cyber threats.

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Short Communication

Virtual Autopsy – A Boon or Bane?

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Abstract

Virtual autopsy, or "virtopsy," is a modern technique that uses imaging technologies like CT and MRI scans to perform non-invasive post-mortem examinations. Unlike traditional autopsies, which require physical dissection, virtopsy offers a less invasive alternative. This article explores the benefits and challenges of virtual autopsy in modern medicine. Supporters highlight its ability to preserve the dignity of the deceased, avoid contamination, provide detailed 3D images for accurate analysis, and create a permanent digital record. It is especially valuable in cases where religious beliefs oppose traditional autopsies and in forensic investigations requiring quick, non-invasive methods. However, critics point out its high costs, need for specialized equipment, and limitations in replacing the accuracy of traditional autopsies in complex cases. Accessibility is also a concern, particularly in developing countries. In conclusion, while virtual autopsy offers significant advantages, its challenges highlight the need for an integrated approach that combines innovation with traditional practices to advance post-mortem examinations.

1. Introduction

Virtual autopsy, known as "virtopsy," is a modern technique that uses imaging technologies like CT and MRI scans to conduct non-invasive post-mortem examinations, unlike traditional autopsies that involve physical dissection. The term virtopsy was coined by Thali et al.[1] It is a combination of terms Virtual and Autopsy, where virtual is derived from the latin word “Virtus” which means Useful, efficient and good”. Virtopsy uses imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) to perform non-invasive post-mortem examinations, in contrast to traditional autopsies, which involve the dissection of the body to determine the cause of death.[2, 3] Introduced in the early 21st century, virtopsy addresses challenges such as the invasiveness of conventional autopsies, cultural or religious objections to dissection, and risks of exposure to infectious agents. It provides detailed visualization of internal structures and permanent digital records, enhancing diagnostic accuracy and forensic investigations. Supporters highlight its ability to improve efficiency, enable remote collaboration among experts, and offer a less invasive option for families. However, critics note its high costs, need for specialized equipment,

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and limited accessibility in resource-poor settings, such as peripheral hospitals. Additionally, while imaging can reveal structural abnormalities, it may not always detect certain pathological conditions as effectively as traditional autopsies and also will not detect, touch, smell and sight senses,[4, 5] subtle injuries, colour changes, inflammatory changes or toxicological findings. Doubts are also raised regarding the legal admissibility of virtopsy findings in court, as well as the ethical implications of virtual autopsies, including issues of consent, privacy, and the potential for misuse of digital data.

This article evaluates the role of virtual autopsy, or "virtopsy," in forensic medicine by analyzing its benefits, limitations, and implications for integration into modern forensic practices, aiming to determine whether it serves as a valuable advancement or poses significant challenges.

2. Pros (Boon):

a. **Non-Invasiveness:** Virtual autopsy offers a non-invasive alternative to traditional autopsies, preserving the integrity of the deceased's body and also respecting cultural and religious sensitivities that prohibit invasive procedures.
b. **Accessibility:** In areas with limited forensic expertise, virtopsy allows off-site examinations and consultations through digital imaging.[4]
c. **Time efficiency:** Virtual autopsy can be conducted more quickly than traditional autopsies, leading to faster turnaround times for investigation results. This can facilitate prompt resolution of legal proceedings and provide closure for the deceased's family.
d. **Comprehensive Imaging:** Advanced imaging modalities used in virtual autopsies, such as CT and MRI, enable detailed visualization of internal organs, soft tissues, and skeletal structures. This clear imaging helps identify injuries, pathology, and the cause of death.
e. **Minimization of Contamination Risks:** Since virtual autopsies do not involve physical manipulation of the body, there is a reduced risk of contamination or exposure to infectious agents, benefiting both forensic pathologists and supporting staff.[5]
f. **Archival Capabilities:** Digital records of virtual autopsies can be stored electronically, creating valuable archives for medical research, education, and training.[5, 6]

3. Cons (Bane):

a. **Accuracy and Reliability:** Virtual autopsy techniques rely heavily on imaging technologies to reconstruct the body's internal structures and identify pathologies. While these methods can provide detailed images, they may not always offer the same level of diagnostic accuracy as traditional autopsies. Factors such as image artefacts, tissue degradation, and limitations in resolution can affect the reliability of virtual autopsy findings, leading to potential misinterpretations or missed diagnoses.
b. **Limited Tissue Sampling:** Unlike traditional autopsies, virtual autopsy techniques do not allow for the collection of tissue samples for histological analysis. As a result, certain types of pathologies, such as microscopic changes or subtle injuries, may be overlooked. This limitation can impact the comprehensive assessment of the cause and manner of death, particularly in cases where detailed tissue examination is necessary for accurate diagnosis.
c. **Cost and Accessibility:** The equipment and expertise required to perform virtual autopsies, including specialized imaging systems and trained radiologists, can be costly and may not be readily available in all healthcare settings. This limitation can restrict access to virtual autopsy services, particularly in resource-limited regions or underserved communities, where traditional autopsies may be the only feasible option.
d. **Inability to Assess Tissue Texture, Consistency and soft tissue injuries**: Virtual autopsies lack the tactile feedback and ability to assess tissue texture and consistency that traditional autopsies provide. Imaging techniques can detect skeletal injuries relatively well, but have limitations in detecting subtle or small soft tissue injuries, such as contusions or small lacerations.[7]
e. **Dependence on Imaging Interpretation**: Virtual autopsies rely heavily on the interpretation of medical images by radiologists and forensic pathologists. Interpretation errors or differences in expertise among interpreters can impact the accuracy and reliability of findings.
f. **Lack of Ancillary Testing**: Traditional autopsies allow for ancillary testing, such as histopathology, [8] toxicology, and microbiology, which can provide valuable additional information. Virtual autopsies may face limitations in sample collection for such testing.

g. **Limited Ability to Address Decomposed or Charred Bodies**: Virtual autopsies may face challenges in accurately assessing decomposed or charred bodies, where imaging quality may be compromised due to tissue breakdown or artefacts
h. **Ethical and Legal Considerations**: Virtual autopsies may raise ethical and legal considerations regarding consent, privacy, and the admissibility of findings in court. Some jurisdictions may require traditional autopsies for legal purposes, particularly in cases involving suspicious or criminal deaths.[9-12]

4. Conclusion

Virtopsy employs CT and MRI scans for non-invasive post-mortem examinations. It offers non-invasiveness, enabling remote consultations and faster results compared to traditional autopsies. However, it has limitations, including potential diagnostic inaccuracies, image interpretation errors, high costs, limited legal acceptance in some jurisdiction, and ethical issues concerning consent and data privacy. Virtopsy's effectiveness depends on available resources and case-specific needs.

Collaboration among forensic, legal, and ethical stakeholders is essential to develop clear guidelines addressing these challenges. Currently, virtopsy serves as a valuable complementary tool, particularly in cases with cultural or logistical constraints, but its diagnostic limitations and high costs prevent it from fully replacing conventional methods, indicating it is more of a complementary tool than a universal solution at present.

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Case Report

Carbon Deposition in Alveolar Structures: A Marker of Ante-Mortem Smoke Inhalation

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Soot Deposition, Smoke Inhalation, Antemortem Burns, Fire-Related Deaths.

Abstract

In **fire related deaths**, especially with no history or injuries, it is not always clear whether death was caused by burns, smoke, or both. In such cases, studying the lungs under a microscope becomes very important, especially when obvious burn injuries are absent. Smoke inhalation shows a recognizable histopathological finding such as congestion of blood vessels, swelling of capillaries, bleeding into the air sacs, and damage to the delicate alveolar walls. The presence of soot particles in the trachea, along with these microscopic changes, strongly suggests that the person was alive and breathing during the fire. However, **carbon particles** seen inside the alveoli but not deeper in lung tissue indicate that they were inhaled rather than passively deposited after death. More convincing evidence is the presence of macrophages actively engulfing carbon particles—proof of a living response to smoke inhalation. This study highlights the value of routinely examining the lungs histologically in fire-related deaths. Doing so helps forensic experts distinguish between injuries sustained before and after death, while also deeply understanding the pathogenesis of smoke inhalation injury in causing death.

1. Introduction

The percentage of burn patients who experience inhalation injury—which consistently stands at around 15–20% of hospital admissions internationally—represents an important aspect of burn care over several decades, as demonstrated by comprehensive systematic reviews and research from multiple countries.[1] Autopsy examinations play a pivotal role in establishing the cause of sudden or unexplained deaths, as well as confirming uncertain clinical diagnoses. Over 96% of fire-related deaths worldwide occur in developing and underdeveloped countries, with the South-East Asia region bearing a disproportionately high share of the global burden. These elevated mortality rates are attributed to factors such as poor infrastructure, inadequate fire safety education, overcrowded living conditions, and insufficient emergency medical services.[2] Accidental burns commonly occur both in domestic and occupational settings. Within households,

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frequent causes include electrical short circuits, clothes catching fire whilst cooking, leakage of cooking gas, and accidents involving lamps or candles. Vulnerable groups include children, elderly, and individuals under the influence of alcohol or drugs. In occupational environments, ranging from small-scale industries to heavy industrial operations, burns remain prevalent and contribute significantly to morbidity and mortality.

One of the major forensic challenges in burn-related deaths is the distinction between antemortem and postmortem burns. The most reliable indicators of antemortem burn and smoke inhalation injuries include the presence of soot particles in the trachea or lower respiratory tract and elevated concentrations of carboxyhaemoglobin in the blood. However, the absence of carboxyhaemoglobin does not exclude antemortem burn injuries, as carbon monoxide generation may be minimal in open-air fires or if the person died rapidly before inhaling large quantities.

Owing to their extremely small size, soot particles can passively deposit within the upper respiratory tract. However, the deposition of soot particles within the trachea and extending into the lower respiratory tract, including terminal bronchioles, indicates active respiration during the fire. This vital reaction usually reflects increased breathing secondary to fear, or smoke-induced airway compromise, confirming that inhalation occurred before death which is usually considered as a telltale sign of antemortem inhalation injury,

Nevertheless, the absence of soot particles in the trachea or bronchi does not exclude antemortem exposure. Several factors may explain such cases, including burn incidents in open spaces where soot is rapidly dispersed by environmental airflow, or cases where the victim survived long enough to receive oxygen therapy and resuscitative interventions that can remove or redistribute carbon particles within the airway. These intricacies highlight the importance of integrating both gross and microscopic findings along with biochemical evidence to accurately establish the role of inhalational injury in burn-related deaths.

2. Case summary

An 82-year-old female was brought to the hospital with a history of breathlessness and loss of consciousness at home due to inhalation of smoke, which developed due to a short circuit in their building. She died within 15 minutes of admission while she was on treatment. She had no history of smoking or any occupational exposure that would significantly contribute to the histopathological findings mentioned below.

3. Pathological findings

On examination there were no external injuries. Soot particles with mucosal secretions were seen in the tracheal lumen on gross examination (**Figure 1, Figure 2**). Histopathology examination with haematoxylin and eosin stain revealed the presence of carbon particles in alveolar walls (**Figure 3, Figure 4**) and spaces along with alveolar collapse and oedema.

Figure 1: Soot in Tracheal lumen.

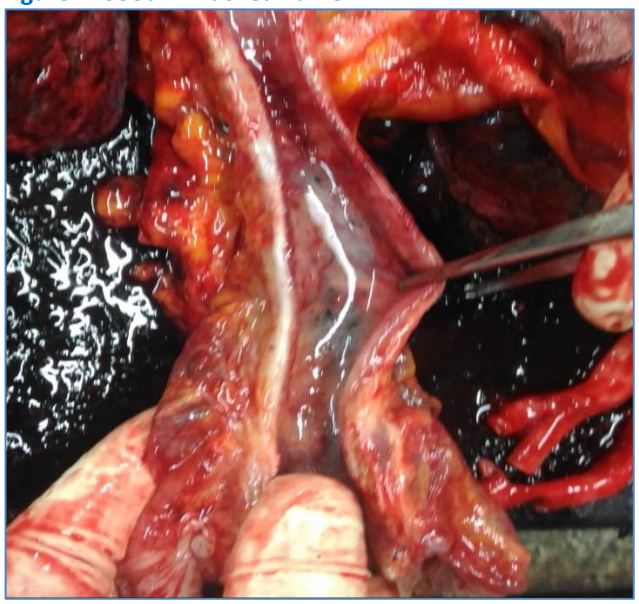
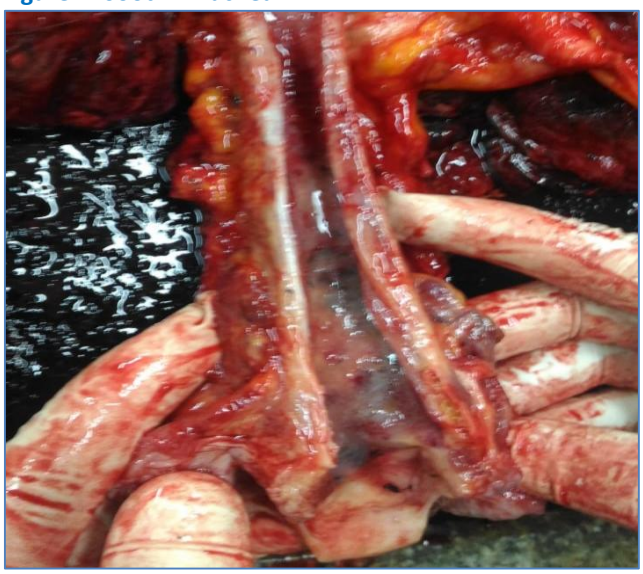


Figure 2: Soot in Trachea.



4. Discussion

In this study, histopathological examination revealed the presence of carbon particles along the alveolar walls in cases of smoke inhalation injury.

Several mechanisms have been proposed to explain the origin of these particles within the lung:

1. Deposition of exogenous soot directly inhaled into the alveoli.
2. Release of endogenous elemental carbon during altered carbon dioxide metabolism, and
3. Accumulation of endogenous blood-derived pigment.[3]

Figure 3: Prominent deposits along alveolar wall (100X).

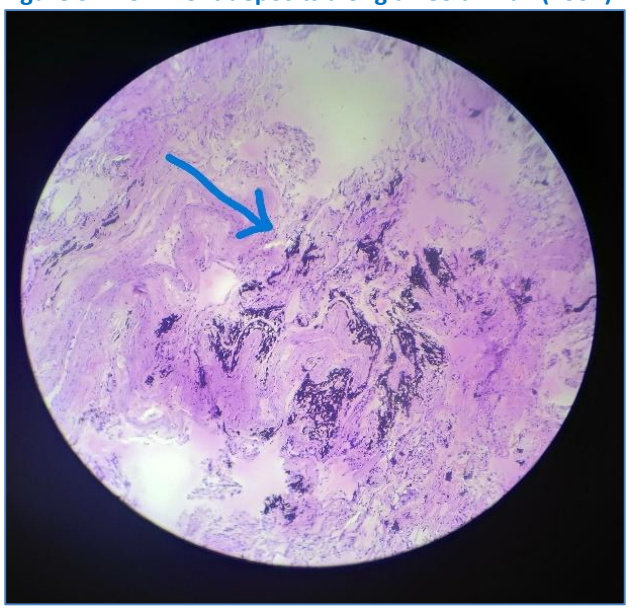
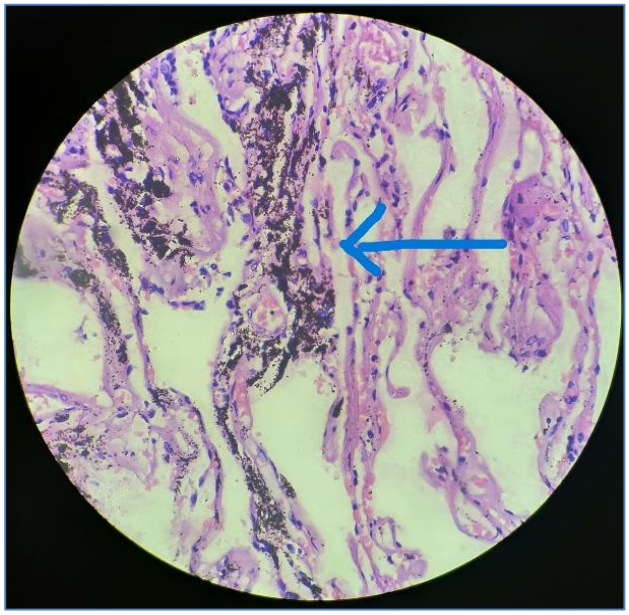


Figure 4: Deposits in alveolar wall (450X).



The endogenous elemental carbon usually is deposited within the deeper layers of the lung parenchyma unlike this case where carbon particles were noted along the alveolar walls and endogenous blood derived pigments can be confirmed with Perl's stain which was not appreciated in this case. Pinkerton et al. demonstrated that carbonaceous particulate matter can be identified in subpleural septa and lymphatics even in nonsmokers, suggesting an important contribution of background environmental exposure.[4]

Similarly, Podovan et al. emphasized that smoking-related carbon deposition may be secondary to ambient air particulate exposure rather than smoking alone.[5] A notable forensic report by Senarath et al. described the presence of soot beyond secondary bronchioles, accompanied by pulmonary congestion and haemorrhage, in a family who died in a house fire. These findings strongly supported soot deposition as a vital sign of ante-mortem inhalation.[6] Rahimi et al. further confirmed the systemic distribution of black carbon particles by identifying them in vascular spaces of multiple organs. These particles were distinguishable from hemosiderin by negative Perl's staining, highlighting their origin as inhaled particulate matter rather than endogenous pigment.[7]

Characteristic histopathological patterns have also been documented in burn-related smoke inhalation cases as "fire lungs" present with bronchiolar dilation and alveolar haemorrhage, while "suffocation lungs" typically show alveolar collapse and vascular congestion. Megahed et al. demonstrated a significantly higher mortality rate among patients with inhalation injury compared to those without, underscoring the clinical and prognostic significance of these findings.[8] Nemmar et al. showed that ultrafine particles are capable of translocating rapidly into systemic circulation, most likely through the alveolar-blood barrier rather than via phagocytosis, thereby contributing to extrapulmonary effects.[9] This concept is further supported by the detection of pneumoproteins in circulation, reflecting increased permeability of the alveolar-capillary barrier.[10] Ultrastructural studies have also documented phagocytosis of carbon particles by alveolar macrophages and associated epithelial injury, reinforcing inhaled soot as a clear marker of vitality.[11] Reviews of smoke inhalation pathology consistently describe progressive patterns of damage: epithelial necrosis, inflammatory cell infiltration, and increased vascular permeability, all of which highlight the destructive cascade initiated by inhaled smoke exposure.[12]

Postmortem studies combining imaging with histopathology corroborate these changes, revealing soot deposition and pulmonary oedema as hallmark features of ante-mortem smoke inhalation.[13]

Furthermore, Gupta et al. provide a detailed discussion of the etiopathogenesis, linking soot deposition with alveolar wall destruction, vascular congestion, and widespread tissue injury.[14] Taken together, our findings are consistent with these prior observations. The demonstration of carbon particles along alveolar walls and within phagocytic macrophages represents a reliable and definitive indicator of ante-mortem smoke inhalation. This not only aids in forensic interpretation of burn-related deaths but also deepens our understanding of the pathological processes underlying smoke-induced lung injury. Explosions and inhalational injuries at workplaces—both in large industries and informal sectors—are a major cause of death. In India, occupational safety and health standards are established by law and are enforced by agencies such as the Directorate General Factory Advice Service & Labour Institutes (DGFASLI) under the Government of India, along with inspectorates of factories and boilers at the state level.[15] Burn injuries are a significant public health problem in India, with millions affected annually and high mortality attributed to socio-economic factors, including poverty and limited access to specialized care. National programs have been instituted to improve prevention and management, recognizing the challenge posed by burns in the society.[16]

5. Conclusion

Surface soot in the trachea and bronchi and carbon deposits in alveolar walls or macrophages are crucial forensic markers of ante-mortem smoke inhalation. These findings help differentiate ante-mortem from postmortem burns and should be assessed alongside clinical context for accurate medicolegal diagnosis.

6. Recommendations

Further studies with larger samples are needed to consolidate soot and mucus-laden macrophages as definitive markers of life at the time of fire exposure.

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Case Report

A Fatal Case of Cardiac Tamponade Consequent to Aortic Dissection

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Abstract

Aortic dissection characterized by the infiltration of blood between layers of the aortic wall, is a grave and fast-progressing medical emergency, with considerable mortality rates even in the context of contemporary advances in imaging and treatment. We present a case study of an 80-year-old female with ruptured aortic dissection, focusing on the autopsy findings, particularly the presence of atherosclerotic plaque and a tear in the aortic intima. The typical and atypical presentations of the condition, including **cardiac tamponade**, are discussed. Major risk factors such as hypertension, atherosclerosis, advancing age, and male gender are elaborated, as well as lesser-known risks like connective tissue and aortic valvular diseases. Emphasizing the importance of early diagnosis and surgical intervention, we conclude with the vital recognition that the management of hypertension is a critical modifiable risk factor in preventing aortic dissection.

1. Introduction

The Aortic dissection occurs when blood tracks between the middle and outer thirds of the aortic media, creating a blood-filled channel within the aortic wall[1]. It is a rapidly progressing, life-threatening condition with high mortality rates despite recent advances in imaging and treatment.[1-3] Complications such as pericardial tamponade, myocardial infarction, malperfusion syndromes to vital organs, or frank exsanguination from aortic rupture usually cause rapid death. The most common risk factors linked to the development of aortic dissection are hypertension and atherosclerosis.[2,3] Other recognised risk factors include connective tissue diseases and aortic diseases such as infective and autoimmune aortitis, and degenerative or congenital aortic valvular disease. Advancing age and male gender have also been cited as risk factors for aortic disease.[1-5] Diagnosis of aortic dissection is challenging because of often non-specific clinical signs and symptoms. Common screening modalities such as chest radiographs appear normal in up to 40% of cases, and ECG findings are often unremarkable; therefore, a high index of

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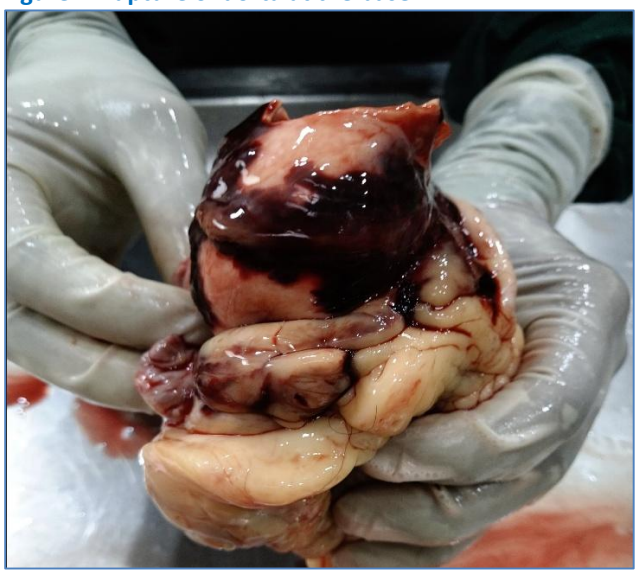
clinical suspicion remains essential for diagnosis.[6] Aortic dissection may also be seen as an artefact consequent to the embalming process.[7,8]

2. Case report

An 80-year-old female was brought dead to the casualty of a tertiary care center with a history of a fall at her residence. The decedent was referred for post-mortem examination. Medical records were not available at the time of autopsy. A verbal history of previous hypertensive disease was obtained from the next of kin. However, the decedent had refused any follow-up treatment for the past two decades. This scenario is common among the lower socio-economic class in the region. Once the police provided the inquest papers, the autopsy proceeded with minimal medical history.

External examination revealed a reddish-brown avulsed laceration on the left frontal aspect of the head, and abrasions on the left elbow and both knees. Internal examination showed extravasation of blood within and beneath the scalp tissue corresponding to the laceration. The brain demonstrated mild edema with a contusion on the frontal aspect. The pericardial space contained 250–300 g of clotted blood, indicating cardiac tamponade. Examination of the heart and aorta revealed rupture of the ascending aorta at its base (**Figure 1**).

Figure 1: rupture of aorta at the base.



Sections from the intimal tear in the aorta (located 1 cm from the aortic cusp and measuring 1.3 cm in length) showed atherosclerotic plaque and an intimal tear with blood dissecting through the tunica media (**Figure 2a, 2b**). The same area demonstrated mucoid extracellular matrix accumulation and focal replacement by hyalinized connective tissue. The tear extended into the adventitial connective tissue, resulting in vascular rupture and haemorrhage encasing the root of the aorta.

Figure 2a: Histopathology of aortic rupture showing tear through the intima.

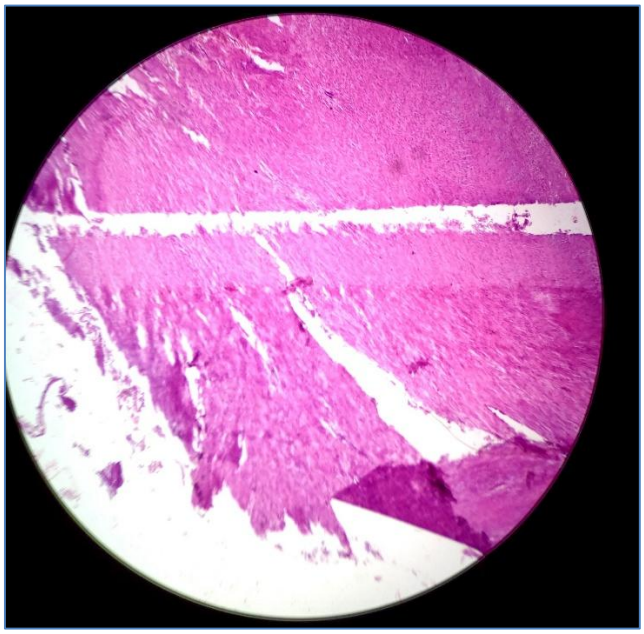
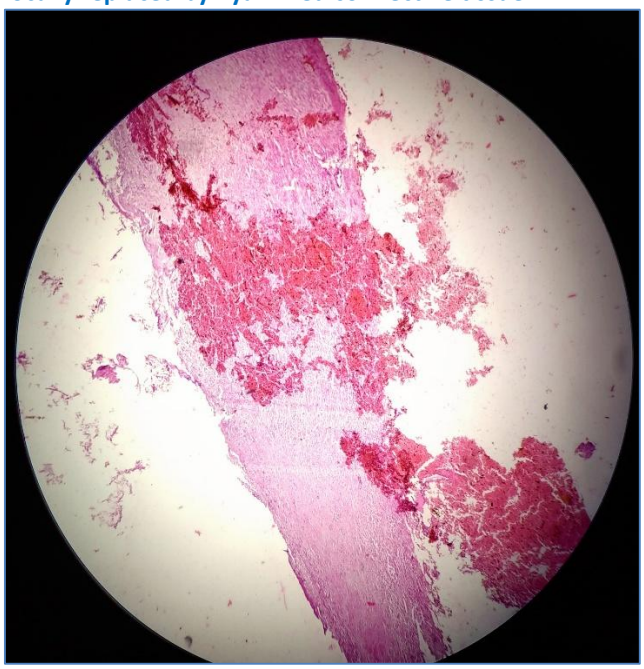


Figure 2b: Mucoid extracellular matrix accumulation focally replaced by hyalinized connective tissue.



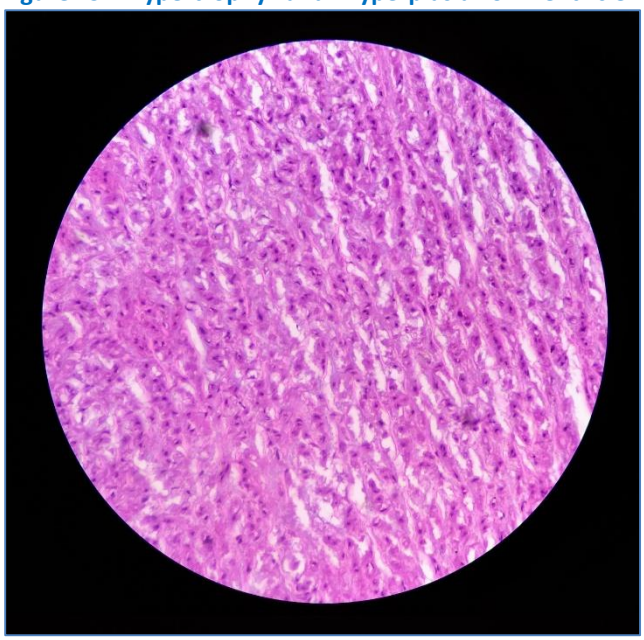
Atheromatous plaques were also present focally at the root of the aorta. Sections from the right and left ventricles showed hypertrophy and hyperplasia of cardiac muscle bundles (**Figure 3**).

No other remarkable findings were noted. The cause of death was certified as cardiac tamponade due to rupture of the root of the aorta consequent to aortic dissection.

3. Discussion

Cardiovascular diseases are one of the leading causes of death in India, surpassing the global average.[9-13] Among fatal vascular conditions, Acute Aortic Catastrophes (AAC) take precedence, consisting mainly of ruptured aneurysms and dissections.

Figure 3: Hypertrophy and hyperplasia of ventricle.



Aortic rupture–related AACs are relatively uncommon; however, they are serious disorders with a high fatality rate.[14] They are typically caused by ruptured aortic aneurysm or ruptured aortic dissection. A 27-year study reported an incidence of approximately 29 cases per million annually, with a mean age of 65.7 years (range: 36–97 years).[4] The present case involves an elderly female (80 years old) with ruptured aortic dissection.

Aortic dissection is classified into two types: type A and type B. Type A involves the ascending aorta, while type B involves the aorta distal to the left subclavian artery. This restricted form of aortic dissection frequently precedes aneurysm formation and late rupture and is usually associated with hypertension.[15]

Previous studies indicate that aortic atherosclerosis is a major risk factor (73% of cases) in the development of fatal aortic dissection.[2, 3] Plaque ulceration can cause intimal disruption, leading to the formation of a dissection plane. Systemic hypertension is also an important risk factor[2] (58% of cases[3]) and, like atherosclerosis, is modifiable. Approximately 11.9% of dissections are associated with an area of aneurysmal dilatation. Other contributing factors include connective tissue diseases (3.5% of cases) and cystic medial degeneration. In the present case, atherosclerotic plaque was found along with aortic dissection. Since no medical history was available at the time of autopsy, a correlation with hypertension could not be established.

A study by Suzuki et al. found that about 60% of aortic dissection cases go undiagnosed until a complete autopsy is performed.[5] The most common presentation of aortic dissection is cardiac tamponade. In fact, aortic dissection is the second most common cause of cardiac tamponade, after ruptured myocardial infarction.[16] Associated symptoms may include chest pain and syncope. Atypical presentations, such as hoarseness of voice, have been described but are rare.[17] In the present case, the aortic dissection ruptured at the root of the aorta, causing cardiac tamponade and resulting in death.

4. Conclusion

Ruptured aortic dissection represents one of the most lethal Acute Aortic Catastrophes, with elderly individuals at highest risk. Atherosclerosis and hypertension are the predominant predisposing factors, with additional contributions from structural and degenerative aortic conditions.

Despite advances in diagnostic imaging and surgical techniques, overall mortality remains high, particularly in cases presenting with cardiac tamponade. Rapid recognition and urgent surgical intervention offer the best chance of survival, yet prevention through risk factor control remains paramount. Hypertension, as the most significant modifiable factor, warrants targeted public health measures, early detection, and strict long-term management to reduce the burden of this fatal condition.

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