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Looking at Recent Evolution in Toxicology Through Legal Lens

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Introduction

Forensic toxicology is a branch of forensic medicine that deals with studying toxic substances and their effects on the human body. It has been essential to criminal investigations, offering important details regarding the cause and manner of death in cases that seem suspicious. Since ancient times, forensic toxicology has been employed to solve crimes involving poisons, narcotics, and other hazardous materials. Forensic toxicology became a separate scientific field in the 19th century due to Mathieu Orfila's groundbreaking work. By combining chemical and physiological techniques, he was able to identify toxins in blood, urine, and other body fluids, laying the groundwork for contemporary forensic toxicology. These techniques were quickly embraced by scientists, and forensic toxicology emerged as a crucial component of criminal investigations. Nowadays, forensic toxicology is widely used to aid in death investigations in civil and criminal matters related to the abuse of drugs.[1–3]

The interplay between toxicology and legal systems has become increasingly vital due to the rising complexity of environmental, pharmaceutical, and industrial challenges. This article explores the recent developments in toxicology through a legal perspective, focusing on both Indian and global contexts.[4,5]

The recent evolution of toxicology has significant implications when viewed through a legal lens. One notable area is the emergence of Behavioral Toxicology, which studies the impact of toxic substances on behavior and cognitive functions. This field has become crucial in legal cases, particularly in assessing the effects of toxins on mental states and behavior.[6,7]

On a global scale, organizations such as the World Health Organization (WHO) and the Organization for Economic Co-operation and Development (OECD) have contributed to international regulations for chemical safety. India, as a developing economy, has also adopted new legal standards to regulate toxic substances, driven by high-profile industrial disasters like the Bhopal Gas Tragedy.

Recent advances in criminal investigation have significantly impacted the way intoxication is evaluated and considered in criminal cases. Here are some key developments:

Forensic Toxicology

1. Improved analytical techniques: Advances in chromatography and mass spectrometry have enabled the detection of smaller amounts of substances, including drugs and poisons.
2. Increase in accuracy level: The reliability of toxicology reports has been enhanced due to advanced technologies. This aids in crime solving and justice delivery.
3. Better understanding of substance interactions: Research has improved our understanding of how different substances interact with each other and with the body.
4. Expanded toxicology panels: Modern toxicology panels can detect a wider range of substances, including novel psychoactive substances (NPS) and synthetic cannabinoids.

Investigative Techniques

1. Roadside testing: Portable devices can quickly detect the presence of certain substances, such as alcohol and cannabis, in drivers.
2. Oral fluid testing: Oral fluid testing can detect the use of recent substances at the workplace and roadside.

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3. Hair analysis: Hair analysis can provide a longer-term record of substance use, which can be useful in investigations.

Interpretation of Results

1. Toxicology expert testimony: Courts increasingly rely on expert testimony to interpret toxicology results and their relevance to the case.
2. Contextualizing results: Investigators consider the context in which substances were detected, including the presence of other substances, medical conditions, and environmental factors.
3. Addressing potential biases: Researchers and investigators strive to address potential biases in toxicology testing and interpretation.

Emerging Trends

1. Artificial intelligence (AI) in toxicology: AI is being explored for its potential to improve toxicology testing, including predicting substance interactions and identifying new substances.
2. Portable and point-of-care testing: Advances in portable and point-of-care testing are enabling faster and more convenient substance detection.
3. Increased focus on poly-substance use: As substance use patterns evolve, investigators are placing greater emphasis on detecting and interpreting poly-substance use.

Global Developments in Toxicology Laws

1. Chemical safety protocols and treaties: The Stockholm Convention on Persistent Organic Pollutants (POPs) has significantly influenced toxicology by mandating the elimination of harmful chemicals from industrial and agricultural processes.
   The Basel Convention regulates the transboundary movement of hazardous wastes, ensuring that toxic materials do not endanger public health.
2. Advances in risk assessment and regulation: The European Union's Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) has become a benchmark for chemical safety laws globally. REACH emphasizes pre-market testing and risk assessment, holding industries accountable for chemical safety.
   The United States has strengthened its Toxic Substances Control Act (TSCA) by incorporating high-throughput screening methods and computational toxicology tools.
3. Environmental justice movements: Globally, there is growing recognition of the disproportionate impact of toxic exposure on vulnerable populations. Legal cases in the United States and Europe have set precedents for compensating marginalized communities affected by industrial pollution.

Indian Context: Legal Evolution in Toxicology

1. Legislative responses to industrial disasters: The Bhopal Gas Tragedy (1984) remains a landmark event that catalyzed India's legal focus on toxicology. The enactment of the Environment Protection Act (1986) and the Public Liability Insurance Act (1991) introduced stringent norms for industrial safety and environmental protection.
2. Strengthening environmental jurisprudence: The National Green Tribunal (NGT), established in 2010, has played a crucial role in enforcing toxicology-related laws. Through judgments on industrial accidents and hazardous waste management, the NGT has integrated scientific principles into legal decisions.
   The "polluter pays" principle, recognized by Indian courts, has become instrumental in ensuring accountability for toxic releases.
3. Regulation of pesticides and pharmaceuticals: India, as one of the largest producers of pesticides, has faced criticism for inadequate regulation. The draft Pesticide Management Bill (2020) aims to replace outdated laws and incorporate modern risk assessment techniques.
   The Central Drugs Standard Control Organization (CDSCO) has tightened regulations on drug safety, especially after controversies surrounding adverse drug reactions.

Brain mapping, narcoanalysis, and other recent advances in neuroscience and technology are transforming the field of criminal investigation. Here are some key developments:

Brain Mapping

1. Functional magnetic resonance imaging (fMRI): fMRI can map brain activity, helping investigators understand cognitive processes and detect deception.
2. Electroencephalography (EEG): EEG measures electrical brain activity, which can be used to detect lies or identify memories.
3. Brain-computer interfaces (BCIs): BCIs enable people to control devices with their thoughts, potentially helping investigators communicate with witnesses or suspects who are unable to speak.

Narcoanalysis

1. Truth serums: Narcoanalysis involves the use of truth serums, such as sodium pentothal, to extract information from suspects.

2. Limitations and controversies: Narcoanalysis is not foolproof and can be influenced by various factors, including the suspect's mental state and the examiner's skills.

Recent Advances

1. AI and machine learning (ML): AI and ML can analyze large datasets, identify patterns, and predict behavior, aiding investigators in crime prediction and prevention.
2. Neuroimaging and neurophysiology: Advances in neuroimaging and neurophysiology enable investigators to better understand the neural basis of behavior, including aggression, violence, and deception.
3. Digital forensics: Digital forensics involves the analysis of digital evidence, such as computer logs, mobile device data, and social media activity, to aid in investigations.

Future Directions

1. Integration of neuroscience and technology: The integration of neuroscience and technology will continue to advance the field of criminal investigation.
2. Standardization and regulation: Standardization and regulation of brain mapping and narcoanalysis techniques are necessary to ensure their reliability and admissibility in court.
3. Addressing ethical concerns: Investigators must address ethical concerns surrounding the use of brain mapping and narcoanalysis, including issues related to consent, privacy, and potential misuse.

Recent Updates in Toxicology Legal Systems (2020–2024)

1. Global developments: REACH amendments (EU): Between 2020 and 2024, the EU expanded its list of restricted substances under REACH, focusing on endocrine disruptors and per- and polyfluoroalkyl substances (PFAS).
   Updated TSCA framework (US): The US Environmental Protection Agency (EPA) has implemented stricter evaluations for new chemicals and issued bans on certain asbestos-containing products.
   Minamata Convention Progress: Continued global efforts to phase out mercury use in industrial applications were achieved, with stricter reporting obligations enforced from 2022 onward.
2. Indian context: Draft chemicals (management and safety) rules (2020): This draft aims to regulate the import, manufacture, and storage of hazardous chemicals, providing a comprehensive framework similar to REACH.

Environmental Protection Act Amendments (2022): The amendments introduced provisions for real-time monitoring of industrial emissions and stronger penalties for non-compliance.
National Action Plan for Chemicals (2023): India launched this initiative to align its policies with global chemical safety standards, focusing on risk assessment and public health.
3. Nanotoxicology regulations: Global Initiatives: By 2024, countries like Canada and Japan introduced dedicated nanomaterial regulations, addressing gaps in existing laws. The New guidelines are issued by the OECD for nanotoxicity testing.
   India's Progress: Although still developing, India's Department of Science and Technology (DST) released a roadmap in 2021 to address safety concerns related to nanomaterials.
4. Pharmaceutical and pesticide regulation: Post-COVID-19 Frameworks: In response to the COVID-19 pandemic, international agencies prioritized the regulation of antiviral drugs and vaccines. India updated its pharmacovigilance guidelines in 2022 to improve the tracking of adverse drug reactions.
   Pesticide Management Bill Advances: Passed in 2021, the bill introduced stricter penalties for harmful pesticide use and promoted safer alternatives.
5. Digital toxicology and AI: Regulatory acceptance: Globally, AI-driven toxicology models gained regulatory acceptance. The European Medicines Agency (EMA) approved AI tools for preclinical toxicology studies in 2023.

India's role: India's AI policy draft (2023) highlighted the potential of AI in environmental monitoring and toxicology, urging collaboration between tech companies and regulatory bodies.

Forensic Toxicology Rules and Regulations in India

Forensic toxicology focuses on the application of toxicology principles in legal investigations, particularly in cases involving poisoning, substance abuse, and unexplained deaths. In India, forensic toxicology operates under several key legal frameworks:

1. BNSS and BNS guidelines: The biological and nanomaterial safety standards (BNSS) provide regulatory protocols for toxicological analysis of biological samples and nanomaterials.
2. BSA standards: The Biochemical Standards Act (BSA) ensures that forensic toxicology laboratories maintain high standards in analyzing biochemical evidence related to poisoning or drug abuse cases.
3. Drugs and Cosmetics Act, 1940: This act regulates the manufacture, sale, and distribution of drugs, ensuring that toxic substances are not misused.

4. Narcotic Drugs and Psychotropic Substances Act, 1985: It governs the control and regulation of narcotic drugs and psychotropic substances. It has given strict penalties for violations of the regulations.
5. Environment Protection Act, 1986: This act indirectly impacts forensic toxicology by regulating the discharge of hazardous substances into the environment, which can cause toxic exposure.
6. Standard operating procedures (SOPs): The Directorate of Forensic Science Services (DFSS) has established SOPs for the analysis of toxic substances in biological samples.

Emerging Trends in Legal Toxicology

1. Nanotoxicology and legal challenges: The rise of nanotechnology has introduced unique toxicological risks. Countries like the United States and members of the EU are developing specialized legal frameworks for nanomaterial safety. India is in its nascent stages, with limited policies addressing nano-specific toxicity.
2. Climate change and toxic exposure: The intersection of climate change and toxicology is a growing concern. Rising temperatures can amplify the effects of toxic substances, necessitating adaptive legal measures.
3. Digital and computational toxicology: The integration of AI and ML in toxicological studies is revolutionizing risk prediction. Legal frameworks must adapt to the use of these technologies in regulatory compliance.
4. Public participation and transparency: Globally, there is a shift toward involving the public in decision-making processes related to toxic substances. The Aarhus Convention in Europe also granted the right to access to information and participation.

In India, the Right to Information Act (2005) has empowered citizens to demand transparency in industrial and environmental matters.

Challenges and Future Directions

Despite progress, significant challenges remain in bridging the gap between toxicology and law:

1. Scientific uncertainty and legal ambiguity: The legal decision-making is always complicated due to scientific uncertainty in toxicological data. Courts must rely on expert opinions, which can vary widely.
2. Harmonization of standards: The lack of harmonized international standards for chemical safety poses challenges for global trade and compliance.
3. Resource constraints in developing countries: Countries like India face limitations in toxicological research infrastructure and enforcement capacity.

To address these issues, a collaborative approach involving scientists, policymakers, and legal experts is essential. Capacity building, investment in research, and public awareness campaigns can bridge existing gaps.

Discussion

Setting up a Clinical Forensic Medicine Unit (CFMU) that operates at the intersection of medicine and law, providing specialized services for legal and medical investigations, is the need of the hour for every hospital. These units are vital in handling cases such as sexual assault, domestic violence, workplace injuries, and unexplained deaths. These units should be equipped with tools for detailed forensic medical assessments, including colposcopes and injury documentation kits and a Toxicology Laboratory for real-time toxicological analysis with forensic medicine experts, toxicologists, and support staff trained in evidence collection and medico-legal documentation adhering to the BNSS, BNS, and BSA.

Challenges

Limited availability of trained professionals and standardized protocols.
Infrastructural gaps in rural areas affect timely evidence collection.

Conclusion

The evolution of toxicology through a legal lens reflects the dynamic interplay between science and society. While developed nations lead with advanced regulatory frameworks, India and other developing countries are making significant strides to address the complexities of modern toxicology. The integration of emerging scientific advancements, coupled with robust legal mechanisms, is pivotal in safeguarding public health and the environment. By fostering global collaboration and adopting cutting-edge tools, toxicology laws can better address the challenges of a rapidly changing world.

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Correlation Among Dental Age, Skeletal Age and Chronological Age in Children Aged 7–15 Years in the Punjabi Ethnic Population: A Retrospective Study

Hitika Gupta[1], Anshul Chaudhary[2] and Rajan Jairath[2]

Abstract

Chronological age (CA) may differ from dental or skeletal age, and its correlation becomes important in the evaluation of biological age. The present study aimed to evaluate the association of dental, skeletal, and CA in the 30 subjects of Punjabi Ethnic population aged between 7 and 15 years, using orthopantomogram and lateral cephalogram. All the seven teeth on the mandibular right side were assessed according to Demrijian's eight stages, while the Cervical Vertebral Maturation (CVM) Index was adopted for the assessment of skeletal maturity. The one-way analysis of variance (ANOVA) test and the Pearson significance (2-tailed) test were performed for statistical analysis. The results of the Pearson correlation analysis showed a moderate to significant correlation between CA and dental age (DA), as demonstrated by most other studies as well. The Pearson correlation significance analysis demonstrated significant positive correlations between tooth development stages and DA for specific teeth. The one-way ANOVA test showed no significant correlation between CA, DA, and CVM stages. The study suggests that specific teeth seem to show a significant relation with dental age; hence, further research needs to focus on individual tooth development stages. The cervical vertebral maturation method should not be considered for estimating biological maturity according to the present study.

Introduction

A knowledge of the optimum growth and progress patterns in patients is essential to maximize the accomplishment of orthodontic treatment and to recognize abnormal growth trends.[1] Dental age (DA) is of chief concern to the orthodontist while organizing the management of various forms of malocclusions in accordance with maxillo-facial growth. Chronological age (CA) is not precise to define developmental status; yet, CA is vital in the cases of a cadaver in sciences, a scandalous skepticism in jurisdictional practice and fostering for an orphan. The conception of physiological age depends on the amount of development of numerous tissue structures. Evidence advocates various biological ages comprising skeletal age, morphological age, secondary sex character age, as well as DA.[2] Biological age employs many indicators, for instance, structural, sexual, dental, and skeletal developmental deviations that are more specific individually.

Even though a substantial association amid skeletal changes and facial development may be observed during the stretch of puberty, the application of hand-wrist radiographs for the estimation of craniofacial growth was doubtful. Alterations in the form of cervical vertebrae have a connection with CA.[3] The Cervical Vertebrae Maturation (CVM) Index, in origin described by Lamparski, performed on the lateral cephalogram, has become a popular method to assess skeletal maturity.

Several studies have seen the correlations in these methods of age estimation worldwide in previous literature on different populations. A master chart was developed for the

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Punjabi ethnic population for the age group of 7–15 years for a study sample of 30 subjects (including boys and girls).

In the present study, we assessed the association of dental, skeletal, and CA in the children of the Punjabi ethnic population.

Materials and Methods

Study Design

It was a retrospective study with the sample size of 30 patients (15 boys and 15 girls) in the age group of 7–15 years, who were undergoing fixed orthodontic treatment.

Calculation of Sample Size

The sample size was calculated to be $n = 30$, using the formula; $n = [(Z\alpha + Z\beta)/C]$ 2 + 3, where $C = 0.5 *\ln[(1 + r)/(1 − r)]$, $Z\alpha$ is standard normal deviate at type 1 error, $\alpha = 0.05$, $Z\beta$ is standard normal deviate at type 2 error $\beta = 0.20$, and r is the correlation coefficient.

Selection Criteria

Inclusion Criteria

Patients of Punjabi origin, that is, patients whose three generations were residing in the Punjab:

1. Patients without any systemic diseases, those affecting normal growth and development of the bone and teeth (If all the subjects were healthy, that is, they are not suffering from any chronic diseases).
2. Patients that have no history of previous orthodontic treatment.
3. Patients with no congenital or acquired malformations of the skeletal or dental origin.
4. Good quality radiographs; both taken on the same day.

Exclusion Criteria

1. Patients with history of extracted teeth.
2. Patients with a history of orthodontic treatment.
3. If the patients were not healthy or on medication for any chronic diseases.

The medical history was collected from guardians of all eligible subjects.

Data Collection

Chronological age of these patients was assessed by knowing the exact date of birth and the date of radiographs.

All radiographic exposures were carried out at the Department of Oral Medicine and Radiology, Christian Dental College, Ludhiana. All the radiographs, including orthopantomogram (OPG) and lateral cephalograms, were assessed by two examiners, and both the examiners were blinded to the age or date of birth of the subjects at the time of assessment of developmental stage. No more than eight radiographs were analysed by the examiner at any session to prevent the examiner's fatigue, resulting in errors in measurement.

Dental Age Estimation

1. Calcification stages of all the seven teeth on right mandibular side were traced in the OPG and were rated following the written criteria and the tooth diagram for each stage (Stages A–H) as given in the New System of Dental Age Assessment[2] by Demrijian, Goldstein and Tanner.
2. This stage was converted to a score or numerical value as given in the tables (separately for boys and girls).
3. All these scores of seven individual teeth were summed up, and the maturity score was calculated.
4. This calculated maturity score was compared with score values given in the Demirjian chart (separate for boys and girls), and the corresponding DA was assessed.

Calculation of Skeletal Age

1. Cervical vertebrae maturation stages were assessed on lateral cephalogram of the same subjects.
2. Lower borders of C2, C3, and C4 were checked for the appearance of concavity or flatness and the overall shapes of C3 and C4.
3. Skeletal age was assessed by correlating the C2, C3, and C4 stages with the explanation and the diagrammatic representation given by Baccetti and McNamara.[3]

Data Management

Obtained values of CVM stages and dental maturity specific to the Punjabi ethnic population were recorded in a Microsoft Excel spreadsheet. The investigator was unaware of the birth dates until all figures into a Microsoft Excel spreadsheet.

Statistical Analysis

The results were analysed using Microsoft Excel and the Statistical Package for Software Science (SPSS, Version 20.0). Independent sample *t*-test was applied for CA and DA of both groups' boys and girls. The one-way analysis of variance (ANOVA) test was used to compare the CA and DA estimates and to clarify the association between the CA, DA, and CVM stages. The Pearson correlation significance (2-tailed) test was used to test the correlation between the CA and DA estimates, and to compare between the tooth development stages (TDSs) and DA.
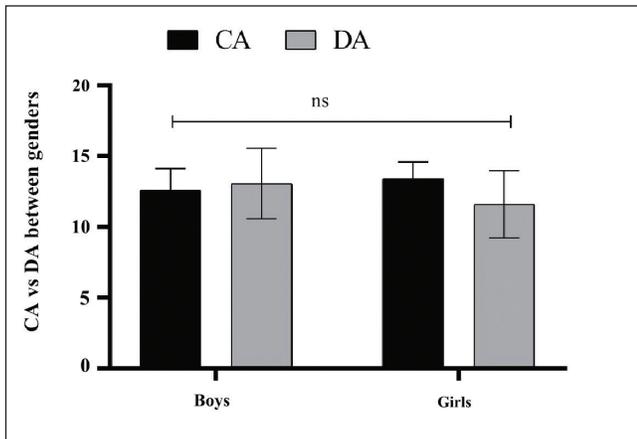
Figure 1. Figure Depicts Comparison of Chronological Age (CA) and Dental Age (DA) Between Genders. Data Were Expressed as Mean ± SD, Analysed by Two-way ANOVA, Followed by Tukey's Post-hoc Test (n = 15). $^{ns}P > .05$ Versus DA.

Results

Comparison of Chronological Age and Dental Age Between Genders

Analysing CA and DA values would help to determine whether gender has any effect on values of CA or DA. This would further help to find if CA and DA values vary across different genders. Independent sample *t*-test was performed to determine CA and DA between genders. Mean values of CA (12.59 ± 1.53 in boys and 13.41 ± 1.18 in girls) gave $P = .112$. Mean values of DA (13.05 ± 2.49 in boys and 11.59 ± 2.38 in girls) gave $P = .112$. No statistically significant difference was observed in means of CA and DA between genders (Figure 1).

Correlation Between Chronological Age and Cervical Vertebrae Maturation Stages

This analysis allows us to compare CA values across different CVM stages. This in turn helps to check the impact of CA on CVM stages. The mean values of CA for each CVM stage were as follows. Stage 1: 12.1989, Stage 2: 12.86, Stage 3: 13.1, Stage 4: 13.6429, and Stage 5: 13.62, with a mean value of 13.00 ± 1.41 (Table 1). For boys, the mean CA values for each CVM stage were as follows. Stage 1: 12.1989, Stage 2: 12.86, and Stage 3: 14.8 (Table 2). For girls, the mean CA values for each CVM stage were as follows. Stage 3: 12.5333, Stage 4: 13.6429, and Stage 5: 13.62 (Table 3).

The *P* values associated with the one-way ANOVA test were .252 (overall), .259 (boys), and .381 (girls), indicating that there was no significant difference in mean CA between the CVM stages.

Correlation Between Dental Age and Cervical Vertebrae Maturation Stages

The correlation between DA and CVM allows us to analyse DA trends across various CVM stages. That further helps to determine the attainment of DA in relation to CVM stages. The mean values of DA for each CVM stage were as follows. Stage 1: 12.9333, Stage 2: 12.72, Stage 3: 11.575, Stage 4: 11.7286, and Stage 5: 12.26, with a mean value of 12.32 ± 2.51 (Table 1). In boys, the mean DA values for each CVM stage were as follows. Stage 1: 12.9333, Stage 2: 12.72, and Stage 3: 15.8 (Table 2). In girls, the mean DA values for each CVM stage were as follows. Stage 3: 10.1667, Stage 4: 11.7286, and Stage 5: 12.26 (Table 3).

The *P* values associated with the one-way ANOVA test were .862 (overall), .551 (boys), and .581 (girls), indicating no significant difference between the CVM stages.

Correlation Between Chronological Age and Dental Age

This analysis permits us to check variations in DA in relation to CA and hence allows us to estimate DA in accordance with CA. The Pearson significance (2-tailed) test yielded the following *P* values: .009 for boys and .018 for girls (Table 4). The Pearson correlation analysis showed a coefficient of 0.650 for boys and 0.600 for girls, indicating a moderate positive correlation between CA and DA. As CA increases, DA tends to increase and vice versa.

Correlation Between Tooth Development Stages and Dental Age

The Pearson correlation significance (2-tailed) analysis was used to test the relationship between TDS and DA (Table 5). Such an analysis enables us to check the maturation of an individual tooth when compared to the overall DA. Any variation or anomaly in the individual tooth may be determined.

Among boys, the second molar (M2), second premolar (PM2), first premolar (PM1), canine (CN), and central incisor (I1) demonstrated significant positive correlations, whereas the first molar (M1), lateral incisor (I2), and DA did not show statistically significant correlations with DA. M2 showed a strong positive significant relationship (0.680), $P = .005$. M1 showed a weak positive nonsignificant relationship (0.400), $P = .140$. PM2 showed a strong positive significant relationship (0.666), $P = .007$. PM1 showed a positive strong significant relationship (0.654), $P = .008$. CN showed a strong positive significant association (0.758), $P = .001$. I2 showed a weak positive nonsignificant relationship (0.408), $P = .131$. I1 showed a moderately positive significant relationship (0.539), $P = .038$.

Table 1. Correlation of Chronological Age (CA) and Dental Age (DA) with Cervical Vertebrae Maturation (CVM) Stages Among Boys and Girls.

Cervical Vertebrae Maturation Stages		No. of Subjects	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
Chronological age (CA)	1	9	12.1989	1.76189	.58730	10.8446	13.5532
	2	5	12.8600	.59414	.26571	12.1223	13.5977
	3	4	13.1000	1.44453	.72226	10.8014	15.3986
	4	7	13.6429	1.24078	.46897	12.4953	14.7904
	5	5	13.6200	1.11669	.49940	12.2334	15.0066
	Total	30	13.0030	1.40761	.25699	12.4774	13.5286
P value				.252 (not significant)			
Dental age (DA)	1	9	12.9333	2.33399	.77800	11.1393	14.7274
	2	5	12.7200	2.96429	1.32567	9.0394	16.4006
	3	4	11.5750	3.27859	1.63930	6.3580	16.7920
	4	7	11.7286	2.98871	1.12963	8.9645	14.4927
	5	5	12.2600	1.51261	.67646	10.3818	14.1382
	Total	30	12.3233	2.50925	.45812	11.3864	13.2603
P value				.862 (not significant)			

Note: Test applied: one-way ANOVA (analysis of variance).

Table 2. Correlation of Chronological Age (CA) and Dental Age (DA) with Cervical Vertebrae Maturation (CVM) Stages Among Boys.

CVM Stages		No. of Subjects	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
CA	1	9	12.1989	1.76189	.58730	10.8446	13.5532
	2	5	12.8600	.59414	.26571	12.1223	13.5977
	3	1	14.8000	–	–	–	–
	Total	15	12.5927	1.53230	.39564	11.7441	13.4412
P value				.259 (not significant)			
DA	1	9	12.9333	2.33399	.77800	11.1393	14.7274
	2	5	12.7200	2.96429	1.32567	9.0394	16.4006
	3	1	15.8000	–	–	–	–
	Total	15	13.0533	2.49224	.64349	11.6732	14.4335
P value				.551 (not significant)			

Note: Test applied: one-way ANOVA.

Table 3. Correlation of Chronological Age (CA) and Dental Age (DA) with Cervical Vertebrae Maturation (CVM) Stages Among Girls.

CVM Stages		No. of Subjects	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
CA	3	3	12.5333	1.09697	.63333	9.8083	15.2583
	4	7	13.6429	1.24078	.46897	12.4953	14.7904
	5	5	13.6200	1.11669	.49940	12.2334	15.0066
	Total	15	13.4133	1.18132	.30502	12.7591	14.0675
P value				.381 (not significant)			
DA	3	3	10.1667	2.05508	1.18650	5.0616	15.2718
	4	7	11.7286	2.98871	1.12963	8.9645	14.4927
	5	5	12.2600	1.51261	.67646	10.3818	14.1382
	Total	15	11.5933	2.38521	.61586	10.2724	12.9142
P value				.581 (not significant)			

Note: Test applied: one-way ANOVA.

Table 4 . Correlation of Chronological Age (CA) with Dental Age (DA) Among Boys and Girls.

DA		Boys	Girls
CA	Pearson correlation	0.650	.600[*]
	Sig. (2-tailed)	0.009[*]	.018
	No. of subjects	15	15

Note: [*]Indicates the statistically significant correlation.

Table 5. Correlation of Tooth Development Stages with Dental Age (DA) Among Boys and Girls.

Dental Age		Boys	Girls
Molar 2	Pearson correlation	.680[**]	.211
	Sig. (2-tailed)	.005	.449
	No. of subjects	15	15
Molar 1	Pearson correlation	.400	[a]
	Sig. (2-tailed)	.140	–
	No. of subjects	15	15
Premolar 2	Pearson correlation	.666[**]	.471
	Sig. (2-tailed)	.007	.076
	No. of subjects	15	15
Premolar 1	Pearson correlation	.654[**]	.271
	Sig. (2-tailed)	.008	.328
	No. of subjects	15	15
Canine	Pearson correlation	.758[**]	.685[**]
	Sig. (2-tailed)	.001	.005
	No. of subjects	15	15
Lateral incisor	Pearson correlation	.408	.451
	Sig. (2-tailed)	.131	.092
	No. of subjects	15	15
Central incisor	Pearson correlation	.539[*]	.633[*]
	Sig. (2-tailed)	.038	.011
	No. of subjects	15	15

Notes:

[**]Correlation is significant at the 0.01 level (2-tailed).
[*]Correlation is significant at the 0.05 level (2-tailed).
[a]Cannot be computed because at least one of the variables is constant.

For girls, significant positive correlations were shown by CN and I1, while nonsignificant correlations were shown by M2, PM2, PM1, and I2. M1 could not be included in the analysis due to constant values. M2 exhibited a positive nonsignificant correlation of 0.211 ($P = .449$). PM2 showed a positive nonsignificant correlation of 0.471 ($P = .076$). PM1 showed a positive nonsignificant correlation of 0.271 ($P = .328$). CN showed a strong positive significant correlation of 0.685 ($P = .005$). I2 showed a positive nonsignificant correlation of 0.451 ($P = .092$). I1 showed a significant positive correlation of 0.633 ($P = .011$).

Discussion

The orthodontic treatment is significantly dependent on the patient's growth potential. Therefore, the determination of biological maturity becomes really important in planning orthodontic treatment. The assessment of DA allows us to check for expected dental development in relation to CA or skeletal development of the patient.

The Demirjian method evaluates the dental maturity score correlated with CA using sex-specific tables. This method is widely used due to its high reproducibility and relatively

simple application in clinical and research settings. The Baccetti and McNamara skeletal maturity system—a skeletal age assessment method—categorizes skeletal maturation into stages corresponding to different phases of pubertal growth based on peak growth velocity. This method helps in determining the optimal timing for intervention for orthodontics and dentofacial orthopedics. Both staging systems provide valuable insights into an individual's biological age and growth potential. Therefore, they are considered complementary tools in age estimation and treatment planning.

In the present study, the means of boys and girls were found to be similar, suggesting that gender does not accomplish a noteworthy effect on the CA and DA. The one-way ANOVA test between CA and CVM gave the P value of .259 in boys, .381 in girls, and .252 in the entire sample. The correlation between the DA and CVM gave the P value of .551 in boys, .581 in girls, and .862 in the entire sample. In accordance with the present study in the children of the Punjabi ethnic population, the correlation between the CA and CVM stages, as well as between the DA and CVM stages, is not statistically significant. In contrast, a study performed in the Romanian population[6] showed a significant correlation between the CA and CVM stages. A study in the French population[7] showed moderate statistically significant correlation between the DA and CVM stages ($R = 0.383$–0.618). A study showed dental development to be positively associated with bimaxillary growth. A Polish study found Spearman's correlation coefficient (Rho) positive, which indicates that ossification centers' development advances by age.[10] A report of the Sudanese population showed high significant correlations between CA, DA, and skeletal maturity.[11] A good agreement was shown between the CA and the hand-based skeletal ages. In a study conducted on patients from the National University of Mexico and the Federico Gómez Children's Hospital, statistically significant differences ($P < .05$) were found between DA, CA, and skeletal age.[17] Another study also showed the correlation between CVM stages and dental development stages to be highly significant. Optimized norms as applied on the Central European population showed increased precision in the evaluation of DA and skeletal age.[19] Another paper demonstrated the positive correlation between CA and CVM stages in each skeletal jaw relation. The study on the Kannur population of Kerala showed a good correlation between the DA and CA as 0.972 and between the CVM Index and CA as 0.919.[20] The Pearson correlation analysis showed a strong association between CA and DA ($r = 0.72$), CA and skeletal maturity ($r = 0.59$), and Skeletal maturity and DA ($r = 0.71$) in the North Indian population.[21] A systematic review disclosed a moderate to high statistically significant association of the CVM Index with other maturation methods. Similar to our results, the correlation coefficient between the CVM stages and CA came out to be relatively low ($r = 0.62$) in the Iranian female population.[12] Dental age showed a weak correlation with skeletal age (0.1) in Guatemalan boys.[25] These results indicate that CVM stages may not be reliable

indicators of CA or DA. Additional factors need to be considered to advance the accuracy of age estimation approaches in orthodontic practice. These findings highlight the need for further research and the consideration of additional factors to improve age estimation methods in orthodontics.

Our study demonstrated a positive correlation between CA and DA in both boys and girls. The moderate positive association of 0.650 observed in boys and the significant correlation coefficient ($P = .009$) observed in girls further validate the utility of this method. These results align with the previous research in this area. The DA calculated by the London Atlas ($P = .148$) represented no variation between estimated DA and CA in the London Atlas.[4] The study by Tunç et al.[5] showed that the calculated DA using Dutch, French-Canadian, and Belgian values stood statistically significantly higher when linked to CA. A comparison of CA and DA gave an overestimation on applying the Demirjian method for both boys ($R^2 = 20.7\%$) and girls ($R^2 = 21.3\%$) in Portuguese, Spanish children, and adolescents.[8] A positive correlation was observed amid CA and DA (correlation coefficient 0.848; $P < .001$) in the Spanish pediatric population.[9] Another paper demonstrated a strong correlation amongst age and third-molar development in Turkish male ($R^2 = 0.61$) and female ($R^2 = 0.63$) children in the southwest Eastern Anatolia region.[13] Compared to the Demirjian method, the Cameriere European formula exhibited the greatest precision in DA calculation in Croatian children, following the Haavikko and Willems formula.[14] The standard error rate for the Indian population[15] through the Demirjian method came out to be ± 1.17 for male subjects and ± 1.6 for female subjects for the mandibular arch. The DA estimated from the digital OPG using Demirjian's method and Willem's method had revealed great accuracy in the children of Faridabad.[16] The study on the Dakshina Kannada population of South India showed the correlation coefficient values of 0.71 in males and 0.82 in females, showing a significant correlation between DA and CA.[18] A study performed on the Brazilian population showed overrating of Demirjian's method, which remained statistically significant ($P < .001$).[22] The Egyptian-specific formula reduced the lag among CA and DA; hence, a virtual estimated age was calculated.[23] Machine learning systems based on Cameriere's maturation stages gave additional precise results in approximating DA, whereas in Mexican patients,[17] a very weak association was found between CA and DA ($r^2 = .63$). The malnourished cohorts of low socioeconomic status Mayas and Ladinos were significantly deferred in dental maturation when equated to the well-fed Ladino subjects.[25]

From the results of the present study, the M2, PM2, PM1, CN, and I1 showed a strong relation with DA among the boys. The CN and I1 showed a strong relation with DA among girls. The results of the Portuguese and Spanish population using R^2 coefficient showed the most significant teeth to be the CN, PM2, and M2.[8] A study amid calcification stages of mandibular CN and skeletal maturity showed significant correlation coefficients of 0.895 for the male and 0.701 for the female

population. A method was developed to estimate the accurate DA for modern Japanese children and adolescents.[24]

These findings support the potential use of DA estimation as an adjunctive method for age assessment. The significant correlations observed for certain teeth support the fact that some TDSs can serve as reliable markers for assessing DA. Teeth seem to be a valuable development guide since they are usually not modified by exogenous influences, including disease. However, not all TDSs showed significant correlations, which indicates that relying solely on tooth development may not provide accurate estimates of DA.[26] Factors such as dental development variations and individual differences can influence the accuracy of DA estimation. Note that DA estimation should be applied as a supplementary tool rather than a stand-alone method[27] for age assessment. Dental age combined with other age assessment techniques, such as skeletal age assessment[28] or anthropological methods, would provide a more comprehensive and accurate estimation of an individual's age. However, further research with larger and more diverse samples on individual tooth development assessment is necessary to validate these results and establish standardized protocols for DA estimation in clinical and forensic settings.

Conclusion

Dental development assessed by Demirjian's method may be used for assessing biological maturity, though further research on individual tooth stages may be necessary. On the other hand, CVM stages may not be relied on for assessing skeletal maturity.

Implications

1. It will be a practical application of methods that have been taught to the students in theory.
2. Easy for the student to determine and correlate the age of the patients.
3. The fallouts will be of help for diagnosing, and for planning treatment for orthodontic, pediatric patients and forensic dentistry.

Data Availability Statement

Data have been provided within the article. Further queries may be submitted to the corresponding author.

Declaration of Conflicting Interests

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

Ethical Approval

Ethical approval was obtained from the Ethical and Research Committee of the Institute, Min no. CDC/ERC/2022/33.

Informed Consent

Consent was obtained from patients' guardians (since the population under study is less than 18 years of age).

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Sexing the Mastoid Region: A Validation Study Evaluating the Effect of Sample Size on Classification Accuracy in Forensic Anthropological Cases

Vineeta Saini[1]

Abstract

Establishing the sex of an unidentified cranium is foremost steps toward its biological profiling. Recent studies on sex estimation using small sample sizes (some even used as small as 50) from anatomy departments claim high accuracy rates, prompting validation efforts. This study focuses on validating such claims and establishing discriminant functions for North Indian populations, particularly in the mastoid region. In a previous study by the author on North Indians, the mastoid region provided very high accuracy (87%) using just two variables, asterion-mastoidale (Ast-Ms) and mastoid breadth. Then the author tried to validate the results of the previous study with increased samples of 158 (M/F: 110:48 females, age 18–70 years) crania using discriminant function analysis and receiver operating curve analysis (ROC).

The highest sex classification accuracy reached up to 79.7% using multivariate discriminant analysis. It is observed that the same variables, that is, Ast-Ms and mastoid breadth couldn't be too discriminating and were not selected in the stepwise analysis. This difference in classification accuracy simply shows the biological variability in a population. However, in ROC analysis, the variables Ast-Ms (area under the curve [AUC] = 0.803) provided an accuracy of 78.48%. By considering sample size, investigators may limit the chance of reporting false-negative or false-positive findings with larger sample sizes, which in turn produce more accurate results. In essence, while smaller studies may boast high accuracy, validation with larger samples is essential. Moreover, utilizing diverse statistical methods ensures robustness in variable selection for forensic applications.

Introduction

In recent years, man-made, natural disasters, and criminal methods of hiding the identity of the deceased have fetched an immense role for forensic anthropologists and odontologists in the identification of unknown and unidentified bodies or skeletal remains. At the very basic level, they use biological profiling, which includes the sex, age, stature, and racial affinity of the unknown. These preliminary methods shortlist the possible matches by narrowing the vast number of victims. For biological profiling, sex estimation is the starting point. A correct and objective sex assessment of skeletal remains will likely reduce the possible victim matches by 50%, thus reducing the time, efforts, and money of the investigating authorities by half. Further, it ensures a correct evaluation of age, stature, and ancestry, as these variables are highly sex-dependent and may simultaneously serve as foundational data for identification methods such as facial reconstruction.[1–3] Further, the correct estimation of sex is also imperative from bioarcheological, anatomical, and forensic perspectives.

Among human skeletal parts, the skull is considered highly dimorphic. In cranial sex indicators, the metric and visually assessed methods of the mastoid region are well documented.[4–6] Its compact structure and anatomical

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position make it more protected and resistant to damage. The mastoid process typically remains intact and is generally more robust in males.[7] Hoshi[8] sexed Japanese skulls based on three shapes of the mastoid process, that is, male (M), neutral (N), and female (F). Because male mastoid processes (M) are longer, the skull rests on them. In females, the shorter height of the mastoid process causes the skull to rest on the occipital condyles when placed on a flat surface. In the last four decades, several research studies have explored the sexual differences in the mastoid region using various qualitative and quantitative methods in different populations around the world.[9,10–20] Garvin et al.[5] and Sinhorini et al.[21] examined the different areas of the cranium for sexual dimorphic ability and found the mastoid area to be most dimorphic, pointing out the limitation of the small sample size in their studies. The relative cranial robustness and gracility of different sexually dimorphic traits vary by population due to obvious genetic and environmental changes.[22] These variations require the osteometric standards to be population specific and updated.[11,23–26]

The reliability and accuracy of sex determination depend on the skeletal assemblage and exposure conditions, the age of the subject, intrinsic variability, the method applied, and the specific population being examined.[10,27,28] Along with these criteria, the reliability of a discriminant function also depends on the number of samples included in the particular study. Metric variables are a noninvasive, low-cost, and suitable method for evaluating sexual differences, stature estimation, age estimation, and racial/population variation, as well as to denote secular/temporal changes. Nevertheless, metric methods are susceptible to error, which can happen due to an insufficient number of samples. Therefore, the primary objective of the current research is to validate the sex-differentiating capability of the mastoid region and to establish latest sex discriminant functions for assessment in cases involving fragmentary crania. The second aim is to deduce the consequences of the sample size on the selection of variables in discriminant function analysis (DFA).

Materials and Methods

To precisely determine the impact of sample size on discriminant formulas, the author conducted a critical assessment of a previous study,[7] which utilized a sample of 138 crania from the North Indian population to estimate sex using the mastoid region. This study included a total of 158 crania (M/F: 110:48, age: 18–70 years) collected in the Department of Forensic Medicine, Institute of Medical Sciences, Banaras Hindu University, Varanasi from January 2007 to January 2011. The crania were collected from the unclaimed bodies as donated to the Department of Forensic Medicine & Toxicology and Department of Anatomy (The Uttar Pradesh Anatomy Act, 1956- The Anatomy Act, enacted by various states in India, mandates the provision of unclaimed bodies to medical and teaching institutions for anatomical examination, dissection,

and related purposes. These cadavers are typically unclaimed bodies acquired by the police).

A total of eight variables were measured using a sliding caliper (0.05 mm precision). Each measurement was taken three times on the left side of crania, and the average values were used for the analysis. The measurements, mastoid length (ML), mastoid breadth (MB), asterion-porion (Ast-Po), posterior end of incisura mastoidea-depression of suprameatal triangle (PEIM-DSMT), posterior end of incisura mastoidea-porion (PEIM-Po), asterion-depression of supra meatal triangle (Ast-DSMT), asterion-mastoidale (Ast-Ms), mastoidale-porion mastoid height (Ms-Po), were taken as described in the previous study.[7]

Statistical Analysis

Statistical analysis was conducted using SPSS 20.0. A *t*-test is used to compare male and female measurements. The intraobserver error was assessed using the paired *t*-test. DFA and receiver operating characteristic (ROC) analysis[7,20] were utilized to examine the degree of sexual dimorphism and the accuracy percentage for each measurement. In DFA, stepwise analysis was followed by direct discriminant analysis to derive specific discriminant formulas aimed at achieving maximum accuracy. Then the mean values, *t*-values, *P* values, and classification accuracies were compared with the previous study, which provided very promising results in a comparatively smaller sample size (total: 138; M: F-104:34).[7]

Results

Table 1 provides descriptive statistics for the small[7] and large (current) samples with *t*-test and *P* values. Males showed significantly larger dimensions than females. It can also be noticed that the standard deviation has slightly decreased after the addition of the samples. Further, it can be deduced from the table that the *t*-values are considerably decreased after the addition of the sample, particularly in the case of MB.

Table 2 shows the findings of intraobserver error. The correlation values show a substantial association between the measures recorded in the first and second occurrences. The *P* values demonstrate that there is no significant difference between the two measurements.

Table 3 shows the result of the stepwise analysis. Wilks' lambda is a measure of how effectively each variable performs in a function to separate cases into groups. The score of Wilks' lambda lies between 0 and 1, where the lesser values close to 0 indicate a higher capacity for discrimination by the function.

Table 4 provides the results of canonical discriminant functions and sex classification accuracies for small and large sample sizes. It is obvious from the table that the functions are very different for a small and large sample. The single variable Ast-Ms is selected in stepwise analysis in both sample groups. Ast-Ms was also selected as the best variable in

Table 1. Descriptive Statistics of Measurements of Mastoid Region (mm), *t*-test and Significance of Differences Between Small and Large Samples.

Variables	Males		Female		t-value		Sig. (Two Tailed)	
	Small Sample# (*n* = 104)	Large Sample (*n* = 110)	Small Sample# (*n* = 34)	Large Sample (*n* = 48)	Small Sample#	Large Sample	Small Sample#	Large Sample
ML	35.82 ± 3.56	33.67 ± 3.16	31.87 ± 3.32	31.21 ± 3.3	5.714	3.536	.000***	.001***
MB	25.58 ± 1.90	23.31 ± 1.78	22.77 ± 2.37	21.93 ± 2.09	7.035	2.824	.000***	.005**
Ast-Po	47.89 ± 3.17	47.59 ± 3.11	44.70 ± 3.75	44.83 ± 3.38	4.869	4.993	.000***	.000***
PEIM-DSMT	28.02 ± 2.42	28.25 ± 2.21	24.95 ± 2.41	25.31 ± 2.31	6.433	5.476	.000***	.000***
PEIM-Po	35.58 ± 2.69	33.98 ± 2.61	31.69 ± 3.10	31.64 ± 2.79	7.058	3.603	.000***	.000***
Ast-DSMT	41.05 ± 3.01	41.15 ± 2.87	38.26 ± 3.52	38.42 ± 2.97	4.500	5.421	.000***	.000***
Ast-Ms	47.84 ± 4.07	48.35 ± 3.72	43.00 ± 4.32	43.88 ± 4.09	5.924	6.736	.000***	.000***
Ms-po	31.78 ± 3.08	31.75 ± 3.00	27.99 ± 3.47	29.35 ± 3.29	6.036	4.489	.000***	.000***

Notes: **P* < .05 Significant, ***P* < .01 Moderate significant, ****P* < .001 Highly significant.
#Values taken from Saini et al. (2012).

Table 2. Results of Paired *t*-test (Intraobserver Error).

Variables	Correlation	Sig (Two tailed)	t-values
ML	.978	.172	−1.38
MB	.970	.681	−.413
Ast-Po	.993	.879	−.152
PEIM-DSMT	.948	.985	.133
PEIM-Po	.993	.033	−2.180
Ast-DSMT	.994	.305	1.033
Ast-Ms	.995	.258	−1.142
Ms-po	.985	.298	1.050

Table 3. Result of Stepwise Discriminant Analysis for Small and Large Samples.

Step Variable Entered	Wilk's Lambda	Equivalent *f*-Ratio	Degrees of Freedom
Small Sample (*n* = 138)#			
Ast-Ms	.643	37.468	2,135
MB	.589	31.211	3,134
Large Sample (*n* = 158)			
Ast-Ms	.775	45.377	1,158
PEIM-DSMT	.699	33.399	2,157

Note: #Values taken from Saini et al. (2012).

Table 4. Canonical Discriminant Function Coefficients for Stepwise and Direct Analysis with Correct Prediction Accuracies for Small and Large Samples.

Function and Variables	Raw Coefficient	Standardize Coefficient	Structure Matrix	Centroids	Prediction Accuracy %		
					Males	Females	Overall
Small Sample#							
*F1 MB	.391	.792	.730	M = 0.469	92.3	70.6	87.0
Ast-Ms	.166	.686	.615	F = −1.435			
(Constant)	−17.49			SP = −0.483			
F3 Ast-Ms	.242	I	I	M = .288	75.0	76.5	75.4
(Constant)	−11.291			F = −.882			
				SP = −0.297			
Large Sample							
*F1 Ast-Ms	.195	.750	.822	M = .431	72.7	66.7	70.9
PEIM-DSMT	.185	.575	.668	F = −.987			
(Constant)	−14.250			SP = −0.278			
F2 Ast-Ms	.260	I	I	M=.354	76.4	79.2	77.2
(Constant)	−12.235			F = −.811			
				SP = −0.229			
F3 Ast-Ms	.229	.880	.848	M = .417	83.6	75.0	79.7
Ms-Po	.235	.726	.565	F = −.957			
ML	−.140	−.560	.445	SP = −0.270			
MB	.093	.262	.356				
(Constant)	−15.565						

Notes: *Selected in stepwise analysis.
#Values taken from Saini et al. (2012).

Table 5. Correct Classification Percentages for Males, Females and Overall Accuracy (%) After Cross Validation.

Variables	Correctly Identified Small Sample#			Correctly Identified Large Sample			% Decrease and Increase
	Males (*n* = 104)	Females (*n* = 34)	Overall Accuracy	Males (*n* = 110)	Females (*n* = 48)	Overall Accuracy	
ML	75.0	64.7	72.46	63.6	66.7	64.6	−7.86
MB	75.0	70.6	73.91	60.0	54.2	58.2	−15.71
Ast-Po	73.1	70.6	72.46	72.7	75.0	73.4	+2.54
PEIM-DSMT	69.2	76.5	71.01	63.6	75.0	67.1	−3.91
PEIM-Po	73.1	64.7	71.91	63.6	62.5	63.3	−8.61
Ast-DSMT	69.2	64.7	68.11	70.9	66.7	69.6	+1.49
Ast-Ms	75.0	76.5	75.36	76.4	79.2	77.2	+1.84
Ms-Po	71.2	64.7	69.56	69.1	75.0	70.9	+1.34

Note: #Values taken from Saini et al. (2012).

Table 6. ROC Analysis and Correct Sex Classification Accuracy for Mastoid Region Measurements of Contemporary Samples.

Variables	Cutoff Value	AUC	Sensitivity	Specificity	Identified Males (*n* = 110) %	Identified Females (*n* = 48) %	Average Accuracy (*n* = 158) %
ML	32.196	.668	65.5	66.7	65.45	66.67	65.82
MB	22.400	.623	63.6	54.2	63.64	54.17	60.76
Ast-Po	46.186	.734	72.7	75.0	72.73	75.00	73.42
PEIM-DSMT	25.928	.766	81.8	70.8	81.82	70.83	78.48
PEIM- Po	32.929	.672	63.6	66.7	63.64	66.67	64.56
Ast- DSMT	39.321	.756	76.4	66.7	76.36	66.67	73.42
Ast-Ms	45.621	.803	78.2	79.2	78.18	79.17	78.48
Ms-Po	30.571	.703	69.1	75.0	69.09	75.00	70.89

both small and large samples, providing accuracies of 75.4% and 77.2%, respectively. After trying various combinations of variables in direction analysis, the sex classification accuracy didn't increase above 79.7%, that is, about 7.3% less in comparison to the small sample.

Table 5 provides the correct sex classification accuracy for both sample groups. In both groups, the Ast-Ms emerged as the best variable, providing an accuracy of 75.36% and 77.2% in the small and large samples, respectively.

Table 6 shows the outcome of the ROC analysis, which clearly depicts that the classification accuracy reached up to 78.48% for two variables separately. A comparative graph also shows the sexing accuracy obtained by DFA and ROC (Figure 1).

Discussion

Effect of Sample Size on Sexing Accuracy

One of the primary goals of the current investigation was to determine the influence of sample size, which is elaborated by the results obtained for the small[7] and large samples

(current study). A sufficient number of samples is considered essential to quality research. Awareness of population-specific anthropological standards has grown, leading to more forensic research across diverse groups. However, sample sizes for Indian populations (dominantly Hindus) remain limited due to cremation practices and religious beliefs. During the literature review, the author came across various anthropological studies where small samples (<100) were used to create a sex discriminant function.[29–31]

In forensic anthropometry, sample size (*n*) is the number of individual/bones utilized to collect data and to calculate a set of statistics. Andrade[32] and Zamboni[33] emphasized the importance of a larger sample size. A bigger sample helps investigators to generate more precise average values, uncover outliers that might bias the results in a smaller sample, and give a narrower range of error.[33] The findings demonstrated significant sexual dimorphism in the mastoid region's size, establishing its relevance as a sex predictor in the North Indian population. But sample size plays a very crucial role in deciding the classification accuracy, as shown by the comparison of results with the previous study on the same population and sample.
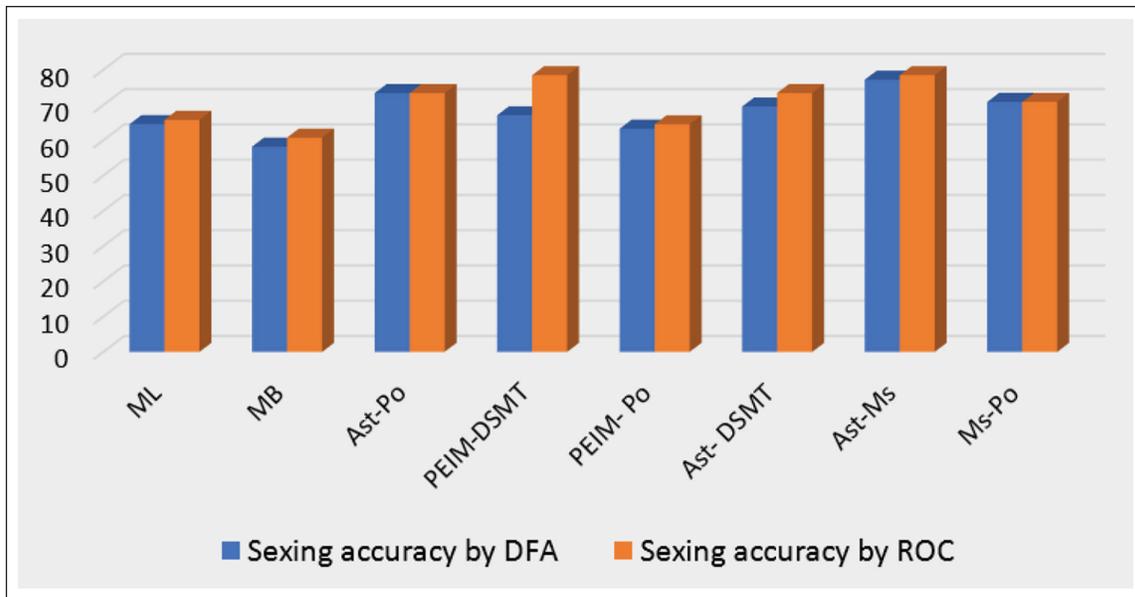
Figure 1. A Comparative Difference in Sexing Accuracy Using Two Statistical Methods.

Source: The bar graph shows the comparison of sex classification accuracies obtained by Discriminant Function analysis and ROC Analysis in contemporary (Large).

A larger sample size more closely estimates population variation. The standard error (which measures the degree of sampling variability) is greater where a sampling size is smaller, and vice versa. So, when the sample size is small, it can be difficult to see a difference between the sample mean and the population mean because too much sampling variability draws the wrong conclusions. If the sample size is large, it is easier to see a difference between the sample mean and the population mean because the sampling variability is not obscuring the difference (http://web.pdx.edu/~newsomj/pa551/lecture4.htm). A positive correlation exists between the sample size and confidence in our estimation. Ultimately, an upsurge in sample size reduces ambiguity and increases confidence in our estimate, which brings high accuracy and meticulousness. These days several online sample calculators are available to ascertain the exact number of samples to be included in the anthropological studies. Additionally, two different statistical approaches (DFA and ROC in this study) may be used to check the reliability of that particular variable in sex discrimination (Table 6).

Inter- and Intra-population Variability in Expression of Cranial Traits, Landmarks, and Measurements and its Effect on Sexing Accuracy

The second aim of the study was to provide discriminant functions that could be used in a forensic scenario. All parameters of the mastoid region were unconventional and new (except Ms-Po). In the small sample, MB and Ast-Ms were selected in stepwise analysis and provided an accuracy of 87%. Upon the addition of more samples, the mean and

t-values changed considerably. Particularly in the cases of MB, PEIM-Po, and ML (Table 1), a decrease in sexing accuracy was reflected as 15.71%, 8.61%, and 7.86%, respectively (Table 5). This resulted in the selection of other variables (PEIM-DSMT and Ast-Ms) in the stepwise analysis (excluding MB) (Table 4) and an overall decreased discrimination of male and female crania in the large sample (Table 5). The only thing constant in both studies was the best variable, that is, Ast-Ms (Table 5). Franklin et al.[34] achieved sexing accuracy up to 95% in a pilot study (40 samples), but when the sample size increased in a subsequent study,[35] the sexing accuracy decreased to 84%. Overall, in this study, direct analysis provided the best separation of sexes (79.7%) by the combination of Ast-Ms, MHt, MLt, and MBr.

Nagaoka et al.[17] found "Asterion" to be the most unreliable landmark, and they attributed the complexity of lambdoid sutures to this unreliability of the position of Asterion. Some earlier anatomical and clinical/neurological studies on 'Asterion' and 'Porion' noticed the location of this landmark fluctuates with age in a population-specific way.[13,29,36–39] However, the above statement could be valid for all craniometric landmarks and measurements, as each population differs from the other. Lesciottoa and Doershuka[40] observed a negligible effect of ageing on the mastoid region and other nonmetric traits, which was validated by Tallman.[41] In this investigation, it was found that once the "Asterion" is identified correctly, it shows almost identical sexing accuracy (slightly increased after the addition of a sample) (Table 5). The variation in accuracy found among groups may be explained by population-specific changes in landmark forms and sample heterogeneity.

Discrimination Ability of Different Mastoid Region Variables in Different Populations

It has been observed that the most dimorphic quantitative variables of the mastoid process also differ among population groups. The current investigation yielded greater sexing accuracies than other groups, including Germans and Portuguese,[13] Brazilians[9,16] and American Whites.[42,43] However, Nagaoka et al.[17] in their study on the Japanese population revealed exceptionally high sexing accuracies (92%) from a combination of mastoid height and width together,[17] but it is futile for a contemporary forensic sample as they used an archaeological sample of the twelfth and fourteenth centuries, which comprised only 50 males and 37 females without documented sex and age. The variable mastoid height (Ms-Po), that was shown to be significantly dimorphic and highly discriminating in their investigation,[17] has provided an accuracy of only 70.9% in this study. Manoonpol and Plakornkul[18] used linear discriminant analysis on 60 males and 40 females' skull samples from the Thai population. They achieved the highest accuracy (76.90%) with Ms-As. Jaja et al. examined the cephalograms of 102 Nigerians for 3 measurements of the mastoid region with the area, and they found this region unreliable for forensic work as the highest accuracy, merely 65%, was obtained for the variable Ast-Ms distance.[44] Madadin et al. investigated 206 computed tomography (CT) scans from the Saudi population to estimate sex, and Ms-Po was the most effective variable, with a 69.4% accuracy.[45] Recently, Ibrahim et al. studied sexual differences in a sufficiently large Malaysian sample using CT scan data and found the area of the mastoid triangle to be the best discriminator of sex (84% sexing accuracy).[46] Nikita and Michopoulou[47] used a different approach and found that the mastoid process had relatively acceptable outcomes, with a correct sexing accuracy of 74.5% for pooled sexes. Toneva et al.[48] also observed the CT scans of the Bulgarian population and found high classification accuracies in test samples for mastoid measurements, that is, 88.1% for left Po-Ms, 78.6% for Ms-Ast, and 83.3% for Po-Ast, which are the highest in the contemporary sample. In the above studies, some researchers used archaeological samples, some used CT scans or cephalograms, and some used dry crania, which may also be attributed to differences in classification accuracy.

Apart from genetic variation, several other nongenetic factors influence the degree of sexual dimorphism in the human skull. Nongenetic factors encompass both local traditions and environmental elements that influence growth and development such as diet, physical activity, lifestyle, and health. Further, studies have shown that late-growing regions that increase slowly, for example, the mastoid region, show high sexual dimorphism at maturity.[12,49,50] The mastoid process is absent in the newborn skull and begins to develop after the first year[51] due to the development and pull of the muscles attached to it.[42] It reaches its final adult size by late adolescence[52] and it extends inferiorly, slightly interiorly, and somewhat medially in the exact direction of pull of the group of muscles, mainly the sternocleidomastoid, splenius capitis (the posterior belly of the digastric muscle), and longissimus capitis.[12,53] Greater development of the mastoid process in males is due to the longer duration of growth, the attachment of muscles over a larger area, and comparatively stronger muscle forces.[7] Petaros et al.[54] presented an elaborated review and put their viewpoint on the different methodologies and measurements employed in sex identification from the mastoid process. Further, they suggested in the terminology of mastoid variables that distance measurements should be denoted by the endpoints employed during the measurement (e.g., distance asterion-porion; distance Ast-Ms), thereby avoiding the terms like mastoid length and height, which are confusing to understand.

As demonstrated in this study, an increase in the sample size may undermine or increase the sex classification accuracy, as may a change in the selection of the best variable. As a result, it is extremely desirable to design sex evaluation criteria that are suited to certain demographic groupings. These criteria will be determined by the exact placement of anatomical landmarks as well as the level of sexual dimorphism in the examined population. In these terms, the precise and accurate localization of the landmarks is of prime significance and a more important precondition for seeking sex differences and assessing the degree of sexual dimorphism in a population. Even in the same population after adding more samples, biological variability in different landmarks may be so obvious that it may lead to a very different level of sexual dimorphism, as shown in this study (Tables 4 and 5).

In conclusion, the current research met the demand for discriminant functions based on the mastoid process and demonstrated the significance of an abundant sample size in forensic anthropological investigations. However, some limitations of the present studies are also acknowledged, including unequal male and female samples, which are common in forensic collections all over the world due to the lesser involvement of females in outdoor activities.

Informed Consent

Not applicable.

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Estimation of Age from Fusion of Cranial Sutures by Computerized Tomography (CT) Examination

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Abstract

Age estimation plays a critical role in forensic identification, particularly for legal and administrative purposes. Traditionally, age estimation relied on visual examination of cranial sutures, but modern radiological imaging techniques like computerized tomography (CT) scans have enhanced accuracy. This study aimed to assess cranial suture obliteration using a seven-stage scoring system on CT scans to estimate age in the Indian population. A total of 141 subjects were analyzed, and regression models were created for males, females, and the total population. The study found a significant correlation between chronological age and cranial suture oblite ration, with better prediction accuracy in females. Comparison with previous studies showed promising results, although caution is advised in using these models as standalone methods due to their relatively large standard error estimate (SEE). Further research is warranted to refine age estimation techniques from cranial sutures across diverse populations.

Introduction

Age estimation is a crucial aspect of forensic identification. Until the age of 25, accurate estimation within a range of one year on either side is feasible through radiological assessment of secondary centers of epiphyses and dental examination.[1,2] This precision is essential for various legal, medical, social, and administrative matters concerning elderly individuals, such as employment regularization, pension settlements, and senior citizen benefits.[3] Beyond the age of 25, age estimation is typically expressed in terms of decades. Traditionally, evaluating cranial sutures involved invasive procedures, including the removal of soft tissues for visual analysis.

However, advancements in radiological imaging, particularly computerized tomography (CT) scans, have significantly improved the ability to estimate ages in both living and deceased individuals.[4–6] Utilizing modern radiological techniques like CT allows for non-invasive evaluation of sutures, eliminating the need for tissue removal.

Numerous studies, such as those by Todd and Lyon in 1924[7] and Meindl and Lovejoy in 1985,[2] Singh et al.,[8] Pardeep Singh et al.,[9] Goyal et al.,[10] Masih W et al.,[11] Khandare et al.,[3] and Mohammed Akbar N J et al.,[12] have investigated forensic age estimation using cranial sutures, employing various techniques and scoring methods.

Despite this body of research, there remains a notable gap in CT-based cross-sectional imaging of cranial sutures for age determination, particularly in India. This study aims to address this gap by providing insight into the ages at which different cranial sutures fuse in the Indian population. Additionally, the study seeks to develop regression models for estimating age in this population by analyzing cranial suture obliteration in cross-sectional CT images, using a seven-stage scoring system developed by Harth et al. in 2009[13] and Chiba et al. in 2013.[14]

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Material and Methods

The study enrolled individuals aged 20 years and older who were referred to the Department of Radiology at Goa Medical College and Hospital, a tertiary healthcare facility in India. Patients were recommended by physicians or surgeons to undergo a head CT scan for diagnostic purposes. They were informed about the study's scope, and inclusion of their CT images was contingent upon obtaining their informed consent and verifying their age and Goan ethnicity through Aadhaar card details. Cases were excluded if they exhibited motion blur or had a history of conditions or events that could affect cranial sutures, such as skull fractures, anomalies like stenocephaly, childhood abuse, or diseases impacting ossification.

Inclusion Criteria

1. Individuals aged 20 years and above.
2. Patients who underwent CT scans of the head for diagnostic purposes.
3. CT scan DICOM files with clear cross-sectional images of cranial sutures for analysis.

Exclusion Criteria

1. Patients with movement blur in CT scans.
2. Individuals with a history of conditions or events known to affect cranial sutures, such as skull fractures, cranial burns, cranial anomalies (e.g., stenocephaly), childhood abuse, or diseases affecting ossification.

Technical Information

CT scans were conducted using a Siemens Medical Solutions DSCT-SOMATOM Definition flash 256-slice CT scanner in Erlangen, Germany. The scan parameters were set to a tube voltage of 80 kV, tube current of 58 mAs, and slice thickness of 0.6 mm. Patient information displayed in the DICOM images was digitally concealed to maintain patient anonymity. Radiant DICOM software was utilized to generate orthogonal multiplanar reconstruction images and volume rendering technique images. The cross-sectional images were examined using a window width of 1,600 HU and a window level of 1,000 HU, specifically for bone visualization.

The sagittal, coronal, and lambdoid sutures were selected for evaluation. A three-dimensional multiplanar reconstructed image of the cranium containing all three sutures was divided into segments. The sagittal suture was divided into four segments, the coronal suture into three segments, and the lambdoid suture into three segments, as mentioned in Table 1.

A 0.6-mm block was selected from the middle of each segment, as illustrated in Figure 1. Cross-sectional images perpendicular to the suture were examined. Axial, coronal, and sagittal sections were obtained at various levels in the bone window of the skull sutures.

Scoring of Cranial Suture Obliteration

Cross-sectional slices of each segment of the sagittal, coronal, and lambdoid sutures were visually assessed and classified into one of seven stages, as shown in Table 2, which is based on the degree of closure, following the criteria outlined by Harth et al.[13] and Chiba et al.[14] the cross-section of the segment showing the degree of closure is shown in Figure 2.

Results

The study analyzed cross-sectional images of sutures from CT scan DICOM files to assess skull suture closure. The study included 141 subjects of known age and sex, comprising 70 males (mean age + standard deviation: 53.14 + 19.78 years) and 71 females (mean age + standard deviation: 53.29 + 19.65 years), ranging in age from 20 to 89 years, as illustrated in Table 3.

All statistical analyses were conducted using the Jamovi project software (2022), Version 2.3. As obliteration scores (ranging from 0 to 6) were ordinal values assigned to cranial suture obliteration, the dataset was recognized to follow a non-normal distribution, necessitating the use of non-parametric

Table 1. Segments of the Sagittal, Coronal, and Lambdoid Sutures.

Abbreviation	Segments of the Sagittal, Coronal, and Lambdoid Sutures
S1	Pars bregmatica (i.e., first part) of Sagittal suture
S2	Pars verticis (i.e., second part) of Sagittal suture
S3	Pars obelica (i.e., third part) of Sagittal suture
S4	Pars lambdicia (i.e., fourth part) of Sagittal suture
C1	Pars bregmatica (i.e., first part) of Coronal suture
C2	Pars complicate (i.e., second part) of Coronal suture
C3	Pars pterica (i.e., third part) of Coronal suture
L1	Pars lambdicia (i.e., first part) of Lambdoid suture
L2	Pars intermedia (i.e., second part) of Lambdoid suture
L3	Pars asterica (i.e., third part) of Lambdoid suture
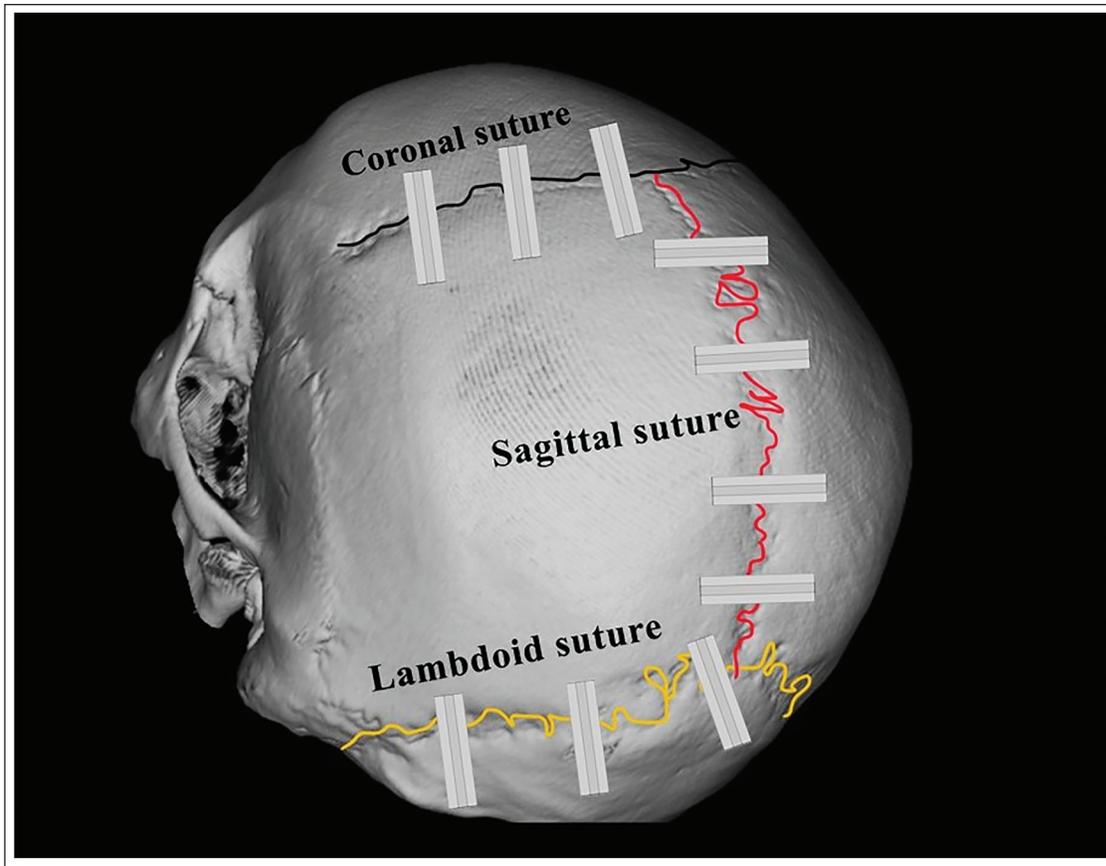
Figure 1. 3D-multiplanar Reconstruction Showing Coronal, Sagittal, and Lambdoid Suture and Their Segment for the Cross-sectional View to Observe the Fusion of Cranial Sutures.

Table 2. Seven Stages According to the Degree of Closure by Harth et al. and Chiba et al.

Stage	Process of Closure	Degree of Ossification (%)
0	Complete open	0
1	Inner bone cortex beginning to close (<10%)	<10
2	Inner bone cortex closed	10–33
3	Less than half closed	34–66
4	More than half closed	67–90
5	Visible relic of the ossification process	>90
6	Complete closure without relic	100

tests such as the Mann–Whitney U test and Spearman's correlation. Spearman's rho correlation was employed to determine the correlation between the suture obliteration score and chronological age.

The mean closure stage was calculated by summing the closure scores for each skull suture segment and dividing them by the number of segments. Simple linear regression models were constructed to estimate age using obliteration scores for each cranial suture part analyzed in this study, separately for males, females, and the entire study population.

Cohen's κ was utilized to assess intra- and interobserver errors, based on 40 individual CT DICOM images and 40 randomly selected CT DICOM images from the participants' scans. The significance level (α) was set to 0.005 for all observations. Intra-observer errors exhibited high agreement, with kappa scores of 0.98, indicating strong consistency between the principal investigator and secondary observations. Additionally, interobserver error kappa was 0.83, indicating substantial agreement between the lead investigator and each individual observer.
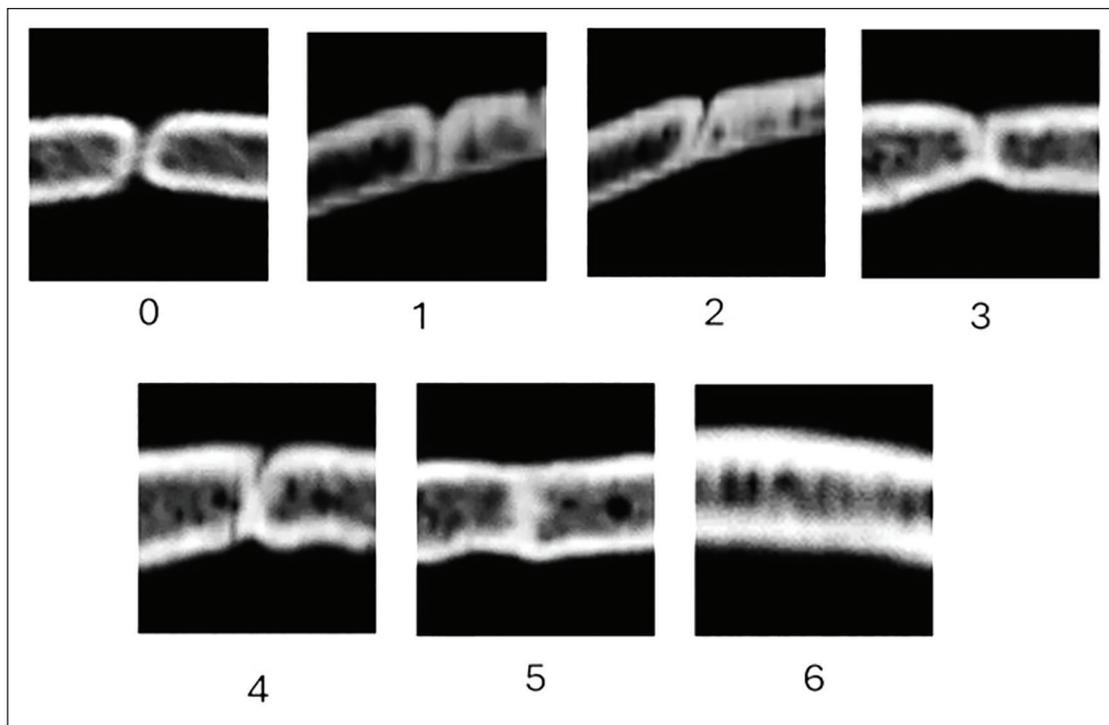
Figure 2. Image of the Seven Stages of Ossification on a Cross-section of Suture.

Table 3. Age and Sex Distribution of the Study Population.

Age	Male	Female	Total	% of Total
20–29 years	10	10	20	14.2%
30–39 years	10	12	22	15.6%
40–49 years	10	11	21	14.9%
50–59 years	10	09	19	13.5%
60–69 years	10	10	20	14.2%
70–79 years	10	10	20	14.2%
80–89 years	10	09	19	13.5%
Total	70	71	141	100.0%
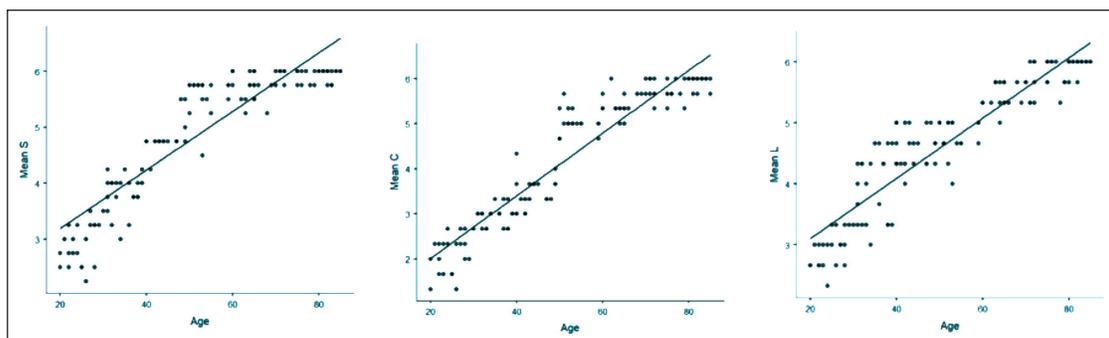
Figure 3. Scatter Diagram Showing the Slope and the Linear Regression Models of Age Estimation with Mean of the Respected Sutures.

Table 4. Regression Model for the Female.

Female Variable	Model	R	SEE
S1	3.557 × S1 + 12.874	0.427	12.23
S2	4.225 × S2 + 18.247	0.232	10.72
S3	5.518 × S3 + 20.814	0.176	10.84
S4	2.616 × S4 + 19.228	0.930	12.28
C1	12.792 × C1 − 5.847	0.197	15.11
C2	10.452 × C2 − 4.123	0.158	15.22
C3	12.768 × C3 + 3.014	0.934	16.59
L1	12.424 × L1 + 2.079	0.330	13.30
L2	9.649 × L2 + 4.919	0.427	11.62
L3	8.112 × L3 + 8.677	0.291	13.54

Table 5. Regression Model for the Male.

Male Variable	Model	R	SEE
S1	3.529 × S1 + 13.206	0.977	14.60
S2	4.218 × S2 + 18.218	0.977	12.60
S3	4.652 × S3 + 20.841	0.106	13.47
S4	3.726 × S4 + 19.365	0.970	19.18
C1	12.812 × C1 + 6.241	0.443	16.15
C2	10.252 × C2 + 9.247	0.587	15.26
C3	12.501 × C3 + 6.187	0.982	18.66
L1	15.834 × L1 − 3.158	0.388	16.14
L2	11.612 × L2 + 4.227	0.898	11.41
L3	7.472 × L3 + 2.859	0.977	12.02

A statistically significant correlation ($p < .001$) was observed between chronological age and the mean cranial suture obliteration scores.

The multiple linear regression models were developed to estimate age using the obliteration scores of sagittal, coronal, and lambdoid sutures for males, females, and the total study population, as illustrated in Figure 3 and Tables 4, 5, and 6, respectively.

For the sagittal suture, the standard error of the estimate was 14.96 years for males, 11.40 years for females, and 11.10 years for the total sample. Regarding the coronal suture, the standard error of the estimate was 16.69 years for males, 15.64 years for females, and 12.38 years for the total sample. Finally, for the lambdoid suture, the standard error of the estimate was 13.19 years for males, 12.82 years for females, and 13.33 years for the total sample.

Discussion

Accurate estimation of age holds significant importance in forensic medicine, particularly concerning the identification of individuals from skeletal remains,[15,16] which is one of the fundamental aspects of forensic investigation. Once all teeth have erupted and most epiphyses have fused with the diaphysis, skull sutures become reliable indicators of age. While various changes such as bone lipping, greying of hair, arcus senilis formation in the cornea, lens opacity, atherosclerotic changes in arteries, and skin wrinkling, particularly on the face, occur with aging, these alterations are generally too nonspecific to serve as reliable markers for age determination in medical-legal contexts.[17]

In forensic medicine and forensic anthropology, skeletal and dental indicators are commonly utilized to determine maturity, with most of these indicators reaching maturity by the age of 25. However, beyond the age of 25, age prediction becomes highly unreliable, and the use of skull sutures as indicators for age estimation remains a topic of debate among experts in the field.[18]

Earlier studies predominantly relied on the fusion of both endocranial and ectocranial skull sutures using "The Acsádi and Nemeskéri method of scoring" for age estimation.[17–23] However, caution is advised when interpreting ectocranial and endocranial suture closures, and they should be used in conjunction with other age indicators, as suggested by Meindl and Lovejoy et al.[2]

In recent times, advancements in imaging modalities have led to the development and testing of multiple techniques for accurate age estimation.[6,10,13,24,25] For instance, Postmortem

Table 6. Regression Model for the Total Study Population.

Variable	Model	R	SEE
S1	3.536 × S1 + 12.206	0.421	12.19
S2	4.315 × S2 + 17.394	0.531	10.16
S3	4.519 × S3 + 19.741	0.254	11.21
S4	3.624 × S4 + 19.421	0.396	10.84
C1	12.172 × C1 + 5.262	0.319	11.23
C2	10.735 × C2 + 8.147	0.301	12.68
C3	12.128 × C3 + 6.187	0.514	13.24
L1	15.671 × L1 − 4.158	0.487	12.29
L2	11.891 × L2 + 5.017	0.341	14.78
L3	7.786 × L3 + 3.859	0.291	12.92

Table 7. Comparison Between the Different Studies and Their Standard Error of Estimate.

	Sample Size			SEE in Years		
Studies	Male	Female	Total	Male	Female	Years
Harth et al.[13]	148	73	221	+30.50	+29.20	+31.10
Chiba et al.[14]	65	61	126	+33.55	+29.56	+31.42
Ruengdit et al.[29]	161	85	76	+13.30	+14.80	+14.00
Fan et al.[4]	230	–	230	+6.22	–	–
Qiu et al.[30]	110	110	220	+6.39	+6.16	+6.29
Akbar et al.[12]	183	80	263	+15.08	+13.27	+14.74
Present study	70	71	141	+14.94	+13.28	+12.27

CT imaging, has been extensively utilized in forensic medicine and forensic anthropology for age estimation in cases involving unidentified, decomposed, and skeletal remains.[26–28]

This study focuses on age estimation based on the cross-sectional analysis of cranial suture closure using CT scans in the Indian population, employing a seven-stage scoring system as proposed by Harth et al.[13] and Chiba et al.[14] A statistically significant correlation was observed between age and suture obliteration in males, females, and the total population.

Harth et al.[13] conducted a study in 2009 to estimate age using flat-panel CT imaging of calvariae, observing 221 samples. The study utilized a seven-stage grading method for suture obliteration, with a standard error estimate (SEE) of 30.5 years in males and 29.2 years in females. However, the present study yielded lower SEE values, likely due to differences in sample size.

Similarly, in 2013, Chiba et al.[14] conducted a study focusing on the sagittal suture using cross-sectional CT imaging. Although their study reported higher SEE values compared to the present study, it highlighted the positive correlation between sagittal suture closure and age, particularly in adult women.

Ruengdit et al.[29] examined suture closure techniques in Thai crania in 2018, using three widely used methods - Acsádi and Nemeskéri (1970), Meindl and Lovejoy (1985), and Mann (1991). Their approach demonstrated an error of 13.3 years in males and 14.8 years in females. The Mann method showed higher accuracy in predicting age in older males but not in Thai females, contrary to the present study, which showed slightly higher accuracy in females than in males. Ruengdit et al.[29] also stated that inter-population variations exhibited biases and inaccuracies, with overestimation in younger adults and underestimation in older individuals, which is more likely in the present study as well.

Fan et al.[4] conducted a study in 2020 on the Chinese male population, employing CT scans for age estimation. Their study, utilizing a seven-stage grading system, reported slightly better accuracy compared to the present study, likely attributed to differences in population demographics and sample size.

Qiu et al.[30] conducted a study in 2020 on Han adults using thin-layer CT imaging for age estimation, achieving a mean absolute error of 6.39 years in males and 6.16 years in females. Although their standard error of estimate may be lower due to the usage of multiplanar reformation images, unlike the present study, which divided suture cross-sections into segments and employed multiplanar images.

In 2023, Akbar et al.[12] conducted a study on the Indian population, utilizing a three-stage scoring system for cranial suture closure assessment on 3D CT scans. Their study reported slightly higher SEE values compared to the present study.

A comparison of study characteristics between the available literature and the present study is provided in Table 7.

Conclusions

The closure of cranial sutures progresses with age and can be evaluated using DICOM images obtained from modern computer tomography scans employing a seven-stage scoring method. The obliteration of cranial sutures demonstrates a statistically significant correlation with chronological age, with a stronger predictive value observed in females compared to males. Linear regression models based on stages of cranial suture obliteration offer valuable tools for forensic practitioners to estimate age.

However, given the relatively large SEE associated with the regression models developed using cranial suture obliteration scores in this study, caution must be exercised when utilizing these models. They should be employed in conjunction with other established age estimation techniques during the process of identification.

Age estimation based on morphological changes in bones has long been subject to debate due to its inherent variability, influenced by diverse factors such as climate, diet, genetics, nutrition, society, race, environment, and geography. Cranial sutures are no exception to this variability. Therefore, further research is warranted to refine age estimation methods based on cranial sutures across different populations.

Declaration of Conflicting Interests

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

Ethical Approval

Ethical clearance is acquired from the Institutional Ethical Committee(letter number: ECR/83/INST /GOA 2013/RR-20). Participant confidentiality is safeguarded through encryption of their identities. Patients are provided with information and their Informed consent is obtained for the usage of CT scans DICOM files for study purposes.

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Estimation of Age of Appearance and Fusion of Secondary Ossification Centers Around Wrist Joint Among Bengali Population by Radiological Study

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Abstract

Determination of age of an individual for medicolegal purpose in civil and criminal cases mostly depends upon radiological data of appearance and fusion of ossifications centers. The X-ray of wrist is important in this regard to determine age in early adolescent age group. This study has been aimed to determine age of appearance and fusion of ossification centers around wrist joint for known aged person among Bengali population and compare them with standard age. Radiological films of wrist joint of 483 individuals (373 male and 110 females) have been studied in retrospective way. Subjects came for age estimation between the period 1 January 2017 to 31 December 2019. Data analyzed in Microsoft excel 10 and presented in the form of tables. The study revealed age of appearance and fusion of Pisiform, lower end of Radius, and lower end of Ulna in Bengali population which corroborate with other studies in some cases and do not match with some studies. This study will help to determine age of early adolescent individuals in Bengali population which vary from existing standard data to some extent due to various factors like nutritional status, environmental condition, food habits and socioeconomic status.

Introduction

Identification of human being is one of the most important aspects of criminal investigation. Estimation of age is one parameter of identification process and is also essential in various civil cases when actual age of a person is challenged because of insufficient or forged documents. Age can be estimated from skeletal remains of dead induvial and from radiological and dental data of both living and dead. Mostly, in children and adolescents, skeletal age and chronological age tally with each other.[1] In this part of the country, age estimation is often termed as "Ossification Test" by judiciary system as age of appearance and fusion of ossification centers of long bones around major joints of human body is considered to be reliable though it varies with different nutritional, developmental, and endocrinal factors which affect skeletal growth.[2]

Notable works on the determination of age from such appearance and fusion of epiphyses in the long bones around different joints of the body namely elbow, wrist, pelvis, knee, shoulder, ankle, and others have been done in different parts of India and abroad. It is evident that there is significant difference in the age of epiphyseal union in different population even within a country.[3] Ossification centers around wrist joint are helpful mostly in determination of age among children and adolescents.[4] In this study, we have examined age of appearance and fusion of ossification centers around wrist joint like lower end of Radius and lower end of Ulna and also age of appearance of Pisiform bone. Three-hundred seventy three male and 110 female subjects have been examined between the age group of 7 and 21 years. Our objectives are to observe status of appearance and fusion of ossification centers around wrist for a known chronological age, to

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determine range of their appearance and fusion in males and females and to compare them with known standards specifically those mentioned in Galstaun chart.[5]

Materials and Methods

It was a cross-sectional study done on 483 individuals (373 males and 110 females) who came for radiological age estimation in the Dept. of Forensic Medicine & Toxicology of Medical College Kolkata between 1 January 2017 and 31 December 2019. All cases within the mentioned time period were examined in a census sampling except those who fell under exclusion criteria, that is, those who did not belong to Bengali population, whose stated ages were not known and who had fracture or pathology of concerned bones. Lower end of Radius and Ulna were examined in respect to their status of appearance and fusion. Presence or absence of Pisiform bone was examined. Stated age was confirmed from age proof documents. Ossification centers of concerned bony structures were examined to observe

1. Whether appeared
2. Whether fusion not started
3. Whether fusion started and in process
4. Whether fused

The epiphyseal scar at the junction of epiphysis and metaphysis has been considered as indicator of complete fusion. The skiagrams examination and evaluation were performed by two observers blindly and independently without knowing about age or sex. The data were put in an excel sheet and the parameters were examined statistically in relation to their stated age and age of their appearance and fusion were determined.

Result

Out of 483 subjects, 373 (77.23%) were males and 110 (22.7%) were females. Males were aged between 7 years and 21 years and females were aged between 8 years and 18 years. Number of male and female subjects seen across the age spectrum at every one-year interval was as follows (Table 1):

Appearance of Pisiform

In females, Pisiform appeared in 77.27% of total population. Pisiform appeared in all subjects between 12 and 18 years of age, whereas 59.68% of female population showed appearance of Pisiform between 8 and 11 years age group. In males, 62.94% subjects showed appearance of Pisiform and all subjects between 15 and 21 years age group had the Pisiform bone on X-ray. Appearance started from eight years age. Between 8 years and 14 years of age, only 48.13% male population showed appearance of Pisiform (Table 2).

Table 1. Age- and Gender-wise Distribution of the Study Samples (*n* = 483).

Age in Years	Male	Female	Total
7	01	00	01
8	18	9	27
9	49	25	74
10	50	10	60
11	46	18	64
12	57	24	81
13	40	07	47
14	35	07	42
15	29	01	30
16	24	07	31
17	19	01	20
18	02	01	03
19	01	00	01
20	00	00	00
21	02	00	02
Total	373	110	483

Table 2. Gender-wise Distribution of Age (in Years) of Appearance of Pisiform (*n* = 483).

Age in Years	Not Appeared		Appeared	
	Males	Females	Males	Females
7	1			
8	17	7	1	2
9	42	14	7	11
10	43	3	7	7
11	26	1	20	17
12	18		39	24
13	5		35	7
14	2		33	7
15			29	1
16			24	7
17			19	1
18			2	1
19			1	
20				
21			2	

Appearance of Lower End of Radius

Lower end of Radius appeared in all 373 male subjects and 110 female subjects.

Fusion of Lower End of Radius

Among females, only nine (8.18%) aged between 13 and 18 years showed complete fusion of lower end of Radius. Lower

Table 3. Gender wise Distribution of Age (in Years) Fusion of Lower End of Radius (*n* = 483).

Age in Years	Fusion Not Started		Fusion in Process		Fusion Complete	
	Male	Female	Male	Female	Male	Female
7			1			
8	13	6	5	3		
9	39	16	10	9		
10	37	4	13	6		
11	33	9	13	9		
12	36	4	21	20		
13	15		25	6		1
14	2		32	6	1	1
15			25	1	4	
16			16	2	8	5
17			9		10	1
18					2	1
19					1	
20						
21					2	

end of Radius was in the process of fusion in 62 (56.36%) females aged between 8 and 16 years. Fusion did not start in 39 (35.45%) females aged between 8 and 12 years. One-hundred percent of female population had complete fusion above the age of 17 years and 71.43% females had complete fusion above the age of 16 years. Among males, only 37 (9.92%) subjects aged between 14 and 21 years showed complete fusion of lower end of Radius. Lower end of Radius was in the process of fusion in 170 (45.58%) males aged between 7 and 17 years. Fusion did not start in 175 (46.92%) males aged between 8 and 14 years. One-hundred percent of male population aged 18 or above had complete fusion, 52.63% in 17 years of age onward, 33.33% in 16 years of age onward, 13.79% in 15 years of age onward, and 2.86% in 14 years of age onward (Table 3).

Appearance of Lower End of Ulna

It appeared in all 110 female subjects, whereas 93.21% male population showed appearance of lower end of Ulna. One-hundred percent of male population had lower end of Ulna appeared above 13 years of age (Table 4).

Fusion of Lower End of Ulna

Among females, only 10 (9.09%) aged between 13 and 18 years showed complete fusion of lower end of Ulna. Lower end of Ulna was in the process of fusion in 46 (41.82%) females aged between 9 and 16 years. Fusion did not start in 54 (49.09%) females aged between 8 and 13 years. One-hundred percent of female population had complete fusion above

17 years of age and 71.43% females had complete fusion above 16 years of age, 28.57% females above 14 years of age and 14.28% females above 13 years of age. Among males, only 35 (9.38%) aged between 14 and 21 years of age showed complete fusion of lower end of Ulna. Lower end of Ulna was in the process of fusion in 141 (37.80%) males between 8 and 17 years of age group. Fusion did not start in 197 (52.82%) males between 7 and 14 years of age group. One-hundred percent of male population had complete fusion above 18 years of age, 57.89% males had complete fusion above 17 years of age, 50% males above 16 years of age, 10.34% males above 15 years of age, and 8.57% males above 14 years of age (Table 3).

Discussion

The study was aimed to guide medical professionals and law keeping authority in relation to estimation of skeletal age among Bengali population. The study was done to determine age of appearance and fusion of various ossification centers around wrist joint and to corroborate them with chronological age. Similar study has been attempted in Northern part (Punjab, Uttar Pradesh), Western Part (Rajasthan, Maharashtra), Southern part (Karnataka, Tamil Nādu), and eastern part (Manipur, West Bengal). In various foreign countries like USA, England, Australia, and Egypt, similar type of study has been carried out. In West Bengal, four studies have been conducted on this background—two in 1937, one in 1995, and one in 2013. In this study, we will compare our result among other similar studies across the country and also those took place in countries outside India. The results of different such studies are summarized in Tables 5 and 6.

Table 4. Age (in Years) of Appearance and Fusion of Lower End of Ulna (*n* = 483).

Age in Years	Appeared		Not Appeared		Fusion Not Started		Fusion in Process		Fusion Complete	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
7	1				1					
8	8	9	10		15	9	2			
9	45	25	4		49	24		1		
10	49	10	1		42	6	8	4		
11	46	18			36	11	10	7		
12	56	24	1		36	3	21	21		
13	40	7			15	1	25	5		1
14	35	7			3		29	5	3	2
15	29	1					26	1	3	
16	24	7					12	2	12	5
17	19	1					8		11	1
18	2	1							2	1
19	1								1	
20										
21	2								2	

We have studied radiological appearance and fusion of the ossification centers of bones around wrist joint including lower end of Radius, lower end of Ulna, and Pisiform. This combined and comprehensive approach have been seen in only few national and international studies as most of the studies have not included Pisiform bone. Moreover, all the earlier researchers specifically in West Bengal and other eastern parts of India have not included both male and female population while observing status of fusion of ossification centers around wrist joint together. Usually, appearance and fusion of these bony landmarks occur earlier in females as compared to males. Similar finding was observed in our study considering no female subject of seven years age was present.

According to this study, age of appearance of Pisiform bone is 8–12 years in females and 8–15 years in males. Age of appearance of Pisiform detected by other studies like Garn SM et al. (*M* = 12 years, *F* = 12 years), Srivastav et al. (11–12 years), Bhise et al. (*M* = 12–13 years, *F* = 10–12 years), Wankhade et al. (11–13 years), Patil et al. (*M* = 12 years, *F* = 1.5–12 yrs) falls within the range of age in years detected in our study.[23,26,30,33,48]

Regarding age of appearance of lower end of Radius, no conclusive opinion could be drawn as it appeared in all cases of both males and females.

As per this study, age of fusion of lower end of Radius is 13–17 years in female and 15–18 years in males. This finding corroborated with the findings of Wankhade et al. of Maharashtra, Bhise and Nanadkar of Mumbai, Nandi A of West Bengal, and Basu and Basu of West Bengal.[9,19,26,30] In few studies like Pillai et al. of Madras, Galstaun of West Bengal, Saxena and Vyas of Punjab, Dutta and Samanta of Rajasthan, and Greulych and Pyle of USA,[5,8,15,22,49] findings

in relation fusion of lower end of Radius were in the higher side of the age range detected by us. Finding of this study does not correspond with the findings of Lal and Nat of Uttar Pradesh, Loomba et al. of Uttar Pradesh, Sharma Yogesh of Rajasthan, Nemade of Maharashtra, Patel et al. of Gujrat, Pryor et al. of USA, Davies and Pearson of England, Flecker et al. of Australia, and some others.[7,13,18,25,27,40,41]

In this study, age of appearance of lower end of Ulna is detected as 8 years in female and 7–11 years in males. Our finding corroborated with the finding of Bhise et al.[26] of Mumbai but does not corroborate with the finding of Wankhade of Maharashtra.[30]

Age of fusion of lower end of Ulna is 14–17 years in females and 15–18 years in male according to our study. This finding was mostly similar to the findings of Hapeworth et al. of Punjab, Basu and Basu of west Bengal, Mittal et al. of Uttar Pradesh, Sharma Yogesh of Rajasthan (males), Sunil and Viswanathan of Karnataka, Pryor et al. of USA (males), and Ledger and Wasson of Pakistan,[6,9,11,18,28,40,47] whereas in studies like Galstaun of West Bengal, Mishra of Odisha, Goel et al. of Rajasthan, Barret et al. of Myanmar, and Greulych and Pyle of USA,[5,20,46,49] the finding was in higher end of age as shown in this study. Our finding does not match with the finding of Lal and Towsend of Uttar Pradesh, Agarwal and Pathak of Punjab, Kothari et al. of Marwar, Gupta et al. of Uttar Pradesh, Banerjee and Agarwal of Delhi, Patel et al. of Gujrat, Paterson of USA, Sidhom of Egypt, and some others.[10,12,16,21,27,42,45]

The discrepancies in findings may be due to geographical location or constitutional factors. But further extensive longitudinal study with wider age range may yield better results.

Table 5. Comparison of Age of Epiphyseal Fusion Around Wrist Joint Given by Various Researchers in Foreign Countries with Findings of This Study.

Author	Year of Publication	Region	Lower End of Radius (Appearance)	Lower End of Radius (fusion)	Lower End of Ulna (Appearance)	Lower End of Ulna (Fusion)	Pisiform
Hepworth[6]	1929	Punjab		16–17		16–17	
Lal and Nat[7]	1934	Uttar Pradesh		M = 19		F = 19	
Pillai[8]	1936	Madras		18		18	
Galstaun[5]	1937	Bengal		M = 18, F = 16–17		M = 17, F = 18	
Basu and Basu[9]	1938	Bengal		16–17		16–17	
Lal and Townsend[10]	1939	Uttar Pradesh		19		19	
Mittal[11]	1952	Uttar Pradesh		M = 16–17, F = 18		M = 17–18, F = 16–17	
Agrawal and Pathak[12]	1957	Punjab		F = 17–17.6		F = 17–17.6	
Loomba[13]	1958	Uttar Pradesh		M = 20–21, F = 18–19		M = 18–19, F = 20–21	
Bajaj[14]	1967	Delhi		16.4			
Saxena and Vyas[15]	1969	Punjab		M = 18		M = 18	
Kothari[16]	1974	Marwar		18–19		18–19	
Ds Gupta[17]	1974	Uttar Pradesh				20–21	
Sharma Yogesh[18]	1994	Rajasthan		M = 19–20, F = 17–18		M = 16–17, F = 18–19	
Nandi[19]	1995	Bengal		15–16		18	
Goel[20]	1996	Rajasthan		M = 18–19, F = 17–18		M = 17–18, F = 18–19	
Banerjee and Agrawal[21]	1998	Delhi		19–20		18–19	
Dutta and Suamanta[22]	2000	Rajasthan		F = 16.5–17		M = 16.6–17, F = 18–19	
Srivastav[23]	2004	Rajasthan	M = 1–2, F = 2–3				11–12
Singh[24]	2007	Manipur		F = 18		F = 18	
Nemade[25]	2010	Maharashtra		M = 20–21, F = 19–20		19–20	
Bhise[26]	2011	Mumbai		M = 17–18, F = 16–17	M = 9–11, F = 8–10	M = 17–19, F = 16–17	M = 12–13, F = 10–12
Patel[27]	2011	Gujarat		19–20		M = 19–20, F = 18–19	
Sunil and Viswanathan[28]	2012	Karnataka				M = 18–19, F = 15–16	
Prasad[29]	2013	Bengal		17–18		18–19	
Wankhade[30]	2013	Maharashtra	2–4	16–17	4–7	17–18	11–13
Rajdev[31]	2015	Gujarat		M = 21, F = 20		M = 21, F = 19	
Vaishnawa[32]	2015	Rajasthan		M = 17–18		M = 19–20, F = 18–19	
Patil RC[33]	2016	Karnataka					M = 9.5 + 1.71, F = 9.5 + 1.7

(Table 5 continued)

Author	Year of Publication	Region	Lower End of Radius (Appearance)	Lower End of Radius (fusion)	Lower End of Ulna (Appearance)	Lower End of Ulna (Fusion)	Pisiform
Gambhir Singh[34]	2016	Tamil Nadu		M = no fusion before 17, F = no fusion before 15		M = no fusion before 14	
Krishnamoorthy[35]	2016	Telangana		M = 18–19, F = 17–18		M = 18–19, F = 17–18	
Gaddewar[36]	2017	Maharashtra		M = 18.6–19.5, F = 17.6–18.5		M = 18.6–19.5, F = 17.6–18.5	
Leena[37]	2017	Rajasthan		18–19		M = 19–20, F = 18–19	
Vashist[38]	2018	Haryana		M = 18–19, F = 17–18		M = 18–19, F = 17–18	
Kumar[39]	2022	Hyderabad		F = 18–19		18–19	
Present study	2023	West Bengal, India	No conclusion	M = 15–18, F = 13–17	M = 7–11, F = 8	M = 15–18, F = 14–17	M = 8–15. F = 8–12

Table 6. Comparison of Age of Epiphyseal Fusion Around Wrist Joint Given by Various Researchers in India with Findings of This Study.

Author	Year of Publication	Region	Lower end of Radius (Appearance)	Lower End of Radius (Fusion)	Lower end of Ulna (Appearance)	Lower end of Ulna (Fusion)	Pisiform
Pryor[40]	1925	(USA)		M = 20, F = 19		M = 16, F = 19	
Davies and Pearson[41]	1929	(England)		19–20		20	
Paterson[42]	1929	(USA)		M = 21, F = 20		M = 21, F = 20	
Borovansky and Hnevkovsky[43]	1929	(Czech)		19		18–19	
Flecker[44]	1931	(Australia)		M = 19, F = 18		M = 19, F = 17	
Sidhom[45]	1931	(Egypt)		M = 19–20		M = 19–20	
Barret[46]	1936	(Myanmar)		17–18		17–18	
Ledger and Wasson[47]	1941	(Pakistan)		M = 20, F = 18–19		M = 18–19, F = 16–17	
Garn SM[48]	1960	(USA)					M = 12, F = 12
Greulych and Pyle[49]	1959	(USA)		M = 18, F = 17		M = 18, F = 17	
Present study	2023	West Bengal, India	No conclusion	M = 15–18, F = 13–17	M = 7 to 11, F = 8	M = 15–18, F = 14–17	M = 8–15. F = 8–12

Conclusion

Only four reliable documented studies among Bengali population have been conducted in 1937, 1938, 1995, and 2013. Most of the studies did not include Pisiform bone and both genders separately. An in-depth study was required for determining a reliable reference range of age in the present scenario. This study is an attempt toward that goal. Radiological analysis of appearance and fusion of ossification centers around wrist joint can be used for estimation of age in Bengali population in future taking this study findings as reference.

Declaration of Conflicting Interests

Ethical Approval

A prior approval was obtained from the Institutional Ethics Committee.

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Stature Estimation from Radius

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Abstract

Estimation of stature for the identification of an individual has got importance in forensic science. In this study, an attempt will be made to estimate the stature from length of radius. Study subject consists of 50 adult males and 50 adult females between the age group of 18–30 years, born in Central India. Simple regression formula was derived showing the correlation between length of radius and stature of an individual.

Introduction

Identification of an individual by estimation of stature has utmost significance from the medico-legal aspect. Stature is defined as height of body in upright position and is considered as one of the important parameters for personal identity.[1] Karl Pearson developed first stature regression formula[2] and thereafter Trotter and Glesser produced series of regression formulae to reconstruct the stature of an individual from the length of a long bone.[3–4] Stature is variable with age, sex, ethnicity, etc.[5–6] Extensive work carried out on correlation of bone length with stature of a person in India and abroad[7–9] concluded that there is a linear relationship between the measurements and stature. Telkka in his study opined that all racial group needed a separate formula for estimation of stature.[10] So, this study was done to derive regression formula for the estimation of stature from the length of radius in Central India.

Aims and Objectives

The aim of this study was to correlate percutaneous length of right and left radius with the body height and thus estimate stature by deriving regression formula.

Material and Methods

Standing height and percutaneous length of radius of 100 apparently healthy individuals comprising of 50 adult males and 50 adult females of age range from 18 to 30 years in Peoples College of Medical Sciences & Research Center (PCMS & RC), Bhopal, were taken for the establishment of regression formulae. Approval from Ethical and Research committee was taken with number PCMS/OD/1084. Written informed consent was taken from all the subjects. Standing height of the individual will be measured by asking them to stand on the baseboard of a standard metric height measuring stand with head oriented in eye-to-eye plateau; that is, the Frankfurt plane was horizontal. The measurement of height will be taken in centimeters by bringing the projecting horizontal sliding bar to

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Table 1. Height and Length of Radius.

Sl. No.	Variables (cm)	Average	Standard Deviation	Summation	Summation of Square	Summation of Product XY	Co-efficient of Variation
1	Height (y)	166	10.05	16600	2755600		6.054
2	Right radius—X_1	24.170	1.32	2417	58418.89	401222	5.461
3	Left radius—X_2	23.900	1.26	2390	57121	396740	5.272

Table 2. Regression Formula Derivation for Calculating Stature from Length of Radius.

Independent Variable	Length of Right Radius in cm (X1)	Length of Left Radius in cm (X2)
Intercept (*a*)	74.00	83.28
Regression coefficient (*b*)	3.662	3.390
Correlation coefficient (*r*)	0.756	0.72
Coefficient of determination (r^2)	0.572	0.518
Standard error of estimate	8.21	7.65

the vertex. Percutaneous radius length will be measured in centimeters (cm) with the help of spreading calipers, by measuring the distance between the most prominent palpable part of head of radius and tip of styloid process with flexed elbow and palm placed over opposite shoulder. The data will be then subjected statistical analysis using computer software SPSS 19.

Observations

Tables 1 and 2 show the various parameters which were calculated by statistical analysis. The mean height of the study subjects was found to be 166 cm with standard deviation (SD) of 10.05 cm. Average length of right radius was 24.17 cm with SD of 1.32 cm, whereas average length of left radius was 23.90 cm with SD of 1.26 cm. Regression analysis was done for estimating individual's height from the length of radius. The correlation coefficient (r) of right and left radius was 0.756 and 0.72, respectively, which shows the positive correlation between length of radius and estimated height.

After statistical analysis, stature can be estimated by using linear regression formula derived for the estimation of height from length of right or left radius. The regression formula derived is

$Y_1 = 74.00 + 3.662X_1$ and
$Y_2 = 83.28 + 3.390X_2.$

Where, Y_1 and Y_2 are estimated heights from length of right and left radius.

X_1 and X_2 are length of right and left radius respectively.

Discussion

The estimation of stature is of utmost importance for forensic experts in identification during medico-legal examination

during ghastly disasters. This study was done to estimate the stature from percutaneous length of radius on living subjects belonging to Central India. A simple regression formula was derived which can be implicated for estimating stature thus showing a positive relationship between the stature and length of radius. Similar strong relations were also observed by Pal and Datta[11] in their study of Indian Bengalis, Mike et al.[12] study in Nigeria, and Babu and Mahesh[13] in their study in South India population.

Conclusion

There exists a positive correlation between stature and length of radius. Regression formula derived can be used in Central India for estimating stature. However, a better accuracy in estimating stature can be arrived by using a combination of bone lengths rather than using a single bone.[14–17]

Declaration of Conflicting Interests

Ethical Approval

Approval from Ethical and Research committee was taken with number PCMS/OD/1084.

Funding

Informed Consent

Written informed consent was taken from all the subjects.

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Electric Fatalities Autopsied at Goa Medical College—A 3-year Review

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Abstract

Electricity, while indispensable in modern society, poses significant risks, with electrical burns resulting in considerable morbidity and mortality, often preventable through basic safety measures. This study investigates the epidemiology of electrical fatalities in Goa, India, spanning from 2021 to 2023. Out of 3,627 autopsies conducted during this period, 37 cases were identified as deaths resulting from electrocution. Detailed analyses revealed insights into the prevalence, demographics, primary contact sites, and seasonal variations of electrocution incidents. The majority of fatalities occurred in the 21–30 age group, primarily due to occupational hazards. Histopathological examinations provided crucial diagnostic clues in confirming electrocution-related injuries. Understanding these patterns can aid in the development of targeted interventions to mitigate risks and enhance safety measures, thus potentially reducing the incidence of accidental electrocutions.

Keywords

Electrical burns, safety measures, autopsy, electrocution, histopathological examinations, accidental electrocutions

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Introduction

Electricity plays a crucial role in modern society, yet it also brings about significant risks, with electrical burns leading to substantial morbidity and mortality, often preventable through basic safety measures.[1–3] While electricity was initially harnessed for commercial use in 1849, it was not until 1879 that unintentional deaths resulting from its use were officially recorded.[4] Artificial electric current exists in two forms: alternating current (AC) and direct current (DC), with the former posing a higher risk contrary to common belief.[4–6] Exposure to significant electric currents can cause skin damage, organ injuries, and even fatalities, with both low and high voltage currents contributing to electrocution deaths, particularly in residential and small industrial settings. In India, the power system operates at AC 220–240 V, 50 A, with the vast majority of electrocution deaths being accidental due to the rarity of electricity-related homicides or suicides.[5,7]

India reports three main types of electrical injuries, varying based on the contact site and current strength: contact injuries, burns or injuries from sparks, and flash burns, all stemming from incidents like high-tension cable accidents, electrical short circuits, and malfunctioning equipment.[8,9]

Causes of death from electrocution range from ventricular fibrillation to respiratory inhibition and complications such as infections and burns, necessitating medicolegal autopsies for all electric shock fatalities.[5,10]

Despite being preventable, electrical deaths remain a persistent issue. This study delves into the epidemiology of electrical fatalities in Goa, India, spanning from 2021 to 2023. It sheds light on the prevalence of accidental electrocutions in both occupational and domestic settings, identifies potential risk factors for fatal incidents, and proposes strategies for implementing effective safety programs to mitigate such risks. The findings of this study hold promise as a valuable resource for researchers, public health officials, and health educators seeking to minimize the occurrence of accidental electrocutions.

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Materials & Methods

This study, conducted at the Department of Forensic Medicine & Toxicology of Goa Medical College, examined records spanning three years from January 1, 2021 to December 31, 2023. Out of a total of 3,627 autopsies, 37 cases (1.03%) were identified as deaths resulting from electrocution. All cases underwent thorough medicolegal postmortem examinations at the Goa Medical College Mortuary. Detailed autopsies were conducted for each case, utilizing police inquest reports, hospital records, and case files to collect data including the deceased's age, gender, date and location of death, occupation, medical treatment received, cause and manner of death, and histopathological findings. This information was then compiled, tabulated, and systematically analyzed.

Results

Overall, we observed 37 cases (1.02%) of electrocuted victims out of a total of 3,627 medico-legal autopsies between January 1, 2021 and December 31, 2023. The majority of cases occurred in the year 2021, with 15 cases out of a total of 1,182 autopsies (1.26%), followed by 12 cases out of a total of 1,229 autopsies (0.97%) in 2023, and 10 cases out of a total of 1,216 autopsies (0.82%) in 2022. In total, 37 electrocution deaths occurred between January 2021 and December 2023. These cases represented approximately 1.02% of all autopsy cases received at the mortuary of Goa Medical College.

In our study, we observed that all 37 cases of electrocuted deaths were accidental in nature; no suicidal or homicidal cases were found. Out of all cases, 32 (86.5%) were dead on arrival at the hospital, and 5 (13.5%) died within 6 hours during treatment, as represented in Table 1.

The age range of all electrocution deaths during the study period was 2–61 years. The majority of cases were observed in the age group of 21–30 years, comprising 13 cases (35.1%), followed by 7 cases (18.9%) each from the age groups 31–40 years and 41–50 years, 5 cases (13.5%) from the age group more than 51 years, and 4 cases (10.8%) from the age group 11–20 years. We observed one electrocuted victim from the age group 1–10 years in our study, as represented in Figure 1.

The majority of the victims, 33 cases (89%), were male, followed by 4 cases (11%) of females, as shown in Figure 2.

The upper extremity was the most common site involved, observed in 27 deaths (73%) as shown in Figure 3, followed by both the upper and lower extremities together in 5 cases (13.5%) as illustrated in Table 2.

Table 1. Survival Period.

Survival Period	Counts	% of Total
Brought dead	32	86.5%
Less than 6 hours	5	13.5%

Among the victims, electrical contact marks, also known as entry wounds, were present in 23 cases (62.2%), both electrical contact marks and electrical grounding marks, also known as exit wounds, in 13 cases (35.1%), and no electrical burn marks in 1 case (2.7%), as represented in Table 3.

Work-related accidents were responsible for 29 deaths (78.4%), followed by household accidents, 7 (18.9%). Regarding the contact details, deaths were most frequently caused by touching electrical wires (16 cases, 43.2%), followed by electric poles (4 cases, 10.8%), electric cables and mobile charger wires (3 cases, 8.1%), and touching electrical water heaters in the bathroom, live wires of concrete mixture electric cutting machines, and standing fans (2 cases, 5.4%), refrigerator, washing machine, and motor railing (1 case, 2.7%) as represented in Table 4.

There was an increase in electrocution fatalities in the months of July–October (17 cases, 45.9%) as represented in Table 5.

Histological analysis of the skin excised from the entry wound/joule burn site indicated collagen degeneration in the dermis, accompanied by coagulation necrosis, degenerative alterations in the keratin layers, dermo-epidermal separation, hyperkeratosis, microvesicle formation, nuclear streaming, and pyknosis of the nucleus. These observations are indicative of an electrical injury, as shown in Figure 4. Among the 37 cases, the most commonly found histopathological finding
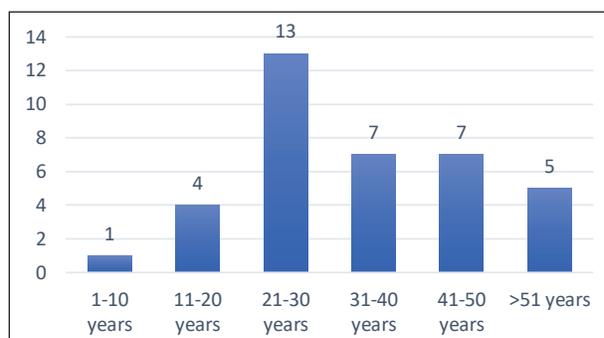
Figure 1. Frequencies of Age.

Figure 2. Age-wise Distribution.

Figure 3. Electrical Lesions on the Left Palm (A-insert), Electric Lesion of the Dorsal Face of the Fourth and Fifth Finger on the RIGHT Hand (B-insert).

Table 2. Primary Contact Site.

Primary Contact Site	Counts	% of Total
Back	1	2.7%
Head chest upperlimbs	1	2.7%
Lower extremity	1	2.7%
Neck region	1	2.7%
No injury	1	2.7%
Upper + lower extremities	5	13.5%
Upper extremity	27	73.0%

Table 3. Frequencies of Type of Injury.

Type of Injury	Counts	% of Total
Entry + exit	13	35.1%
Entry wound	23	62.2%
No wound	1	2.7%

Table 4. Frequencies of Source of Electricity.

Source	Counts	% of Total
Electric cutting machine	2	5.4%
Electric cable	3	8.1%
Electric pole	4	10.8%
Electric rod for water heating	2	5.4%
Live 11 kv high-tension line	1	2.7%
Live open uninsulated wire	16	43.2%
Live wire of the concrete mixer	2	5.4%
Metal railing	1	2.7%
Mobile charging wire	3	8.1%
Standing fan	2	5.4%
Washing machine	1	2.7%

Table 5. Frequencies of Seasonal Variation.

Seasonal Variation	Months	Counts	% of Total
Summer	March–June	13	35.2
Rainy	July–October	17	45.9
Winter	November–February	7	18.9

was nuclear streaming, followed by dermo-epidermal separation with vacuolation, and coagulative necrosis accompanied by collagen degeneration in the dermis.

Discussion

This study investigated fatalities resulting from electrocution between January 1, 2021 and December 31, 2023. We observed 37 cases of electrocuted victims, out of which 33 cases (89%) were male, constituting the majority of the victims. According to data published by the National Crime Records Bureau in 2022,[11] there were 12,971 registered cases of electrocution, with 12,918 fatalities recorded, the majority of which were male. This male predominance may be attributed to men often being the primary breadwinners in families and being involved in occupations related to electricity, construction, painting buildings, etc. Similar findings were noted in studies conducted by Sumangala et al.[12] (2023), Shobhana et al.[13] (2022), as well as Reddy et al.[14] (2015).

The study found that electrocution deaths occurred across a wide age range, from 2 years to 61 years. The death of a 2-year-old resulted from contact with an electric immersion water heater rod. This tragedy could have been avoided with
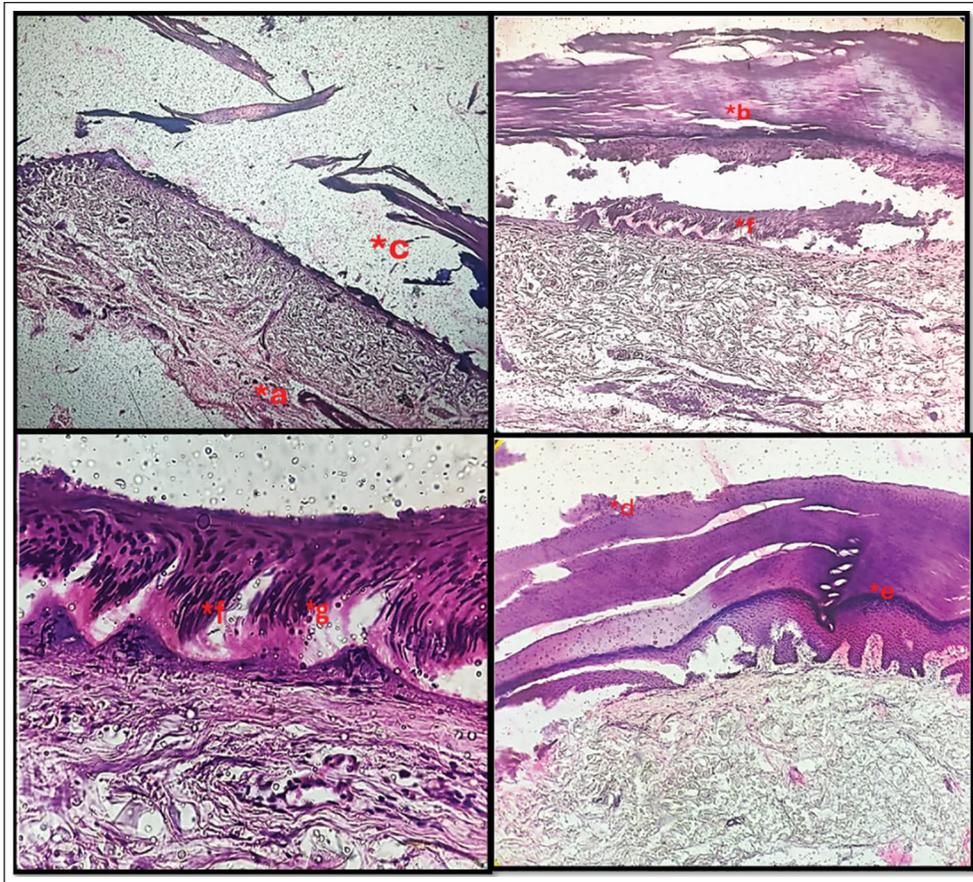
Figure 4. Histopathological Findings of Skin Samples. (a) Collagen Degeneration in the Dermis Accompanied by Coagulation Necrosis, (b) Degenerative Alterations in the Keratin Layers, (c) Dermo-epidermal Separation, (d) Hyperkeratosis, (e) Micro Vesicle Formation, (f) Nuclear Streaming, and (g) Pyknosis of the Nucleus.

relative ease, at least in theory. Kuhtic et al.[15] (2012) study proposed the idea of improving parental awareness regarding potential dangers and the importance of adjusting their conduct when in the presence of their children.

The majority of fatalities fell within the 21–30 age group. In this age bracket, individuals often begin working to support themselves and their families, often undertaking risky jobs like climbing to elevated areas. This increases the chance of accidental exposure to high-voltage wires and transformers, many workers are unaware of the electrical hazards in their workplaces, heightening their vulnerability to electrocution.

Consequently, the high rate of work-related electrocution fatalities may be attributed to insufficient safety training for both workers and employers. The occurrence of a significant number of fatalities within the third decade of life is also noted in studies done by Sachil Kumar et al.[16] (2014), Akber et al.[4] (2021), and Tirasci et al.[6] (2006).

Most of the fatalities occurred during the rainy season (July–October), followed by summer (March–June). The elevated rate during the rainy season aligns with findings from studies conducted by Kumar et al.[16] (2014), Sachin Giri et al.[7] (2019), and Rautji et al.[8] (2003). Seasonal fluctuations in

electrocution-related deaths are attributed to variations in humidity, moisture levels, and individual behavior. The higher incidence of electrocution deaths during summer could be attributed to increased humidity and heightened usage of electrical appliances such as coolers, air conditioners, and refrigerators, Reddy and Sengottuvel[14] (2014). Moreover, excessive sweating during the hot and humid season contributes to a decrease in skin resistance to electric current, thereby increasing the risk of electrocution as described by Spies et al.[17] (2006).

In electrical accidents, skin injuries can vary from mild redness to severe burns affecting deep tissues, including charring. Additionally, in certain situations, there might be no evident signs of electrical injury.

In our research victims with electrical contact marks, also known as entry wounds, were present in 23 cases (62.2%), both electrical contact marks and electrical grounding marks, also known as exit wounds, in 13 cases (35.1%), and no visible alterations were detected on the skin electrical burn marks in 1 case (2.7%). The upper extremities were overwhelmingly the most frequent area (73%) of initial contact with the electrical source. The occurrence of an electric burn mark arises when

the skin closely interacts with an electrical conductor, enabling the current to pass through the skin's high resistance, resulting in tissue heating. Additionally, fluids beneath the skin may produce steam. Conversely, if the contact is less secure and an air gap forms between the conductor and the skin, the current may traverse this space, leading to a lesion caused by sparks (known as a spark lesion). This burn, resembling sparks, is caused by exceptionally high temperatures, leading to the carbonization of the keratin layer, as noted in the present study and also observed in other study conducted by Bellini et al.[18] in 2016, Kuhtic et al.[15] in 2012 and Michiue et al.[19] in 2009.

In this study, among the 37 cases examined, the most frequently observed histopathological finding was nuclear streaming, followed by dermo-epidermal separation with vacuolation, and coagulative necrosis alongside collagen degeneration in the dermis. This study shares similarities with research conducted by Sachin Giri et al.[7] (2019), and Shobhana et al.[13] (2022), who identified nuclear streaming, dermo-epidermal separation, and coagulative necrosis as significant histopathological findings. These findings were instrumental in resolving cases where the exact cause of death was uncertain.

Conclusion

This study underscores the persistent threat posed by accidental electrocutions in both occupational and domestic settings. The majority of fatalities occurred in young adults, highlighting the need for increased awareness and safety training, particularly in high-risk occupations. Histopathological examinations emerged as a valuable tool in diagnosing electrocution-related injuries. Seasonal variations in electrocution incidents underscore the importance of adapting safety measures to environmental factors. Implementing targeted safety programs and promoting awareness among the general public, especially parents and caregivers, are essential steps in reducing the incidence of electrocution fatalities. By addressing these challenges, we can work towards creating safer environments and preventing needless loss of life due to electrical accidents.

Declaration of Conflicting Interests

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

Ethical Approval

Ethical clearance was obtained from the Institutional Ethics Committee (Letter No: ECR/83/INST/ GOA/ 2013/RR-20, Reference Code: GMCIEC/2024/07).

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Informed Consent

Informed consent was obtained, and participant confidentiality was safeguarded through the encryption of their identities.

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Profile of Mechanical Asphyxia Cases: An Autopsy-based Study at a Tertiary Care Centre in Raichur

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Abstract

Mechanical asphyxia, a significant cause of accidental, suicidal, and homicidal deaths, merits comprehensive analysis to inform prevention strategies, medico-legal investigations, and the administration of justice. This prospective observational study profiles cases of mechanical asphyxia based on autopsy findings from a tertiary care centre in Raichur over 18 months.

Out of 450 autopsied cases, 79 were identified as mechanical asphyxia deaths. Data on demographic characteristics, the manner and circumstances of death, and time of the incident were collected and analysed.

The majority of the asphyxia cases involved males (60.8%) with a notable prevalence in the 21–40-year age group (55.7%). Urban residents constituted 59.5% of the cases. A significant number of victims were unmarried (58.2%) and unemployed (67.1%). Morning times saw the highest occurrence of asphyxial deaths (29.1%). Suicide was the predominant manner of death (72.2%), with hanging being the most common method employed (60.8%). Familial disputes, academic failures, and financial crises were the primary circumstances leading to these deaths.

This study underscores the complex interplay of demographic and socioeconomic factors in mechanical asphyxia deaths, with a significant finding being the high incidence among young, unemployed males. The timing and methods of asphyxial deaths shed light on potential preventive measures. The data advocate for targeted public health interventions and underscore the need for comprehensive support systems to mitigate factors contributing to the high rates of mechanical asphyxia, particularly those stemming from social and economic pressures.

Keywords

Asphyxia, mechanical asphyxia, prospective study, autopsy, suicide, hanging

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Introduction

The word Asphyxia is derived from Greek (*a* = not; *sphyzein* = to throb), meaning without throbbing or pulse, which occurs soon after asphyxia, that is, on exclusion of air from lungs.[1] Asphyxia can be Mechanical/violent, Pathological Toxic/Chemical, Positional, Traumatic or Iatrogenic.[2] Mechanical asphyxia per se is a broad term in which enough external pressure is applied to the neck, chest or other areas of the body, or the body is positioned in such a way that respiration is difficult or impossible.[3] The phenomenon of mechanical asphyxia is frequently encountered in a wide array of incidents, including accidents, traumatic physical altercations, and occupational hazards, and is of particular interest within forensic pathology due to its implications in cases of homicide and homicide involving compressive forces.

Suicide is the most common form of Mechanical Asphyxia, in India, it has seen a dramatic rise over the years. In 2022, the suicide rate increased by 4.2%, reaching 12.4 per 100,000 population—the highest recorded rate in 56 years.[4] The regional variations and cultural contexts further complicate the understanding of other forms of mechanical asphyxia across India. Raichur, a district in Karnataka, exemplifies this challenge. While national data offers a broader perspective, it

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often fails to capture the specific nuances and contributing factors at the regional level. Limited research exists on the patterns and risk factors contributing to mechanical asphyxia deaths in Raichur, hindering the development of targeted preventive measures and interventions.

This prospective study, conducted at the autopsy centre of a Tertiary Care hospital in Raichur, aims to address this critical gap by investigating the incidence, demographics, and circumstances surrounding mechanical asphyxia deaths in the region. By leveraging the unique vantage point of an autopsy centre, we got a deeper understanding of the often-hidden stories behind these fatalities.

Materials and Methods

This research was conducted as a prospective observational cross-sectional study at a tertiary care centre in Raichur, extending from November 2019 to April 2021. The primary focus was on delineating a comprehensive profile of mechanical asphyxia cases through an autopsy-based analysis.

The samples for this study were selected based on cases that were brought for autopsy at the Department of Forensic Medicine. Inclusion criteria were set to encompass all autopsied individuals within the study period, where mechanical asphyxia was determined as the cause of death, as confirmed by detailed autopsy reports. Excluded from the study were cases where the cause of death was unclear or pending further investigation, and cases without comprehensive autopsy records.

The study collected a wide array of data on each case, which included Demographic Information, Circumstantial Data, Inquest details, and Autopsy Findings. The collected data underwent analysis using Microsoft Excel.

The study protocol was reviewed and approved by the Institutional Ethics Committee vide IEC letter number Staff/2019-20/12, dated 17-09-2019. In all cases, data was anonymised and handled with the utmost confidentiality to respect the privacy of the deceased and their families.

Results

The detailed analysis of autopsy reports conducted over the specified period revealed that out of 450 autopsy cases, 79 (17.6%) were identified as deaths due to mechanical asphyxia. The demographic, educational, and circumstantial data associated with these cases provided a comprehensive view of the profile of mechanical asphyxia victims within the study's context.

Demographic Profile

Gender Distribution

Among the 79 mechanical asphyxia cases, there was a predominance of male victims (60.8%, $n = 48$) compared to female victims (39.2%, $n = 31$), resulting in a male-to-female ratio of 1.5:1.

Age Distribution

The most affected age group was 21–40 years, accounting for 55.7% ($n = 44$) of the cases. This was followed by the 0–20-year age group, which comprised 31.6% ($n = 25$). Ages 41–60 years represented 10.2% ($n = 8$) of the cases, and the least represented group was those older than 60 years, accounting for only 2.5% ($n = 2$).

Area of Residence

A significant portion of the deceased hailed from urban areas (59.5%, $n = 47$), compared to 36.7% ($n = 29$) from rural areas, with 3.8% ($n = 3$) of the cases having an unknown residential status.

Socio-economic and Marital Status

Marital Status

The study found that 38.0% ($n = 30$) of the deceased were married, 58.2% ($n = 46$) were unmarried, and the marital status was unknown in 3.8% ($n = 3$) of the cases.

Level of Education

A noticeable distribution was seen in the educational levels of the victims, with 34.2% ($n = 27$) having completed a degree and 32.9% ($n = 26$) having received higher primary education. Illiterate individuals and cases with unknown educational backgrounds and illiterate constituted 6.3% ($n = 5$) of the total cases (Figure 1).

Employment Status

Employment status was another critical factor, with 29.1% ($n = 23$) of the deceased being employed, whereas a significant majority (67.1%, $n = 53$) were unemployed. The employment status of 3.8% ($n = 3$) of the cases remained unknown.

Circumstantial Data

Time of Incidence

The distribution of the incidents over different times of the day revealed that 29.1% ($n = 23$) occurred during the morning, followed by 25.3% ($n = 20$) in the afternoon, and 20.3% ($n = 16$) in the evening. The early morning incidents accounted for 16.5% ($n = 13$), and night-time incidents were at 5.1% ($n = 4$), with 3.5% ($n = 3$) of incidents having an unknown time of occurrence (Figure 2).

Manner of Death

Suicide was identified as the most common manner of death, accounting for 72.2% ($n = 57$) of the mechanical asphyxia
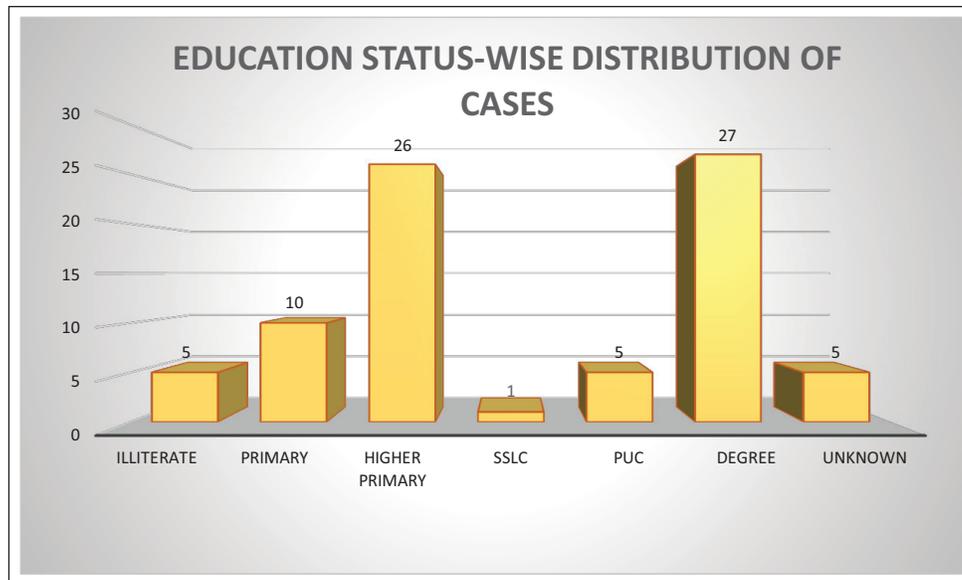
Figure 1. Distribution of Education Status-wise Distribution of Cases.
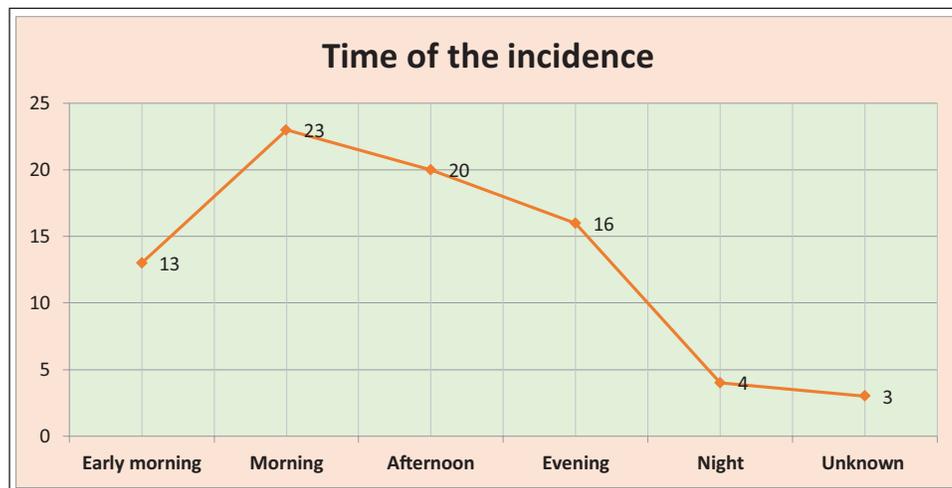
Figure 2. Distribution of Incidents in Relation to the Time of the Day.

cases. Accidental deaths followed at 20.3% ($n = 16$), and homicidal deaths were the least at 5.1% ($n = 4$), with an unknown manner of death in 2.4% ($n = 2$) of the cases.

Motive of Death

Apart from accidental asphyxia in 20.25% ($n = 16$) cases, the various personal and social factors were attributed as motives in the remaining cases ($n = 63$), those including family issues (29.1%), failure in exams (13.9%), love failures (10.1%), financial issues (8.9%), job-related issues (6.3%), marriage problems (3.8%), and no motives mentioned in 3.8% of the cases. Chronic illness was mentioned in 2.4% of the cases, and in the homicidal cases, revenge was noted as a motive in 1.3% (Figure 3).

Types of Asphyxia

Incidence of Asphyxial Deaths

Hanging emerged as the most common type of mechanical asphyxia (60.8%), followed by drowning (32.9%). Traumatic asphyxia accounted for 3.8% of the cases. Other forms, including strangulation and throttling, constituted 1.3% of the mechanical asphyxial deaths (Figure 4).

Discussion

The current study aimed to elucidate the profile of mechanical asphyxia cases through an exhaustive analysis of autopsy reports at a tertiary care centre in Raichur. The findings
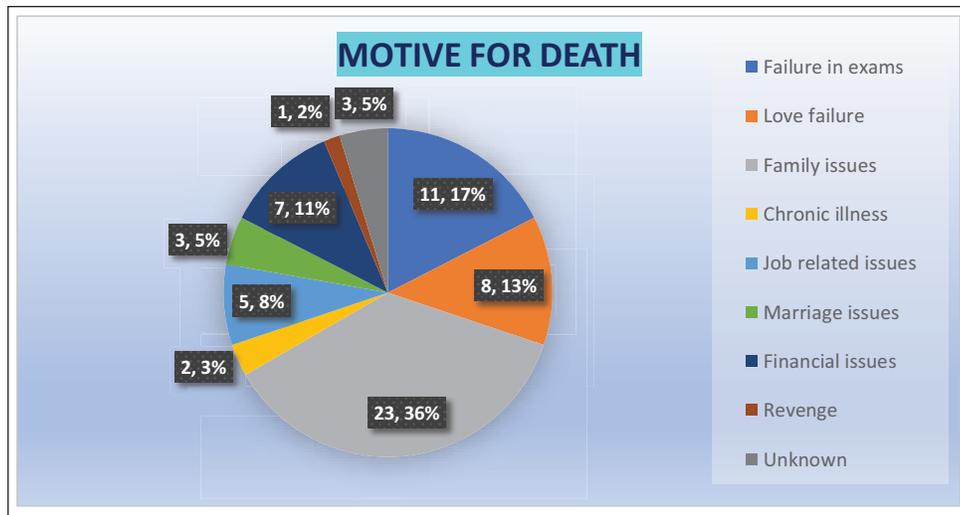
Figure 3. Distribution of Motive for Death Among All Cases.
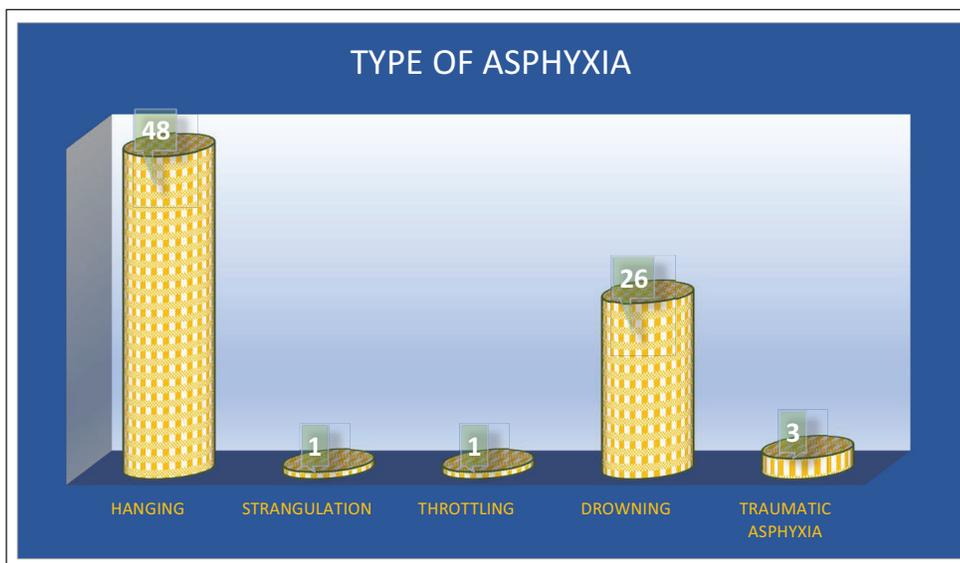
Figure 4. Distribution of Type of Mechanical Asphyxia.

corroborate and expand upon existing literature, offering insights into demographic patterns, socioeconomic status, educational backgrounds, and the circumstances leading to mechanical asphyxia deaths.

Demographic and Socioeconomic Observations

The predominance of male victims in mechanical asphyxia cases, with a male-to-female ratio of 1.5:1, aligns with similar studies conducted in various locations within Karnataka, including Raichur,[5] Chitradurga,[6] Tumkur,[7] and Manipal,[8] and also across various places across India like Khammam (Telangana),[9] Thane (Maharashtra),[10] Rajkot (Gujarat),[11]

Delhi,[12] Varanasi (Uttar Pradesh),[13] Jorhat (Assam),[14] suggesting males are at a higher risk, except one study conducted at Guntur (Andhra Pradesh)[15] where females (51.8%) outnumbered the males. This gender discrepancy, male majority, could be attributed to various socioeconomic factors and possibly greater exposure to risky behaviours among males. The most affected age group, 21–40 years, emphasises the vulnerability of younger adults, resonating with findings from other regions of Karnataka and India, indicating a national pattern where the prime of working age is most susceptible to such occurrences.

The higher occurrence of cases in urban areas (59.5%) could be linked to increased stressors and lifestyle factors

Table 1. Regional Comparison of Types of Asphyxia.

Place (Study Year)	Hanging (%)		Drowning (%)		Strangulation (%)		Other (%)	
Present study	**60.8**		**32.9**		**1.3**		**5.0**	
Comparison with other places within Karnataka								
Raichur[5] (2015–2016)	46.8	↓	44.68	↑	2.12	↑	6.4	↑
Chitradurga[6] (2012)	77.77	↑	8.33	↓	5.55	↑	8.35	↑
Tumkur[7] (2006–2010)	61.19	↑	31.96	↓	4.34	↑	2.51	↓
Manipal[8] (2008–2011)	56.3	↓	34.81	↑	8.8	↑	–	
Belgaum[19] (2009)	61.16	↑	28.15	↓	3.88	↑	6.81	↑
Comparison with other places outside Karnataka								
Khammam[9] (2016–2018)	52.02	↓	18.91	↓	5.4	↑	**23.67**	↑
Guntur[16] (2017)	64.8	↑	20.1	↓	9.3	↑	5.8	↑
Hyderabad[20] (2018)	68.5	↑	27.1	↓	4.4	↑	–	
Thane[10] (2006–2015)	62.5	↑	31.2	↓	1.4	↑	4.9	↓
Delhi[12] (2012–2013)	60.73	↓	19.63	↓	14.6	↑	5.04	↑
Jorhat[14] (2012–2013)	78.12	↑	20	↓	**0.94**	↓	**0.94**	↓
Varanasi[13] (2016–2018)	57.33	↓	24	↓	4.67	↑	14	↑
Rajkot[11] (2014–2016)	37	↓	52	↑	5	↑	6	↑
Ahmedabad[17] (2008–2010)	**82.48**	↑	**3.09**	↓	**14.43**	↑	–	
Patiala[18] (2000–2003)	**24.3**	↓	**59.4**	↑	5.4	↑	10.9	↑

Note: Data of the present study and the highest and lowest percentage among each type of asphyxia are marked in bold. The ↑/↓ signs indicate comparison data of more % or less % with respect to the present study.

associated with urban living. Socioeconomic aspects, including marital status and employment, illustrated that the majority of victims were unmarried and unemployed. Unemployment was a notable factor, implicating financial stress and potential social isolation as significant contributors to the risk of mechanical asphyxia, particularly in cases classified under suicides.[16] The data on marital status has shown a reversal trend in Raichur[5] as compared to a similar study conducted in the year 2015–2016 in which married victims (65.9%) were more than unmarried. A similar married victim majority was also found in the studies conducted at Chitradurga[6] (63.9%) and Khammam[9] (69.69%).

Educational Background and Circumstances Leading to Death

Moreover, the varied educational backgrounds, with a considerable portion having completed higher education, suggest that educational attainment does not necessarily mitigate the risk of encountering circumstances leading to mechanical asphyxia. Our observations showed a bit of variance with the similar studies conducted at Varanasi[13] and Khammam[9] in which the majority of victims completed higher secondary (24.66% and 44.59%), and illiterate accounted for 16.67% and 28.37%, respectively. This area highlights that higher education might, in some contexts, heighten expectations and

pressures, thereby not acting as a protective factor against stressors leading to suicidal tendencies.

The circumstances leading to death highlighted familial issues, academic pressures, and financial woes as predominant triggers behind suicidal asphyxiation, aligning with the broader societal challenges noted in prior research conducted at various locations across India, like Guntur,[15] Varanasi,[13] and Ahmedabad.[17] This underscores the need for targeted mental health interventions and support systems in addressing these pervasive stressors.

Temporal Patterns

The distribution of incidents across different times of the day indicates a varied temporal pattern, with the majority occurring in the morning (29.1%). Similar observations were found in the study conducted at Manipal[8] and Varanasi,[13] however, the majority of cases were during evening and night hours in the study conducted at Chitradurga.[6] This temporal clustering may be influenced by factors such as routine activities, stressors related to daily life, or altered circadian rhythms. The time of incidence further provides vital clues into potential preventive strategies, with mornings and afternoons being particularly critical periods. The detailed exploration of temporal patterns contributes to understanding the context in which these incidents unfold.

Manner of Death

The observed preeminence of suicide as the primary manner of death in mechanical asphyxia cases (72.2%) underscores the critical role of mental health considerations in understanding and preventing such incidents. The high incidence of suicides aligns with studies conducted at Tumkur,[7] Manipal,[8] Varanasi,[13] and Rajkot[11] emphasising the urgent need for mental health interventions and community support systems. The association of family issues (29.1%) and academic failures (13.9%) as primary motives for suicide emphasises the complex interplay of social, familial, and educational factors contributing to psychological distress. Addressing these underlying issues is paramount for effective suicide prevention strategies.

Accidental deaths, comprising 20.3% of cases, which is higher compared to other studies (Tumkur[7] and Varanasi[13]), necessitate a closer examination of environmental and situational factors contributing to unintentional asphyxia. Public awareness campaigns on safety measures, especially in high-risk settings, may play a crucial role in mitigating accidental deaths. Homicidal deaths, though relatively less frequent (5.1%), highlight the need for a meticulous investigation into the motives and circumstances surrounding these cases. The rate is much lower compared to the study conducted at Rajkot[11] (15%), Manipal[8] (10.3%), Tumkur[7] (9.58%), and Varanasi[13] (6.67%). The presence of revenge as a motive (1.3%) emphasises the interpersonal dynamics contributing to homicidal asphyxia cases, necessitating targeted interventions in interpersonal conflicts.

Types of Asphyxia

The prevalence of hanging as the most common type of asphyxial death (60.8%) is consistent with past literature (Table 1) except in a study conducted at Patiala,[18] reflecting the ease of accessibility and lethality of this method. Drowning, the second most frequent type (32.9%), underscores the significance of water safety measures, especially in regions with water bodies, except in studies conducted at Patiala[18] and Ahmedabad.[17] The occurrence of traumatic asphyxia (3.8%), strangulation, and other less common methods (1.3%) requires a nuanced investigation into the circumstances surrounding these incidents. Understanding the mechanisms and contexts of different asphyxial deaths is crucial for tailoring preventive measures and intervention strategies.

Conclusion

Our study highlights the critical need for a comprehensive approach to address the multifaceted nature of mechanical asphyxia and contributes to the understanding of these deaths by highlighting the prevalence among young adults, males, and unemployed individuals. Suicide remains a significant concern, and addressing its underlying causes, particularly family issues and academic pressure, is critical. By understanding the demographic, educational, and circumstantial nuances, stakeholders can develop more targeted interventions to mitigate the factors contributing to these fatalities. Further research is considered crucial to develop effective prevention and intervention strategies to reduce the burden of these preventable tragedies.

Limitations

Our study is limited by its limited prospective nature and single-centre design, hindering generalisation to the broader population. Additionally, the study period may not capture seasonal or long-term trends.

Future Directions

Further research is needed to explore:

1. In-depth analysis of motives associated with suicide and self-harm, particularly among young adults.
2. Gender-specific risk factors for mechanical asphyxia deaths.
3. Prevention strategies targeting specific populations and methods of asphyxia.
4. Culturally appropriate interventions to address mental health challenges and promote help-seeking behaviours.

Declaration of Conflicting Interests

Ethical Approval

Approved by Institutional Ethical Committee vide IEC letter dated 19-10-2019.

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Informed Consent

Informed consent is obtained from the next-of-kin of the deceased.

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An Autopsy-based Study on Victim Profile and Pattern of Thoracic Injuries in South India

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Abstract

Trauma is a major cause of disability and death in India, and thorax injuries constitute an important aspect of trauma. Our aim was to study the nature and pattern of thoracic injuries among the cases autopsied in the study period. Aforementioned data was compiled, analyzed and results drawn after 306 cases involving chest injuries were examined.

The deaths due to chest trauma constituted 24% of the total autopsied cases, and 84% were males. The majority of the deceased belonged to the age group of 21–40 years (N = 124 and 40.5%). Rib fractures were the most common skeletal injuries, followed by clavicular and sternal fractures. Head and neck (56%) were the commonest sites of other injury associated with chest injuries, followed by limb fractures (23%). Common internal organs injured were liver (15%), lung (8.9%), and heart (2.7%). Among accidents, road traffic accidents (RTA) was the most common cause of chest injuries, and pedestrians (24.4%) were the main affected than occupants of vehicles. In the majority of cases, the cause of death was hemorrhagic shock (51.5%), followed by trauma to head (27%).

This study concluded that road accidents were the most common causes of chest trauma, followed by railway accidents. Males in the productive age group (21–50 years) were the most affected in trauma. Lacerations and contusions were the most common injuries in intra-thoracic organs. Efforts can be made to decrease fatalities through the strict implementation of safety measures at workplaces and creating public awareness about road safety and precautions.

Keywords

Accidents, fatality, chest trauma, road traffic accident (RTA)

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Introduction

Thorax is the upper part of the trunk, consisting of a musculoskeletal cage, a wall and an internal cavity. The chest wall surrounds the thoracic cavity with 12 pairs of ribs and articulates with 12 thoracic vertebrae posteriorly and with the sternum anteriorly. The diaphragm is the key muscle in thoracic cage movements of breathing.[1] The chest or thorax is regarded as one of the most vulnerable regions of the body to injury. Due to its accessible anatomical position and circumscribed dimension, the thorax is a major site of impact in any form of trauma.[2] Typically, chest injuries are caused by blunt mechanisms such as motor vehicle accidents or penetrating mechanisms such as stabbings.[3]

Trauma to the thorax is responsible for over 70% of all deaths following road traffic accident (RTA), and blunt trauma to the chest alone is fatal in 10% of cases, rising to 30% if other injuries are present. In most cases, the cause of death is hemorrhage.[4] Thoracic cage injuries like abrasions, contusions and rib fractures are found in all fatal falls. Multiple fractures of the whole cage, including the sternum and thoracic spine, are found when the height of the fall is more than 25 meters along with ruptures and contusions of the lungs and heart.[5] In spite of high mortality rates, about

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80%–90% of patients with life-threatening thoracic injuries can be managed by simple interventions like tube thoracotomy.[6] In this study, thoracic injuries were evaluated according to age, sex, pattern, and manner of causation of injuries, and period of survival after sustaining injury. All this information can be used in policymaking to reduce mortality and develop preventive strategies.

Materials and Methods

This study was aimed at knowing the epidemiologic pattern and characteristics of chest injuries in the autopsied trauma cases in our region and also to find out the mechanism of injury causation. This was a prospective study based on 306 trauma-related deaths with thoracic and other associated injuries brought to the mortuary of a referral center in Tirupati among the total of 1251 autopsies conducted during the study period (January 2014 to June 2015).

All the trauma victims with thoracic injuries were considered for the study and examined. The cases screened for thoracic injuries were mostly resulting from RTAs, railway accidents, assault, firearm injuries, falls from height, and falls due to electric shock. Relevant information regarding the circumstances of trauma and the course of death was obtained from friends, relatives, and police sources. The details were noted in a proforma prepared for the study, and data were analyzed. Cases with thermal injuries over the chest and those with head injuries from RTAs and assaults without chest injuries were excluded.

No conflict of interest or financial help has been taken from any source.

Observations

The pattern of injuries is as shown in the form of tables.

Table 1 shows the age and gender-wise distribution of fatal thoracic injuries. Of the 306 cases studied, 257 were male (84%). The majority of the victims belonged to the age group of 21–40 years ($N = 140$, 43.5%).

Table 2 shows the manner of causation of thoracic injuries with the number of casualties. RTAs were the most common cause of chest trauma (65%), followed by railway accidents (17%) and assault cases, including stab and firearm injuries (10%).

Table 3 shows the distribution of fatal thoracic injuries in terms of the period of survival of victims after the trauma. More than half of the victims were found spot dead (52%).

Table 4 shows the type and distribution of thoracic injuries. Rib fracture (37.3%) was the most common type of

Table 1. Age and Gender Wise Distribution of Cases.

Sl. No.	Age Group (Years)	Number of Cases	Male		Female		Total%
			N	%	*N*	%	
01	01–10	04	02	0.6%	02	0.6%	1.2%
02	11–20	13	12	4.2%	01	0%	4.2%
03	21–30	62	57	18.6%	05	1.6%	20.2%
04	31–40	70	63	20.5%	07	2.3%	22.8%
05	41–50	63	49	16.1%	14	4.7%	20.8%
06	51–60	56	42	13.7%	14	4.7%	18.4%
07	61–70	32	28	9.1%	04	1.2%	10.3%
08	71–80	07	03	0.9%	04	0.7%	2.3%
	Total	306	257	83.9%	49	16.1%	100%

Table 2. Manner of Causation of Thoracic Injuries.

Sl. No.	Manner of Causation	Total	Percentage
01	Road traffic accidents (RTA)	199	65.0%
02	Railway injuries	51	16.6%
03	Assault cases (firearm, stab and blunt force injuries)	32	10.5%
04	Fall from height	15	4.9%
05	Unknown	07	2.3%
06	Wall collapse (Traumatic asphyxia)	02	0.7%
	Total	306	100%

Table 3. Period of Survival After Trauma.

Sl. No.	Period of Survival	Number of Cases	Percentage
01	Spot death	165	54%
02	During transport	024	08%
03	In hospital death	116	38%
	Total	306	100%

Time Interval (Hrs = Hours)	0–6 Hrs	6–24 Hrs	24–48 Hrs	>48 Hrs	Total
Number of cases	178	87	32	9	306
Percentage	58.1%	28.4%	10.5%	3.0%	100%

Table 4. Nature and Distribution of Fatal Thoracic Injuries.

Sl. No.	Type of Thoracic Injury	Number of Cases	Percentage
	Fractures	**344**	**74.2%**
01	Rib fractures (± hemothorax)	253	54.6%
02	Clavicular fractures	37	8.0%
03	Sternal fractures	35	7.5%
04	Thoracic vertebral fractures	19	4.1%
	Lung injuries	**77**	**16.6%**
01	Lung lacerations	59	12.7%
02	Lung contusions	21	4.5%
03	Stab wounds-lung	07	1.5%
	Heart injuries	**24**	**5.2%**
01	Heart lacerations	19	4.1%
02	Stab wounds-heart	03	0.6%
03	Heart contusions	02	0.4%
	Miscellaneous (diaphragmatic ruptures, rupture of aorta, stab wounds-Aorta)	**08**	**1.7%**
	Total	463	100%

Table 5. Association of Other Bodily Injuries Contributing to Death.

Sl. No.	Associated Injuries	Seen in Number of Cases	Percentage
1.	Head injury	139	45.4%
2.	Limb (fractures)	73	23.8%
3.	Neck	31	10.1%
4.	Abdomen and pelvis	24	7.8%

Table 6. Type and Distribution of Accident Victims with Thoracic Injury.

Sl. No.	Type of Victim	Rider/ Driver	Occupant/ Pillion Rider	Total Cases	Percentage
01	Pedestrian	–	–	73	23.8%
02	Bike rider/ pillion rider	37	17	54	17.6%
03	Car/jeep	04	12	16	5.2%
04	Auto	03	14	17	5.6%
05	Tractor/ truck/bus	04	11	15	4.8%
07	Bullock cart/ road roller	03	–	03	0.9%
9	Bicycle	03	–	03	0.9%
10	Others			125	40.8%
	Total			306	100%

Table 6 shows the types of victims with thoracic injuries in road accidents. Pedestrians (24.4%) were the most affected type of victim.

Table 7 shows the various causes of death among fatal cases involving thoracic injuries. Hemorrhagic shock (51.5%) was the major cause of death among the victims, followed by head trauma (27.7%).

Table 8 shows the pattern of diurnal variations. The majority of the incidents occurred between 6 pm and 12 am (29%) and the least between 6 am and 12 pm (17%).

Figure 1 depicts the agent causing chest injury.

Discussion

Injuries to the chest are mostly accidental, occasionally homicidal, and very rarely suicidal due to the accessible nature of the chest. In chest trauma, the mortality is very high unless promptly recognized and treated, the margin of safety is very slim, and initial care dictates the final result with varying degrees of severity. Chest injuries occurred in almost

skeletal injury, followed by clavicular (8.2%) and sternal fractures (7.7%). Internal injuries were lacerations of the lung (13%), followed by those of the heart (4.2%).

Table 5 shows the association of other bodily injuries contributing to death.

Table 7. Causes of Death in Cases Involving Thoracic Injuries.

Sl. No.	Cause of Death	Number of Cases	Percentage
01	Hemorrhagic shock	156	50.9%
02	Trauma to head	85	27.7%
03	Trauma to spine	09	2.9%
04	Neurogenic and septic shock	10	3.2%
06	Miscellaneous (shock lung, peritonitis, asphyxia)	05	1.6%
07	Multiple and other injuries	41	13.4%
	Total	306	100%

Table 8. The Pattern of Diurnal Variations.

Sl. No.	Diurnal Variations	Number of Cases	Percentage
01	12.00 AM–06.00 AM	52	17%
02	06.00 AM–12.00 PM	81	26.4%
03	12.00 PM–06.00 PM	76	25%
04	06.00 PM–12.00 PM	88	28.6%
05	Not known	09	03%
	Total	306	100%

70%–80% of RTAs. Sternal fractures are common due to steering wheel injuries in blunt trauma to the chest.[7] It was found that thoracic injuries were common, affecting about half of all trauma patients. Demirhan et al. observed that the mortality rate was 6.8%, and the morbidity rate was 3.3% among chest trauma patients in their study.[8] High mortality was explained by the multisystem injuries sustained by victims, among which the head injury is the most common associated lethal injury.

Age and Gender

In this study, the majority were in the age group between 21 and 40 years ($N = 132$ and 43%), that is, 21% of victims were aged between 21 and 30 years, followed by 22% between 31 and 40 years. Victims of extreme of ages (<10 years and >60 years) were fewer. Males outnumbered their female counterparts with 84% of fatalities, which was reflected in a study in Wardha where the most commonly involved age group was 21-40 years, with males outnumbering the females in a ratio of 6.7:1.[9] Minimum cases in the extremes of ages could be related to the care taken by the accompanying people and less mobility in this age group. B. Shetty et al.[10] and Katageri et al.[11] mentioned that the male-to-female ratio is more than 6:1 and 7.5:1, respectively, and commonly noticed between 21 and 40 years. Male preponderance is explained by the fact that the males work outdoors more compared to their female counterparts to earn a livelihood and are involved in driving, traveling, etc. Meera and Nabachandra[12] in their study of 120 cases of blunt thoracic injuries observed that the commonest
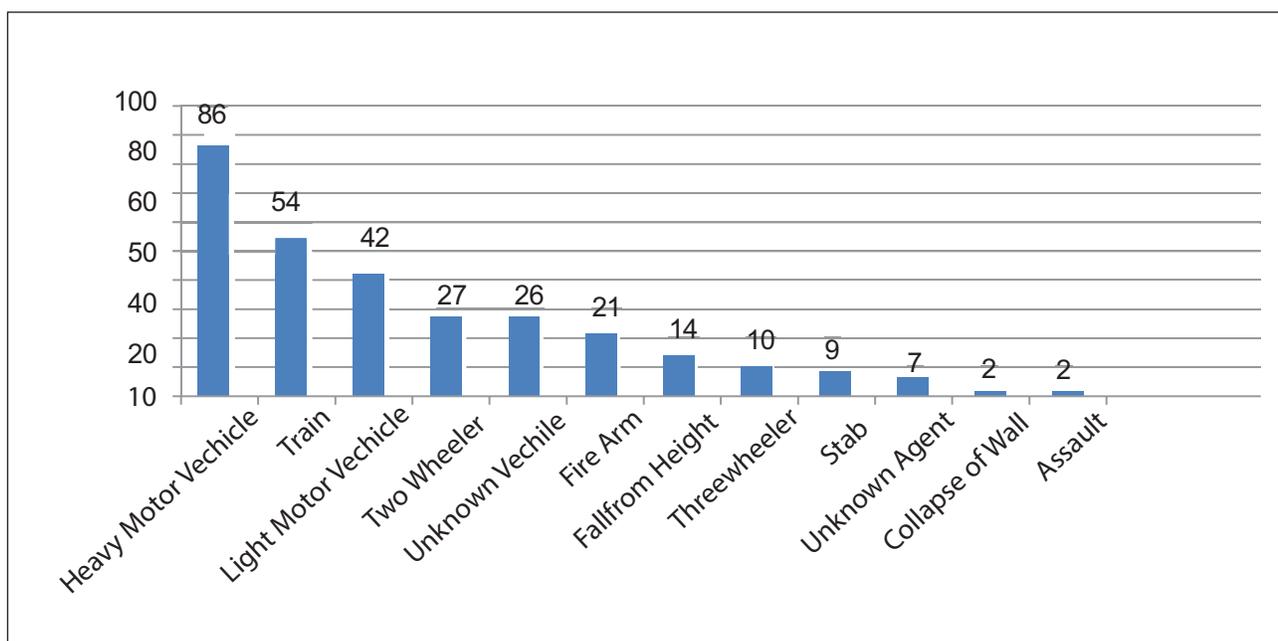
Figure 1. The Agent Causing Chest Injury.

age group of the victims was between 21 and 30 years, while the study by Abdul Raoof et al.[13] in 2019 found that the most commonly affected age group in chest trauma was 30–40 years (31%) and the commonest causative agent was RTA (71.4%), followed by firearm injury (19.4%).

Manner of Causation

In our study, the most observed manner of injuries were RTAs (65%), followed by railway injuries (16.6%), assault (10.5%), and falling from height (4.9%). This was in accordance with the studies[8,13] where in 65% of cases, blunt injury to the thorax was mostly related to traffic accidents. Partial agreement was observed with a study[12] in which vehicular accidents were the leading cause of blunt trauma to the thorax (86.40%), followed by assault by blunt weapon (8%), while another study[9] stated that vehicular accident was the leading cause of fatalities in 66.48%, followed by railway accidents in 19.55%, and domestic accidents in 3.91%. In a study on thoracic injuries in RTA victims by Agnihotri and Agarwal,[14] the most common victims were pedestrians (76), motorcyclists (15), cars (6), and cyclists (5), The pattern seen in external thoracic injuries was contusion in 58, abrasion in 32, laceration in 10, and incised wound in four cases in the same study.

Bad roads, speeding, inadequate and unscientific traffic planning, low use of helmets, consuming alcohol, using phone while driving, and violations of the traffic rules have contributed to much of the occurrences of RTAs. This may be explained by the fact that RTAs constitute a complex phenomenon with multiple causative factors. The rise in the number of RTAs can be attributed to the rashness of the drivers and carelessness of pedestrians, tiredness, fatigue of the drivers, and poor visibility due to a lack of street lights, rapid urbanization, and tremendous growth in road transport.

Period of Survival of Victims

In this study of 306 autopsied cases with thoracic injuries, 54% of victims died on the spot, 38% died while undergoing treatment in the hospital, and 8% died during transportation. Regarding time interval, 178 cases died between 0 and 6 hours after trauma (58%), 87 cases died between 6 and 24 hours (28%), 32 cases died between 24 and 48 hours (10.5%), and nine cases died after 48 hours (3%). A study in 2012 on various patterns of injuries due to falling from height observed that in 57.69% of cases, death occurred on the spot.[15] The percentage of victims of thoracic trauma who died at the place of incidence was 47% in a study by Meera and Nabachandra, which is similar to our study. This study is also comparable to one in Vijaypur (2016), which showed 48 of 104 cases of deaths due to chest injuries had died on the spot, while 33 cases died on their way to the hospital and 21 cases died while undergoing treatment in the hospital.[16] Deaths occurring within the first few hours may be due to the grave injury itself, which rapidly progresses to death. Deaths that occur between the first few hours of trauma and the next 24 hours result from secondary complications. In cases of survival for two or more days, apart from the primary injury, the associated infection, metabolic and nutritional disorders may play a role in causing death.

Pattern of Injuries

Similar to many studies[9,11,12,16] on the chest injuries, rib fracture was the most common skeletal injury in thorax in our study (55.8%), followed by the fracture of the clavicle (8.2%). The fractures of sternum and thoracic vertebrae occurred in 8% and 4% of cases, respectively. In injuries to the thoracic cavity, the lung is the most injured organ involved in 77 cases, followed by heart in 24 cases, which is similar to an autopsy-based study in Pune.[17] Diaphragmatic and aortic ruptures and stab wounds of the aorta were seen in eight cases. Lungs are easily injured as they occupy most of the space in the thoracic cage, making them more vulnerable to injury from trauma. This study is comparable with studies where blunt chest trauma in vehicular accidents in nearly 50% of the cases was associated with ribs and sternal fractures.[12,13]

Chest wall bones were the commonest bones to have been fractured in most types of victims of RTA, but pelvic and limb bones were also more commonly involved in pedestrian victims as compared to other types of victims of RTA.[18] Our study disagrees with Ismail and al-Refaie; in their study over a period of 10 years examined 472 victims and observed rib fractures in only 23.9% of cases, pulmonary contusions in 27.1%, and lacerations in 6.9% of cases.[19] The lung (61%) was the most common organ involved in the chest trauma, as per many studies.[10–14] Bhimrao et al.[20] in their study on injuries from RTAs noted that the thorax was more commonly involved than the abdominal region and abrasion was the commonest external injury, followed by contusion and laceration.

Association of Other Injuries

The associated bodily injuries contributing to death were head injuries in 45.3%, limb injuries (fractures) in 23.6%, and neck in 10% of cases. Our study varies slightly with the study by Aggarwal et al.[21] who conducted a study on 100 cases of RTA referred for autopsy in Patiala and found that the most common site involved was head and face (85%) followed by lower limb (65%) and upper limb (54%). Head injury was the most common injury, present alone in 130 cases (46%) and in 220 (78%) cases along with other injuries in a study on RTA victims in Bhopal.[22]

Distribution of Accident Cases with Chest Injuries

Pedestrians (24.4%), followed by two-wheeler occupants (18%), four-wheeler occupants (16%), and auto (5.2%), were the commonest victims involved in RTA and most of the patients succumbed on the way to hospital (56%) as observed in our study. A study on deaths due to RTA revealed that pedestrian injuries are seen in 38.3% of the victims, motor vehicles in 28.1%, and motorcycle crash in 19.9%.[19] Motorcyclist occupants formed the largest group (28.84%) followed by the pedestrians (25%) in a study in Chitradurga, Karnataka[11] where pedestrian had sustained head injuries (84.61%). This can be explained by the fact that majority of the road users are pedestrians thus exposed to higher risk of accidents.

With regard to agents causing thoracic injury in this study, heavy motor vehicles (HMV) constituted 28% followed by train 16.6%, light motor vehicles (LMV) 14%, and two-wheelers 9% and firearms (7%) (Figure 1). A study[10] mentioned that HMV constituted 44.4% which is similar to this study, while another study[13] noted LMV (car) as the commonest offending vehicle in 36.3% of cases, followed by HMV (truck) in 29% and two wheelers in 14.5% of cases. Two-wheelers were the commonest type of victim's vehicle in contrast to HMV (truck/bus) as the major type of offending vehicle causing thoracic injuries in RTA, as claimed by Bhimrao et al.[20] while four wheelers (46.9%), followed by two wheelers (37.9%), were the vehicles involved as in a study in Northeast India.[23]

Causes of Death

It is well known that head injury is the leading cause of death in trauma patients. Head and neck (56.2%) were the commonest sites of injury associated with chest injuries followed by limb fractures (23.6%) in our study. Hemorrhagic shock (51.5%) was the main cause of death in thoracic injuries, followed by trauma to the head (27%) and poly trauma (13.6%). Study by Dhillon et al. was identical to ours in that hemorrhagic shock was the cause of death in the majority of the victims.[24] Meera and Nabachandra stated that the commonest cause of death was hemorrhagic shock in chest trauma combined with head injury in 48.8% of cases.[12] The high percentage of deaths was due to severe hemorrhage from rib and sternal fractures with associated injury to vital organs like the heart, lung, liver, and spleen and injury to great vessels.[8] Gupta et al. concluded that head and neck injuries were responsible for most deaths (70%) in their study on two-wheeler accident cases in Davanagere (Karnataka), though the commonest thoracic injury in riders and pillion riders was rib fracture.[25]

Diurnal Variation

From this study, it was observed that the maximum number of cases were reported between 6 PM and 12 AM (29%), followed by 6 AM and 12 PM (27%), 12 PM and 6 PM (25%), and the least were found between 12 AM and 6 AM (17%). The reason for the occurrence of more number of incidents, especially during the hours of late evening and night, may be due to poor visibility of drivers, due to sudden focusing of headlights of opposite vehicles, tiredness and exhaustion of the drivers, and being unaware of the bad/risky road conditions during the journey. It was noticed that, in a study on RTA victims in 2017, most of the accidents occurred in the afternoon hours between 12 pm and 6 pm, followed by late evening.[23]

Conclusion

Trauma in the form of accidents, assaults, and railway injuries is the most dreaded problem in present-day society. This study concluded that RTA is the most common cause of chest trauma, followed by railway injuries. Males in the productive age group (21–50 years) are most susceptible to chest trauma, as they are more involved in work, driving, or traveling. The fatality rate in chest trauma cases depends on the severity of thoracic injuries and associated injuries like head injuries as contributing factors. Rib fracture is the most common thoracic wall injury, and lung laceration is the most commonly seen intrathoracic lesion.

The increasing incidence of trauma and accident cases is adding more burden to the autopsy workload of the tertiary care hospitals and justifies the need for appointing emergency physicians and medico-legal experts both at primary and secondary health care centers to effectively cater to the trauma cases. The mortality due to trauma cases can be decreased if victims are transported to a trauma care center nearby at the earliest. The fact that majority cases were spot deaths affirms the urgency and priority of having a robust pre-hospital trauma care and quick ambulance services.

Good awareness about the traffic rules and helmet use, both among riders and pedestrians, helps in the prevention of RTAs. Public education regarding the ill effects of speed driving, drunken driving, and the usage of phones while driving should be given. Improving road conditions and training the public on pre-hospital management of trauma and basic life support (BLS) can go a long way in saving many more lives.

Declaration of Conflicting Interests

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

Ethical Approval

Institution's Ethics Committee (IEC) was taken on November 26, 2014, prior to starting the study (as shown in Appendix A, page no.17).

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Informed Consent

Not applicable.

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Appendix

Appendix A. Institutional Ethics Committee (IEC) Approval Letter.
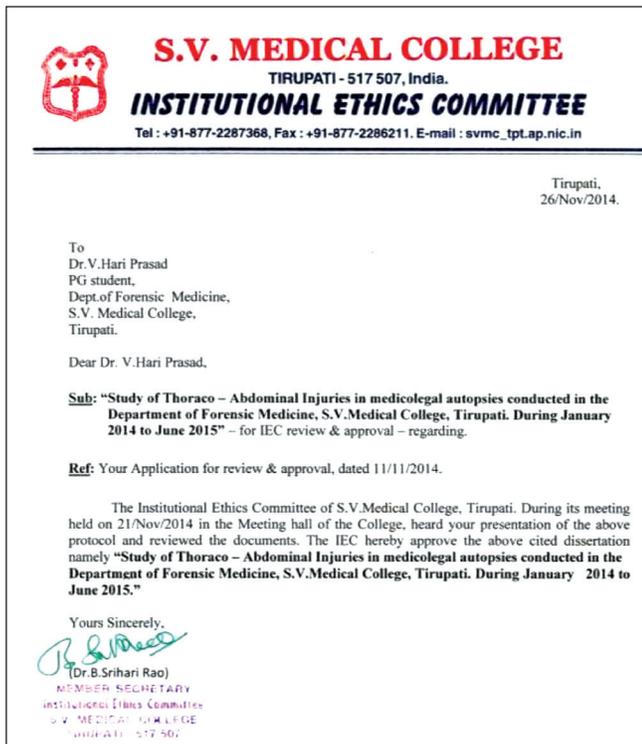
Pic 2. Picture of Rib Fracture (PM 151/2014).

Appendix B. Pictures Related to Chest Trauma.

Pic 3. Picture of Rupture of Liver (PM 293/2015).

Pic 1. Picture of Firearm Injury (PM 209/2015).

Study of Suicide Among Coaching Students in Kota Rajasthan

Pradeep Meena[1], Ashok Moondra[1], Poorvi Moondra[1] and Sachin Kumar Meena[1]

Abstract

Suicide represents a significant cause of mortality in India; however, the estimated suicide rates derived from the national crime records bureau are not dependable. The current suicide rate in India stands at 10.3 per lakh. Over the past 30 years, this rate has risen by 43%, while the male-to-female ratio has remained consistent at 1.4:1. Kota, a renowned coaching hub in India, is experiencing a daily influx of students. These students are arriving from various states, including Uttar Pradesh, Bihar and Madhya Pradesh. The objective of this study is describing the risk factors and different methods adopted for suicide, along with age sociodemographic profile in education city Kota by coaching students. It is a descriptive type of observational study. GMC Kota and attached group of hospitals were used during the study period. Hanging was reported as common methods to commit suicides. Males were more commonly involved (81.5%). National Eligibility cum Entrance Test (NEET) aspirants were involved which was more than 92.59%. Students from Uttar Pradesh were most commonly involved which was 37.03%. There is a notably higher prevalence of stress among male coaching students compared to their female counterparts. Additionally, 17-year-old students are more susceptible to suicidal tendencies, with factors such as academic pressure, financial difficulties, romantic failures and a lack of interest in studies contributing to this issue. Students are resorting to straightforward methods, such as hanging, to commit suicide.

Keywords

Suicide, coaching city, students

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Introduction

The Government of India classifies a death as suicide, when it is an unnatural death and the intent to die commenced within the person. Suicide is the major cause of death in the present world. In every country, the ratio suicides are increasing day by day. According to Durham French biologist, suicide is death resulting directly and indirectly from a positive or negative act of the victim himself[1] Suicide is a major socioeconomic and public issue worldwide.[2] Moreover, there is a reason for the person to end his or her life. Those who have previously attempted suicide are at a greater risk of future attempts. The commonly used method of suicide varies between countries, and depends on the availability of effective means. Common methods adopted for suicide include hanging, pesticide poisoning, burns and drowning. Suicide is a worldwide phenomenon, though its rate varies from place to place. Kota is very progressive city for education where coaching students are coming from all over India. As per the details of coaching institutes, up to July 2022 more than 3 lakhs student admitted with dreams of success. Top coaching of Kota managed to admit more than 1.27 lakhs registration which was registered as world record in Guinness Book of World Record.[3] As the number of students increase in Kota, the cases of suicide also increase from the coaching city. This study targets to describe the most common methods adopted and to describe the sociodemographic profile and risk factors that lead to suicide. We can prevent suicide only by finding out the reasons behind it. The reasons may vary from region

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Table 1. Total Postmortem Versus Suicide Cases (1 October 2022 to 30 September 2023).

Total Postmortem	Suicide	Other
990	253 (25.55%)	737 (74.45%)
	Coaching student	Other
	27	226

to region as they face different problems. So, it is necessary to find out the stressors affecting that particular region. To find out such stressors, medicolegal autopsy may have to be followed by psychological autopsy.

Materials and Methods

This study was conducted on the dead bodies brought for postmortem examination at the mortuaries of Government Medical College and allied hospitals during the period of October 2022 to September 2023 with the alleged history of suicides by various methods. A standard Proforma was prepared and the details collected with consent of parents. We collected all data of victim's history, behaviour, relation with friends, food habits performance in class, attendance and how often they contacted their family, any issue that they share with their parents. The information was gathered in an Excel spreadsheet and extracted our findings. The manner of death was collected from relatives, police and law authorities. Only confirmed cases of suicides from hanging and poison jump from height were included in the descriptive study at GMC Kota and allied hospitals during the study period.

Inclusion Criteria

1. Study subjects are dead bodies brought for medicolegal autopsy with a history and postmortem finding being consistent with suicide.
2. Students aged between 15 and 24 years of any of the coaching institute.

Exclusion Criteria

1. Students who were attached with distant learning programme.
2. Students who were taking coaching for competitive examination after graduation.

Observation and Results

A total of 990 medico-legal autopsies were conducted during the study period, out of which 253 deaths were suicidal and among those cases, and 27 victims were coaching students (Table 1 and Figure 1). Most of the victims of suicide by any
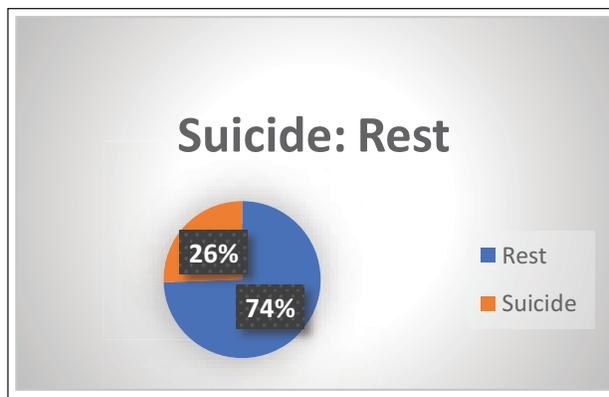
Figure 1. Number of Autopsy.

form of asphyxiation except suffocation were of 17 years age which was followed by the age 18 years (Table 2 and Figure 2). Total 23 students preferred hanging for suicide which was most common method followed by jump from height 2 (Table 3) 23 out of the 27 hanging deaths, belonged to the 15–25 years age group (Table 2). Out of 27 coaching students death, 22 students belonged to the male sex and 5 students were females. 25 students were preparing for National Eligibility cum Entrance Test Undergraduate (NEET UG) and 2 for Indian Institute of Technology Joint Entrance Examination (IIT JEE) competitive exam (Tables 3 and 4). Out of 27 cases, 10 cases belong to UP followed by 8 cases from Bihar state (Table 5). This research indicates that educational stress was the primary factor leading to suicide in 20 out of 27 cases. It is also observed that out of total suicides 81.42% were male students and rest 18.57% were female (Table 6). This was followed by financial and family issues, which contributed to 6 cases. Additionally, 1 death was attributed to a love affair (Table 7). Academic stress and emotional instability may be the possible reasons for higher involvement in this age group.

Discussion

Kota is the Manchester of coaching centre; lakhs of students come every year for coaching of medical and engineering. The age group of students is usually between 15 and 25. This age group is most vulnerable to depression, loneliness, curious about new things, usage of smartphone which make them vulnerable to harmful sites. Study conducted by Sreedevi et al. observed that hanging was the most common method adopted followed by poisoning, burns and drowning in the study population. Burns were chosen as a preferred method by females, same findings observed by us.[4] Hanging has been found to be the preferred method because fans are available in all rooms and ligature materials such as bedsheet and dupattas are also easily accessible. Males also outnumbered the females in study conducted by Sharija et al.[5] The study
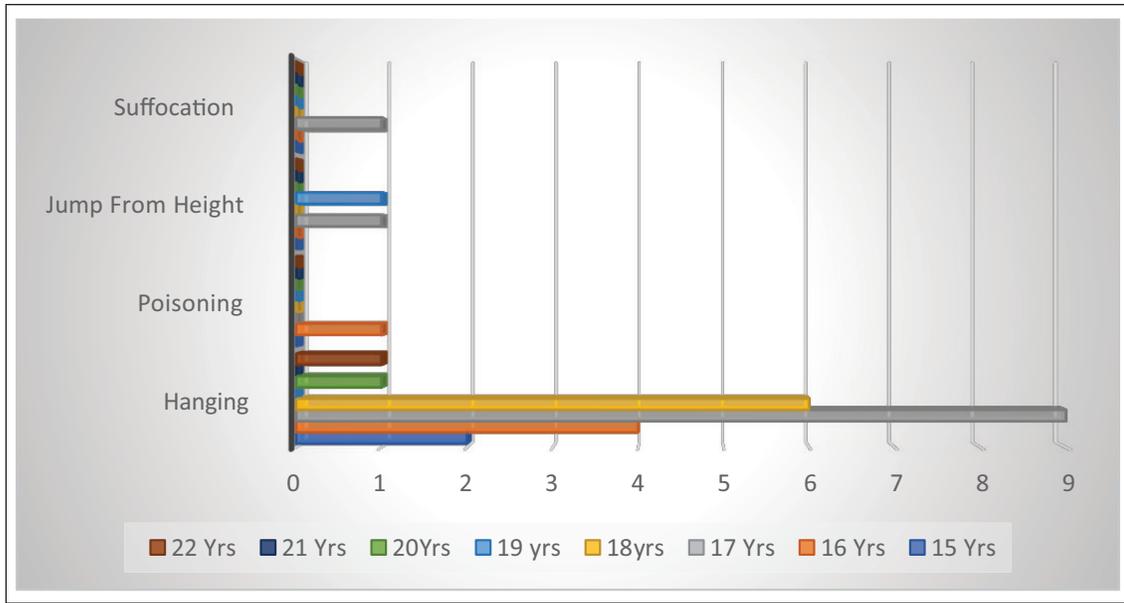
Figure 2. Age-wise Difference in Method Used for Suicide.

Table 2. Age-wise Difference in Method Used for Suicide.

Method of Suicide	15 Years	16 Years	17 Years	18 Years	19 Years	20 Years	21 Years	22 Years	Total
Hanging	2 (8.69%)	4 (17.39%)	9 (39.13%)	6 (26.08%)	0	1 (4.34%)	0	1 (4.34%)	23
Poison	0	1 (100%)	0	0	0	0	0	0	1
Jump from Height	0	0	1 (50%)	0	1 (50%)	0	0	0	2
Suffocation	0	0	1 (100%)	0	0	0	0	0	1
Total	2 (7.40%)	5 (18.51%)	11 (62.96%)	6 (22.22%)	1 (3.70%)	1 (3.07%)	0	1 (3.07%)	27

Table 3. Gender-wise Difference in Method Used for Suicide Deaths.

Method Used	Male	Female	Total
Hanging	19 (70.3%)	4 (14.81%)	23 (85.18%)
Poison	0	1 (3.7%)	1 (3.70%)
Jump from height	2 (7%)	0	2 (7.40%)
Suffocation	1 (3%)	0	1 (3.07%)
Total	22 (81.5%)	5 (18.5%)	27 (100%)

Table 4. Course in Which Student Preparing for Exam.

Course	Number
NEET	25 (92.59%)
I.I.T.	2 (7.41%)
Total	27

Table 5. State-wise Student Distribution.

Rajasthan		Bihar		UP		MP		Maharashtra		Jharkhand	
M	F	M	F	M	F	M	F	M	F	M	F
2	1	8	1	10	1	0	1	1	0	1	1

Figure 3. Anti-hanging Device.

Table 6. Male Versus Female % Among Suicide Case.

Total Suicide	Male	Female
253	206	47
100%	81.42%	18.57%

Table 7. Risk Factor Affected Student Life Most.

Risk Factor	Male		Female	
Study	16	72.72%	4	80%
Depression	5	22.2%	1	20%
Love affair	1	4.5%	0	
Total	22	100%	5	100%

conducted by Meera et al. observed that 57.14% used rope as a ligature material[6]; in our study hanging was the common method for suicide. Behera et al observed in their study that family dispute was he most common cause for suicide, whereas in our study it is academic pressure as our study is conducted on coaching students.[7] Vijayakumari in her study[8] and Sharma et al.[9] observed that most vulnerable age group is 21–30 years, whereas in our study it is 18 year.[9,10] Coaching centers administer weekly assessments and display the results on a notice board. Students who score lower marks are transferred to a different group according to their rankings. Additionally, results are communicated to their parents, which can be quite stressful for the students. There are no physical activities, no one at hostel to take care of them, food quality is also compromised in many hostels. Most of students take admission in dummy school; hence, they do not get any exposure to extracurricular activities such as sports and annual functions and their attendance is managed by the concerned school authorities. Students from same part of state will develop a relation of brotherhood and several students of the develop romantic feelings towards other students resulting in love affairs, which when fail can lead to students taking the drastic step of attempting suicide. All of these conditions make students mentally weak and depressed, hence, leaving them more prone to suicidal tendencies.

Conclusion

For reducing the incidence of suicide among students, administration must take steps like stopping weekly test or stop coaching management to publish results on notice board, stop changing their batch, make them to organize sports activities other cultural function, appoint local guardians for students, install C.C.TV cameras in hostel campus, regular monitoring of students activities, make groups of students to take care of themselves and make students to take care of each other and motivate each other. Administration should also make hostel owners to install anti-hanging rods in hostel rooms (Figure 3), make a toll-free help line no. for students and publish it publicly. We are happy to inform that after completing the study till January 2024 no coaching committed suicide.

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Evidentiary Rigour of a DNA Match

Preet Inder Singh[1], Mandar Ramchandra Sane[2], Dasari Harish[3], Amandeep Singh[3] and Ajay Kumar[4]

Abstract

DNA evidence has been used in India in criminal and civil matters since 1989. Despite the use of DNA fingerprinting evidence in trials, it is not 'generally accepted' by Courts, as against the technique of fingerprinting, which has been used for decades as incriminating evidence. Further, its acceptability as forensic evidence in Indian courts has been challenged, citing relevance and reliability. The current article provides a review of the conventional principles of evidence admissibility in courts and its pertinence related to DNA evidence in India in the backdrop of civil and criminal case laws of the country.

Introduction

DNA profiling is a technique used to chemical divide the DNA complex into fragments that form a unique pattern and then to match that identity profile with the pattern obtained by similarly testing a suspect's blood specimen.[1] DNA profiling, as a forensic test, was first put to use by Sir Alec Jeffreys in 1985 in the case of a maternity dispute.[2] It was first applied to a criminal investigation in 1986 in England after two girls, aged about 15 years, were found raped and strangulated near the village of Narborough.[3] It arguably has been the most dramatic advancement that has ever occurred in the field, but its acceptance, especially in the Courts, has not been without challenges.[4] Though DNA evidence has met the challenges in some countries through scientific reasoning and legal scrutiny, it happens to be in a struggling phase in India. Science has no borders for its acceptability; however, the novel scientific evidence must meet the standards of legal acceptability according to the constitutional and legislative provisions of different jurisdictions. This article attempts to clear the issues regarding the current status of the admissibility of 'DNA evidence' in India.

Background: Acceptability of New Scientific Evidence

Scientific evidence is accepted by courts only if it stands the scrutiny of legal tests set by case laws. These legal tests or guidelines for scientific evidence have not been adequately explored or discussed in Indian courts for DNA evidence. A review of such legal tests is discussed, followed by their applicability in Indian courts as regards DNA evidence.

Legal Tests and Cases

The admissibility of scientific evidence has evolved through the legal challenges of accepting it. The acceptance of evidence depends on its relevance and reliability. Various tests that apply before evidence is admissible are as follows:

1. **Frye's test ('general acceptance' test):** Frye mandates that a novel technique must pass through an experimental stage in which the scientific community scrutinises it. Only after the technique has been tested

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successfully in this stage and has passed into the demonstrable stage, it will receive judicial acceptance. It means that expert scientific evidence should not be deemed admissible unless and until the methods and principles on which it was based have achieved widespread acceptance in the relevant discipline. Thus, through this statement, Frye had delegated the burden of evaluating complex scientific merits, from judges to the scientists who are the experts in their particular discipline. It was argued that Frye's standard is only a proper condition for taking judicial notice of scientific facts and not a suitable criterion for the admissibility of scientific evidence, and relevant conclusions supported by a qualified expert witness should be received for its admissibility. Frye's test was accepted in the landmark judgement of *People v. Castro*[5] and *Kunhiraman v. Manoj*.[6]

2. **Daubert's guidelines:** In Dauberts's case, the court held that an expert's scientific testimony must establish a standard of evidentiary reliability, and in order to admit evidence as scientific, it must be both relevant and reliable. The factors can be summarised as follows[7]:

   a. Whether the theory or technique can be or has been tested (its falsifiability, refutability or testability);
   b. Whether the theory or technique has been subjected to peer review and publication;
   c. The known or potential error rate of a technique;
   d. Whether the theory or technique has received 'general acceptance'.

Novel evidence must go through the rigour of *Daubert* before it is admissible. Exclusions owing to procedural errors are usually beyond the control of the expert witness. Reliability factors relating to the exclusion of expert witness testimony may include failure to address reliability in the context of the case, use of unfounded statistics, failure to adhere to recognised standards, insufficient documentation of analysis, inability to clearly explain the methodology, custom experiments, lack of objective standards, the existence of observer bias, unrealistic proficiency testing and the insufficient relationship of expertise to facts of the case.[8]

3. **Doheny case:** Landmark guidelines have been laid down in 1996 when judgement was given in the Doheny case.[9] Several relevant points from this judgement can be summarised as follows[10]:
   a. The scientist should properly explain to the jury the nature of the match between the stain found at the crime scene and the suspect.
   b. The scientist should give the frequency of occurrence with which a matching DNA profile is likely to be found in the population.
   c. It might be appropriate if the scientist has the necessary data and statistical expertise to say how many people might be found to have matching profiles in the relevant section of the population.
   d. The jury would then decide, on all the information available, whether the stain originated from the suspect or some other individual with a matching DNA profile.

4. **Bayes' theorem:** Analysis by Bayes' theorem shows how the probability of a false positive could influence a proposition that a particular individual is the source of a biological specimen. It takes into consideration both scientific and non-scientific pieces of evidence. In the case of DNA evidence, the likelihood of a DNA match is affected by both the probability of a random match and the probability of a false positive. If we consider the traditional standard of proof in criminal cases, that is, the crime must be proved 'beyond a reasonable doubt' and the dictum that 'it is better that ninety-nine offenders should escape than that one innocent man should be condemned', then the posterior odds ratio must exceed 99:1. When the random match probability is of the order of 1 in one billion (10^{-9}), then it can meet this threshold. Such random match probabilities are possible when laboratories are able to match two single source samples over 10 or shorter tandem repeat (STR) loci, which is now a common norm.[11]

False positive results may occur while processing DNA matches. They may occur due to mislabelling, mixing the wrong ingredients or failing to follow routine precautions against contamination. Although the probability of such a false positive may be between 1 in 100 (0.01) and 1 in 1,000 (0.001), its impact on the strength of DNA evidence does not decrease if other pieces of evidences are fairly strong to implicate the accused. However, in cases where other pieces of evidence against the suspect are less, ignorance of the true probability of error creates a disturbing element of uncertainty about the value of DNA evidence.

However, courts may have different views on 'random match probability' and 'Bayes theorem'. As regards 'random match probability',[12] it is held that the statistical interpretation of DNA evidence is undeniably strong evidence pointing to a conclusion that the accused was the source of the incriminating DNA but is not the direct evidence of that fact. However, when DNA evidence is analysed in the light of non-DNA evidence by Bayes theorem,[13] it is likely to be rejected as it involves subjectively attaching numerical values to evidence and usurps the role of the jury. Thus, the court laid down a proper approach in this case by saying that the judge must treat the statistical evidence along with the other circumstantial evidence, not allowing it to displace or overwhelm the consideration of all material evidence. Similarly, if there is any evidence like an alibi, which suggests the absence of the accused while the crime was committed, it cannot be overtaken by DNA statistical evidence.

Legal Fallacy

While arguing the question of the probability of a match/no match of the DNA evidence in a court, one has to take into account two fallacies: the prosecutor's fallacy and the defendant's fallacy.

These can be dealt with by the following two questions:

1. If we assume that the accused is innocent, what is the probability of his DNA sample matching with the one recovered from the scene of the crime?
2. If we assume that the DNA profile of the accused matches with the one recovered from the scene, what is the probability that he is innocent?

This was explained by the US Supreme Court in *MC Daniel v. Brown*, 588 US 120 (2010)[14]:

If we consider that the frequency of a DNA profile match is 1in 10,000 and that the suspect's DNA profile matched with the one from the crime scene, the prosecutor may erroneously express that there is only a 1 in 10,000 chance that the suspect is innocent. (Prosecutor fallacy)

However, taking the same argument further, if the population of the city is 1,00,000, then there are at least 10 individuals in that city alone who would possess the same DNA profile as the suspect. The defence may argue that just in the city alone, there are at least 9 more people who could have committed the crime. (Defendant's fallacy)

Medical Predicament

It is a known fact that monozygotic twins have 100% similar DNA profiles. Theoretically, there are conditions wherein the DNA of two individuals may match. It has been observed that the individuals who had undergone successful bone marrow transplants show a true mixed profile of recipient and donor (in buccal and fingernail samples) or purely a donor's profile (in the blood), with the exception of hair, wherein the recipient's profile remains unmixed. Similarly, stem cell transplants may raise the risk of identical DNA, and such possibilities may have serious implications in civil and criminal law.[15]

Table 1. Criminal Cases that Scrutinised DNA Evidence.

Sr. No.	Case	DNA Evidence Accepted/Rejected	Reason	Court
1.	*MV Mahesh v. The State of Karnataka*[17]	Rejected	No prima facia case to order a DNA test, where the evidence adduced was enough to reach a conclusion. • Quantity that was required for the test was not sufficient • Bones did not belong to Beena • The method followed by the expert was not universally adopted.	Karnataka High Court (1995)
2.	Swami Shradhananda Case[31]	Accepted	It was the first in which the DNA analysis of the skeleton remains of an exhumed body was used as evidence in a court of law.	Supreme Court (2008)
3.	Beant Singh Assassination Case	Accepted	Helped in nabbing the main accused/suspected in the human bomb blast.	Punjab and Haryana High Court (2012)
4.	Naina Sahni (Tandoor Case)[32]	Accepted	Helped in establishing the identity of the victim.	Supreme Court (2013)
5.	Rajiv Gandhi Assassination Case[33]	Accepted	Not only helped in identifying the victims but also helped in establishing the identity of the accused by extracting the DNA from the flesh attached to the belt.	Supreme Court (2000)
6.	Priyadarshini Mattoo Case[15]	Rejected by ASJ (1999) Accepted by Delhi High Court (2006)	Rejected: 1. Tampered with swabs, slides and accused samples 2. Samples reduced when opened at lab 3. Delay in the submission of samples in Malkhawna 4. The accused was given the benefit of the doubt. Accepted: 1. There was no fault in the DNA testing 2. DNA was recovered from the sperm stains present over the swabs, slides and underwear.	Supreme Court (2010)

Table 2. Civil Cases that Scrutinised DNA Evidence.

Sr. No.	Case	DNA Evidence Accepted/Rejected	Reason	Court
1.	*Kunhiraman v. Manoj Case*[6]	Accepted	Manoj had inherited a total of 15 bands, which were not derived from the mother, but derived from the Kunhiraman alone; therefore, it was proved beyond doubt that the Kunhiraman is the biological father of Manoj.	Kerala High Court (1991)
2.	*Gautam Kundu v. State of West Bengal*[34]	Rejected	Supreme Court made the following guidelines: • The courts in India cannot order blood tests as a matter of course. • No one can be compelled to give blood samples. • It was not a violation of the right to personal liberty under Article 21. • Matrimonial courts have the power to order a person to undergo the test.	Supreme Court (1993)
3.	*Rohit Shekhar v. ND Tiwari Case*[35]	Accepted	A single-judge bench of the High Court ordered the DNA analysis, but ND Tiwari refused to give blood samples and applied against the order, but the double-judge bench of the High Court upheld the single-bench order. The Supreme Court also refused the stay order.	Delhi High Court (2012)
4.	*Banarsi Das v. Teeku Dutta*[36]	Rejected	DNA Tests cannot be directed as a matter of routine and can be conducted only in deserving cases. The case in discussion does not fall into that category.	Supreme Court (2005)
5.	*Nandlal Wasudev Badwaik v. Lata Nandal Badwaik*[37]	Accepted	Court held that 'when the conflict between a conclusive proof envisaged under the law and a proof based on scientific advancement accepted by the world community to be correct, the latter must prevail over the former'.	Supreme Court (2014)

Indian Scenario

The admissibility of DNA evidence in Indian courts can now be discussed considering the guidelines and various standards for accepting novel scientific evidence. Tables 1 and 2 summarise some of the seminal cases in India, both civil disputes and criminal cases. The first case where DNA evidence was accepted in India dates back to 1989 and 1991 when it was used in a paternity case.[6,12,15,16] 'General acceptance' by the scientific community was sought in its initial proceedings. Similarly, population statistics were used in an argument to prove the admissibility.[6] Since then, the DNA results are being given due recognition by Indian courts, and in most cases, it is accepted that if the DNA result does not match, then the identity of the person is not established and vice versa.[15]

In the case of *MV Mahesh v. The State of Karnataka*[17] *and Priyadarshini Mattoo*,[18] reliability factors not related to expert witnesses resulted in the rejection of the DNA evidence. The rigour of DNA evidence was tested by Daubert's guidelines without directly referring to them. It is apparent that in such cases while the court takes judicial notice of scientific evidence, conclusions are drawn by balancing the probative value of the evidence against the danger of unfair prejudice, confusion of issues or misleading the jury.

Population statistics for 'random match probability' has been a contentious issue and has recently been raised in the Arushi murder case by a London-based genomic expert.[19] It was highlighted that DNA evidence submitted by the prosecution was not powered by 'random match probability', that is, the lack of data regarding the frequency of alleles in the population. Doheny's case also highlighted the same contentious issue. Of late, population statistics of allele frequency are available through various studies from West Bengal,[20] Andhra Pradesh,[21] Karnataka,[22] Arunachal Pradesh,[23] Madhya Pradesh,[24] and other subsets.[25,26] These studies showed that there was genetic polymorphism to such an extent that these databases can be used for forensic identification. However, this argument remains unexplored by the Indian courts. The probable reason may be that DNA profiling complexities are perceived untenable and incomprehensible by defence counsel so as to explore its fallacy or that the frequency statistics may be beyond 10^{-9} (achieved by analysing 10 STRs). Indian

laboratories are analysing 16 STR loci, the product rule frequency of which may exceed the world population. Nevertheless, even though DNA profiling achieves exceedingly high levels of individualisation, it does not theoretically indicate uniqueness.

Another lagging area is the inappropriateness of DNA technology. In the world scenario, the Technical Working Group on DNA Analysis Methods (TWGDAM, 1988), National Research Council I (1992), National Research Council II (1996) and Scientific Working Group on DNA Analysis Methods (SWGDAM, 1999) were formed to address the general applicability and appropriateness of DNA technology to forensic science. They also acted as a forum to discuss issues, conduct studies and reach a consensus on the DNA methodologies to use.[27] It was stated that due to these working groups, now there remains no problem that could prevent the full use of DNA evidence in any court.[28] However, the use of DNA profiling as established evidence is still in the budding stage, and the government is struggling to legislate the 'DNA Technology (Use and Application) Regulation Bill, 2019' which purportedly intends to introduce the use of DNA for forensic and other purposes, provides guidelines for the appropriateness of DNA technology, administration and licensing of DNA laboratories and also seeks to create DNA database.[29] However, till it sees the light of day, the reliability and relevance of DNA evidence depend on legal 'acceptance' by the Apex Court.

By reviewing the seminal cases from India, a summary of the admissibility of DNA profiling evidence can be as follows:

1. The DNA technique and its scientific validity have received a judicial notice and have not been found to be disputable. It is accepted as such. As evidence, it withstood the standard of admissibility as mandated by Section 45 of the Indian Evidence Act, of 1872.[30] Expert scientific evidence is covered by Section 45, in which the relevance of an expert's opinion is closely connected with competency. Therefore, courts were considering the competency of the expert as a criterion for admissibility rather than the reliability of the scientific theory or technique he used for arriving at a conclusion.

2. Its admissibility as per Daubert's guidelines was considered, but each of its principles was not tested in every case.

3. Population statistics and random match probability were discussed in a few cases. However, courts did not refute the evidence even if such statistics were not up to the mark. Effects of other errors like false positives on the evidence reliability seemed to be unexplored.

4. The evidentiary value of DNA profiling was refuted only on grounds of sample handling and strength of the chain of custody thereto.

5. Courts have considered DNA evidence in corroboration with other non-DNA evidence in cases that may have varying cogency. A review of judgements shows that isolated DNA evidence was not presented by the prosecution to incriminate the accused.

6. DNA evidence was used for incriminating the accused and also for excluding the innocent.

7. DNA evidence was given priority over Section 112 of IEA related to the paternity dispute.

8. Many cases have relied upon 'general acceptance' or 'acceptance by the courts' as reasoning for the admissibility of forensic evidence. However, it is reasonable to comment that 'acceptance by the courts' does not qualify as 'general acceptance' under Daubert.

Declaration of Conflicting Interests

Ethical Approval

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Snake Envenomation in Raigarh—A Four-year Retrospective Study

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Abstract

Envenomation by poisonous snakes is an occupational hazard that causes considerable morbidity and mortality worldwide. Deaths due to snake bite envenomation in the Asian subcontinent contribute to the major part of the global burden of disease. Venomous snakes are found all over the world, and their envenomation leads to a significant proportion of loss of life every year. The present cross-sectional retrospective study was conducted from 2015 to 2019 in the Department of Forensic Medicine and Toxicology at Late Shri Lakhi Ram Agrawal Memorial Government Medical College, Raigarh (Chhattisgarh), to know the pattern and distribution of cases according to year and season, activity and period of survival of the victims in all age groups and both sexes. In our study, 2.72% of all autopsy cases involved snake bite incidents. Maximum cases occurred in the rainy season, that is, 60.66% and at night times (63.93%). Male victims (68.85%) outnumbered female victims (31.15%), and the most commonly affected age group belongs to 21–30 years, that is 36.07%. In most cases, the site of bite was the lower limb (65.57%), and the survival period was 0–6 hours, which is 52.46%. The majority of cases were reported in the agricultural field (49.18%). The majority of snake bites are accidental and require public awareness and speedy transportation of the patient to the medical facilities within the golden period. Ensuring the availability of Anti Snake Venoms and trained staff at the grassroot level may reduce the number of fatalities due to snake bites.

Introduction

Snake bite is an occupational hazard, causing considerable morbidity and mortality worldwide.[1] Worldwide, there are around 2,400 species of snakes, of which 10% are poisonous to human beings.[2] In Asia, up to two million people are envenomed by snakes each year, while in Africa, there are an estimated 4,35,000 to 5,80,000 snake bites occurring annually that need treatment.[3] Snakes can be classified into two categories: (a) poisonous and (b) non-poisonous. In India, around 90% of snake bites are caused by the 'big four' snakes-common krait, Indian cobra, Russell's viper and saw-scaled viper. According to WHO, it has been estimated that in India alone, as many as 2.8 million people are bitten by snakes, and 46,900 people die from snake bites every year.[4] In India, non-reporting of snake bite cases in hospitals in time remains the most common cause behind fatality.[5] Again, in the Indian context, snake bite is one of the critical medical emergencies, especially in rural populations, where the challenges of limited transport access, non-availability of Anti Snake Venom (ASV), and inadequate treatment facilities need to

be addressed at elementary levels to diminish the sufferings of human life. Chakma et al. (2020)[6] had discussed various reasons that could be attributed to the high mortality and morbidity due to venomous snakes and also provided recommendations on policy decisions, improvement on the quality of venom and anti-snake venom and promoting awareness on how to avoid snake bites. Doshi et al. (2019)[7] had made a significant task to aware urban and rural populations with respect to snakes and snake bite

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management. The present study was also aimed for educational purposes as well as to help the investigating agencies in the correct identification of snake bite cases and correlation with circumstantial findings.

Materials and Methodology

The present cross-sectional retrospective study was conducted in the Department of Forensic Medicine and Toxicology at Late Shri Lakhi Ram Agrawal Memorial Government Medical College, Raigarh (Chhattisgarh). Permission from the institutional ethical review committee was taken before the commencement of the study. All the post-mortem records of snake bite cases autopsied at the mortuary of Kirodimal Government Hospital, Raigarh (Chhattisgarh), were considered for the research study. All cases other than snake bites were excluded from the study. People of all age groups from both sexes were included in the study. The study was conducted from April 1st, 2015 to March 31st, 2019 (four years). All the snake bite envenomation cases were arranged after applying different criteria, such as year and season-wise distribution, age and sex-wise distribution, pattern of snake bite and the activity and period of survival of the victims. Then the data was tabulated and subjected to statistical analysis.

Observations and Results

In our study, 2.72% of total cases of autopsy were snake bite cases. We have found the maximum number of cases of death due to snake bites in the rainy season that is 60.66% and at night times (63.93%). The maximum number of victims were males (68.85%) followed by females (31.15%), and the most commonly affected age group belongs to 21–30 years, that is 36.07%. In maximum cases, the site of the snake bite was in the lower limbs (65.57%). In most cases, the survival period was 0–6 hours, which is 52.46%. In most snake bites occurred while the victim was working in an agricultural field (49.18%). Table 1 shows year-wise distribution of envenomation cases compared with total autopsy cases during the period of four years. The study shows that out of a total of 2,244 cases of autopsy, 61 cases of death were due to suspected snake bite, that is 2.72% of total cases of autopsy. Table 2 shows season-wise distribution of cases. In our study, the maximum cases of snake bites were found during the rainy season (60.66%), followed by the summer (29.51%). The least number of cases (9.84%) were recorded during the winter season. Table 3 shows the distribution of cases based on age and sex. According to table, the maximum number of victims belonged to the age group of 21–30 years, that is 36.07%. Male victims and female victims were 68.85% and 31.15%, respectively. The males were predominantly affected in all age groups except 11–20 years and 41–50 years. The

Table 1. Year-wise Distribution of Cases.

Sl. No.	Year	Total No. of Autopsy Cases	Total No. of Autopsy in Envenomation Cases	% of cases
1	2015*	473	8	1.69
2	2016	561	20	3.57
3	2017	514	11	2.14
4	2018	551	21	3.81
5	2019**	145	01	0.69
Total		2244	61	2.72

Note: *= From March 2015 to December 2018.

**= January 2019–March 2019.

Table 2. Season-wise Distribution of Cases.

Year	Summer (Mar–June)	Rainy (July–Oct)	Winter (Nov–Feb)	Total
2015	02	07	01	08
2016	07	08	03	20
2017	03	08	–	11
2018	06	14	01	21
2019	–	–	01	01
Total	18	37	06	61

Table 3. Age and Sex Wise Distribution of Cases.

Sl. No.	Age Group	No. of Cases
1	0–10	07 (M = 05, F = 02)
2	11–20	06 (M = 02, F = 04)
3	21–30	22 (M = 18, F = 04)
4	31–40	05 (M = 05, F =00)
5	41–50	07 (M = 03, F = 04)
6	51–60	09 (M = 06, F = 03)
7	61–70	05 (M = 03, F = 02)
8	71–80	00
9	81–90	00
10	91–Above	00
Total		61 (M = 42, F = 19)

table also shows that no case of snake bite was recorded after the age of 70 years. Table 4 shows that in the maximum number of cases, the site of the snake bite was in the lower limbs (65.57%). In the lower limbs majority (95%) of bites were found in the foot and adjacent parts like the ankles. In upper limbs, the most common site of bites was the hands, including fingers in 71.43% of cases. The table also shows that in most cases (96.72%) the site of snake bite on various body regions

Table 4. Distribution According to the Site of Bite.

Sl. No.	Site of Body	No. of Cases	%
1	Head, Face and Neck	04	6.56
2	Chest and Abdomen	01	1.64
3	Upper Limbs	14	22.95
	a. Arms = 01		
	b. Forearms including wrist = 03		
	c. Hands including fingers = 10		
4	Lower Limbs	40	65.57
	a. Buttocks = 01		
	b. Thighs = 01		
	c. Lower Leg, including ankles = 13		
	d. Foot including toes = 25		
5	Not Identified	02	3.28
Total		61	100

Table 5. Distribution of Cases According to Time of Envenomation.

Sl. No	Time of Snake Bite	Total No. of Cases	% of Case
1	Day time	22	36.07
2	Night time	39	63.93
Total		61	100

Table 6. Distribution of Cases According to Period of Survival of the Victim.

Sl. No.	Period of Survival	Total No. of Cases	% of Cases
1	0–6 hrs	32	52.46
2	6–12 hrs	09	13.11
3	12–24 hrs	09	11.48
4	24–48 hrs	05	6.56
5	48–96 hrs	02	3.28
6	>96 hrs	04	6.65
Total		61	100

was clearly identified, whereas in very small number of cases (3.28%) the site of snake bite on any part of body was not identified. Table 5 shows the distribution of cases according to the time of incidence of snake bite. Maximum cases of snake bites occurred during the night (63.93%). This can be attributed to the fact that most victims were bitten while resting or sleeping at night. Table 6 shows the survival period of the victims. In the maximum cases (52.46%), the victims could not survive beyond six hours. Out of the total 61 cases, only four victims survived for more than 96 hours. Table 7 shows the distribution of cases according to the place and the activity of the victims at the time of the snake bite. According to the table, the maximum number of cases occurred while

Table 7. Distribution of Cases According to Place and Activity of the Victim.

Sl. No.	The Activity of the Victim	Total No. of Cases	% of Cases
1	Working at home	03	4.91
2	Working in an agricultural field	30	49.18
3	Working in industry	01	1.64
4	Resting (Sleeping, Sitting, etc.)	21	34.43
5	Playing	05	8.20
6	Other places (forest, river, etc.)	01	1.64
Total		61	100

the victim was working in an agricultural field (49.18%). In 34.43% of total cases, the victims were bitten by poisonous snakes while resting.

Discussion

In our study, 2.72% of the total autopsy cases were due to snake bite, which closely matches with the study of Yogiraj et al. (2013),[8] where they found that 2.62% of total autopsy cases were of snake bites. We have found that the maximum number of cases of deaths due to snake bites were autopsied in the rainy season that is 60.66%, which is closely matching with the study of Singh et al. (2015).[9] In the present study, the maximum number of victims belonged to the age group of 21–30 years, that is, 36.07%, which closely matches with the study of Hareesh et al. (2018),[10] where they had reported 34.28% of the victims in the same age group. In most cases, snake envenomation occurred at night (63.93%), this finding closely matches with the study of Ali et al. (2018),[11] where they found that 67.1% of the total number of cases occurred at night. In maximum number of cases, the site of the bite was in the lower limbs (65.57%), which closely matches the study of Singh et al. (2015),[9] and Anjum et al. (2012),[12] where they found that in 67.09% and 69.2% of the cases of snake bite respectively, the bite mark was in lower limbs. In our study, the exact site of snake bite was clearly detected in maximum (96.72%) cases and minimum number (3.28%) of cases, the site of bite was not found in any body part of victims, the same finding was observed in the study of Jakhar et al. (2022)[13] at a tertiary care hospital in Haryana, where the researcher had confirmed that in very minimum number of cases evidence of bitemarks may not be found in the body of victims. In the present study, the survival period for the greatest number of victims was within 6 hours, that is 52.46%, which closely matches with the study of Anjum et al. (2012),[12] that is 48.5%. The percentage of male victims and female victims was 68.85% and 31.15%, respectively in our study, which also matches the study of Anjum et al. (2012)[12] where they found the total number of male victims to be 68.7% and female victims to be 31.3%, respectively. In our study the maximum number of snake bite cases occurred while the

victim was working in the agricultural field (49.18%), this finding also closely matches the study of Singh et al. (2015)[9] and Anjum et al. (2012),[12] where they found that 48.10% and 48.5% of snake bite cases respectively occurred while the victims were engaged in some agricultural activities.

Conclusion

Despite significant mortality and morbidity, snake bite remains an unnoticed disease in large parts of India. In our study, the epidemiological distribution of snake bite cases, their patterns, frequency, and seasonal variations nearly match with most of the studies in other geographic regions of India. Some other victim-related parameters, like activities and survival period of the deceased, were also showing consistent results. The study will add some value to the academicians and will also help the state agencies in statistics to strategize their plans. Still, more studies and research need to be done and analyzed in Chhattisgarh before taking sufficient preventive and corrective measures in a particular region. It is also worth mentioning that in case of death due to snake bites, the dependent family of the deceased gets compensation from the government, but it is not possible to recompensate the substantial loss of a family member through any means. Therefore, public awareness regarding first aid in snake bite cases, along with precautionary measures during peak snake bite seasons, should be taken. Also, the availability of ASV and critical care treatment facilities should be developed at the basic level to bring down the death rate.

Confidentiality

The identity of the deceased and autopsy surgeon was not disclosed.

Declaration of Conflicting Interests

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

Ethical Approval

IEC of Late Shri Lakhiram Agrawal Memorial Govt. Medical College had conferred their permission vide S. No / Med./ Ethics Commi. / 2021/66, Raigarh, Dated 24/03/2021.

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The informed consent has been obtained for the study.

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An Analysis and Profile of Paraquat Poisoning in and Around Khammam, Telangana

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Abstract

Morbidity and mortality of acute poisoning is a major serious health issue in the world. Paraquat is seriously known to be responsible for acute poisoning. The study aims to present the various aspects, including the epidemiological profile, clinical presentation, analysis of poisoning, outcome and cause of death. This is hospital based, prospective study of all the confirmed cases of paraquat poisoning. The paraquat poisoning patients were presented to the Emergency Department, Mamata General Hospital, attached to Medical College, Khammam, a one year study period from January 2022 to December 2022 was studied. A total of 16 paraquat poisoning cases were admitted during the study period. Complete data were collected and analysed from patients,attendants and hospital records. A total of 102 poisoning cases were admitted, out of which paraquat poisoning cases, 16 men were most involved. In this study, it was shown that most cases were reported from urban, married people.
Paraquat is widely marketed and easily available. The lack of availability of a specific antidote increases the paraquat fatality. The most common cause of death is respiratory failure. Paraquat causes renal failure by causing hypovolemia, circulatory failure, septicemia, and direct toxicity leading to multiorgan failure. The present study determines the most vulnerable age group, 31–40 years, males, married people from rural populations belonging to low socioeconomic strata. Most of people are employed in the agriculture sector. Most of the victims committed suicide due to financial problems.

Keywords

Paraquat, poisoning, lethality, multi-organ damage, fatalities

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Introduction

Paraquat, a herbicide and weed killer of the bipyridyl group, is widely encountered. Paraquat (C6H7N2]CL2) chemical composition is 1,1'-Dimethyl-4,4'-bi-pyridinium. It is commercially available in India in liquid form as GRAMOXANE (10%–30% conc) and in granule form as WEEDOL.[1] This toxic substance quickly gets absorbed through skin and mucus membranes and imparts cytotoxicity through free radical injury. As the highest concentration is found in lung tissue, pulmonary toxicity followed by liver damage is the main terminal pathology.[2] As little as a teaspoon of a concentrated amount of paraquat can result in death. In an adult human, the estimated fatal dose is about 30 mg/kg or 3–6 grams of paraquat ion, which is equivalent to 10–20 ml of 20% solution of paraquat.[3]

Aims & Objectives

The main aim of the present study is to describe the demographic profile, including seasonal variation, time, place of consumption, amount of poison consumed, manner of poisoning, clinical presentation, outcome, and cause of death.

Materials & Methods

This prospective study was conducted in an Emergency Department at Mamata General Hospital, the study period was one year from January 2022 to December 2022, in Khammam, Telangana. This prospective study was conducted in an Emergency Department at Mamata General Hospital, the study period was one year from January 2022 to December 2022, in Khammam,Telangana.

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Study Design

During this hospital-based study, a total of 106 poisoning cases were admitted, out of which 16 were Paraquat poisoning cases.

Study Population

All confirmed 16 paraquat poisoning cases were included in the present study as the study participant/population.

Inclusion Criteria

In the present study, paraquat patients who were presented to the casualty were considered, diagnosed, and confirmed paraquat poisoning cases were included as study samples, for one year between January 2022 and December 2022.

Exclusion Criteria

Criteria for the selection of cases, involving trauma, drugs, other poisons, asphyxia, diseases, unknown poison, and decomposition cases were excluded. The exclusions mentioned above are external factors that do not justify paraquat poisoning.

Sample Size

A prospective study was conducted in an Emergency Department at Mamata General Hospital. The study period was one year, from January 2022 to December 2022, in Khammam, Telangana, and a total of 16 paraquat poisoning cases were admitted during the study period.

Statistical Data Analysis

Proforma prepared, prospective data were collected from the patient, patient's relatives, and hospital records, who received treatment regarding the demographic characteristics, occupation, time, place and amount consumed, symptoms, target organ damage, manner poisoning, outcome, histopathological changes, and cause of death were systematically analysed and results were tabulated.

Observations/Results

One hundred and two poisoning cases were admitted to the emergency department during the study period, of which 16 cases were diagnosed as paraquat poisoning cases, accounting for 1.56%. When compared with previous studies, the incidence has increased, which shows that the misuse of the paraquat has increased a lot.

Most of the victims were young adults between 21 and 30 years of age, 10 (62.75%) in both genders, followed by 31–40 years, 5 (31.75%) as depicted in Table 1.

In our study, the male population 12 (75.00%) predominates the female population (25.00%) as depicted in Table 2. Most of the victims 11 (68.75%) were married people, whereas 5 (31.25%) were unmarried people, as depicted in Figure 1. In the present study,10 (62.50%) belonged to a nuclear family, 5 (31.25%) were from a joint family, and the rest 1 (6.25%) belonged to an extended family depicted in Figure 2.

The present study showed that paraquat poisoning was more common in rural than urban populations. Out of the 16 cases studied, 12 (75.00%) were from rural backgrounds and 4 (25.00%) were from urban populations as shown in Figure 3.

We observed that the poisoning and its fatality were found to be more common and prominent in the people employed in the occupation of agriculture 8 (50.00%) of them were farmers, 3 (18.75%) were students, next laborers were 2 (12.05%) cases and 2 (12.05%) were housewives. Only 1 (6.25%) case was unemployed, as depicted in Figure 4.

The present study showed that out of 16 cases, the highest number of cases were reported during the rainy season 7 (43.75%) followed by winter 5 (35.21%), and 4 (25.00%) cases were reported during summer as depicted in Figure 5. Month-wise, cases reported the highest number of cases during the last quarter of the year, which is October to December, with 7 (43.75%) cases. Each month, only one case was reported from January to September, as in Table 1.

The present study noted that the highest number of 10 (62.50%) cases were consumed poison during the morning hours between 6 AM and 6 PM, while compared to nighttime (6 PM–6 AM), 6 (37.50%) showed in Figure 6

The present study found that the most common place of poison consumed at their residency was indoors, 9 (56.25%) than outdoors 5 (31.25%) as depicted in Figure 7.

In this study, observed that the exact dose of paraquat amount ingested was noted in detail in all 16 patients, the same amount consumed is based on the history given by patient/attendants, and the amount consumed was approximately 20–30 ml in 10 (62.50%) cases,10–20 ml in 3 (18.75%) cases, 40–50 ml in 2 (12.50%) cases, and more than 50 ml in 1 (6.25%) case were respectively as depicted in Figure 8. The Paraquat concentration is present in the consumed liquids, ranging from 5% to 30%.

The present study showed that in most cases, in 11 (68.75%) cases where the time of onset of ingestion to the presentation of poison is less than four hours, while 4–24 hours after ingestion in 2 (12.50%) cases, as shown in Figure 9. In this present study, the commonest presented symptom after ingestion of paraquat included vomiting in 9 (75.00%) cases, followed by difficulty in breathing in 4 (25:00%) cases. One patient (6.25%) was febrile at admission, as depicted in Figure 10.

Our study on clinical examination showed oral cavity erosions in one patient (6.25%) and icterus in one patient (6.25%). The results of clinical presentations and the key laboratory investigations are the pattern of organ involvement and mortality assessment in paraquat poisoning.

Table 1. Profile of the Victims of Paraquat Poisoning.

Age	Sex	Month	Occupation	Time	Quantity	Survival	Manner	Outcome	Cause of Death
39	M	January	Farmer	6 AM–6 PM	30 ml	1–2 weeks	Suicidal	Death	Multi-organ failure
38	M	February	Laborer	6 AM–6 PM	20 ml–30 ml	<1 days	Suicidal	Death	Acute renal Failure
25	F	March	Student	6 PM–6 AM	20ml–30 ml	>3 weeks	Suicidal	Death	Respiratory failure
30	M	April	Farmer	6 PM–6 AM	30 ml	>1 week	Suicidal	Death	Multi-organ failure
28	M	May	Farmer	6 AM–12 PM	15 ml–30 ml	1–2 weeks	Suicidal	Death	Acute liver failure
39	M	June	Farmer	6 PM–6 AM	30 ml	1–2 days	Suicidal	Death	Respiratory failure
28	F	July	Student	6 PM–6 AM	20 ml	1–2 days	Suicidal	Death	Multi-organ failure
30	M	August	Farmer	6 PM–6 AM	30 ml	1–2 days	Suicidal	Death	Nosocomial pneumonia
26	F	September	Housewife	6 PM–6 AM	30 ml	1–2 days	Suicidal	Death	Multi-organ failure
30	M	October	Farmer	6 AM–6 PM	30 ml	1–2 days	Suicidal	Death	Respiratory failure
25	M	October	Student	6 PM–6 AM	25 ml	1–2 weeks	Suicidal	Death	Acute Renal failure
39	M	October	Labor	6 AM–6 PM	30 ml	1–2 days	Accidental	Death	Multi-organ failure
24	F	November	Student	6 AM–6 PM	20 ml–30 ml	1–2 weeks	Suicidal	Death	Respiratory failure
29	M	November	Mechanic	6 PM–6 AM	30 ml	>3 weeks	Suicidal	Death	Multiorgan failure
40	M	December	Farmer	6 PM–6 AM	30 ml	1–2 days	Suicidal	Death	Acute renal failure
50	M	December	Farmer	6 AM–6 PM	20 ml–30 ml	3–4 days	Suicidal	Death	Multiorgan failure

Table 2. Age & Sex-wise Distribution.

Age (Years)	Male	Female	Total (%)
10–20	0	0	0
21–30	7 (43.75%)	3 (18.75%)	1 (62.75%)
31–40	4 (25.00%)	1 (6,25%)	5 (31.75%)
41–50	1 (6.25%)	0	1 (6.25%)
>51	0	0	0
Total	12 (75.00%)	4 (25.00%)	16
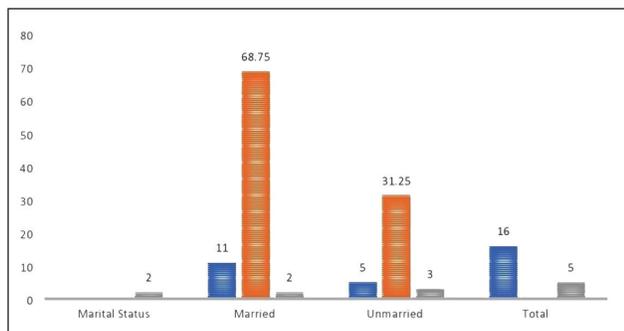
Figure 1. Marital Status.
Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]
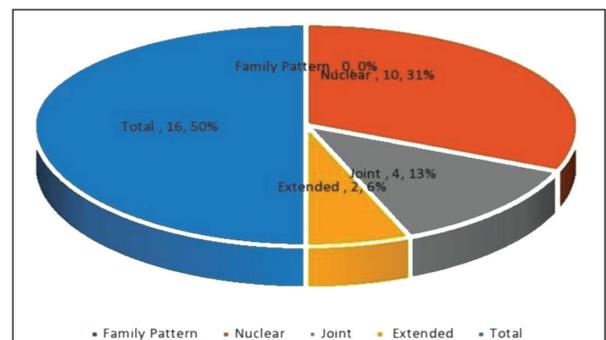

Figure 2. Family Pattern.
Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]

In this study, in almost all patients, the manner of paraquat poisoning is in a suicidal manner in 15 (93.75%) cases and accidental in 1 (6.25%) case.

In the present study, the overall survival period of post-paraquat consumption ranged from 10 hours to 25 days, as shown in Figure 11. In the present study, of the total fatalities, eight patients (50.00%) survived in 24–48 hours, and at least two patients (12.50%) survived one week. The outcome of the cases, in the present study, we observed that almost all 15 patients died.
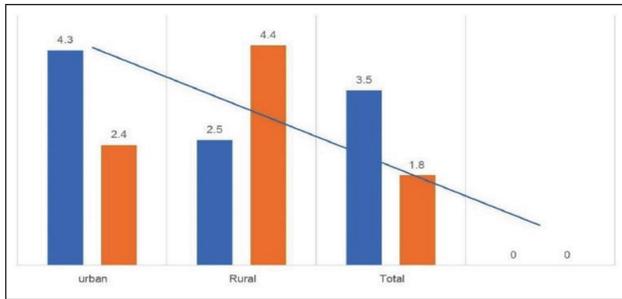
Figure 3. Locality.
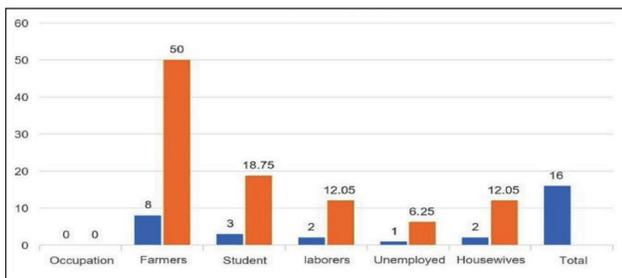**Source:** Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]

Figure 4. Occupation.
Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]
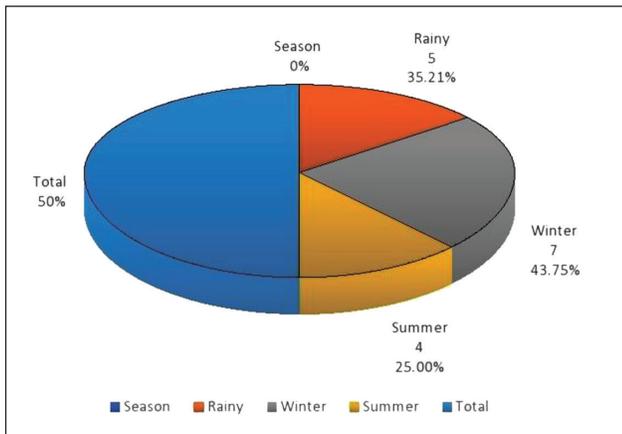

Figure 5. Seasonal Variation.
Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]

On analysing the cases for organs involved, the stomach was affected in 15 (9375%) cases, the lungs were affected in 15 (93.75%) cases, the liver in 14 (87.50%) cases, and the kidneys in 10 (62.50%) cases.

The underlying cause of death was a multi-organ failure in 6 (37.50%) patients, followed by acute respiratory distress syndrome in 5 (31.25%) patients and acute renal failure in 3 (18.74%) patients. In the remaining two patients, one is acute liver failure and another one is nosocomial pneumonia, as depicted in Figure 12.

On autopsy, the brain was congested and edematous, and visceral organs showed marked congestion in all cases. Lungs
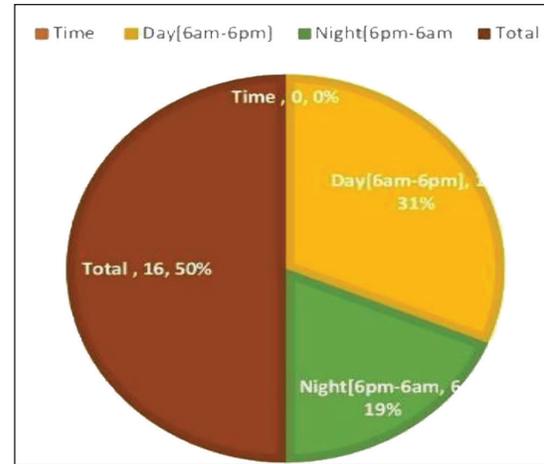
Figure 6. Time of Consumption.
Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]
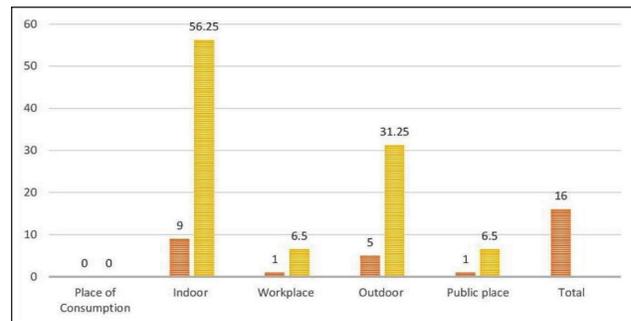
Figure 7. Place of Consumption.
Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]
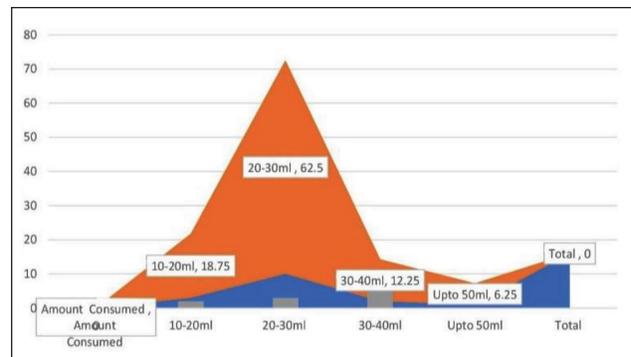
Figure 8. Amount of Poison Consumed.
Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]

were congested with marked pulmonary edema in 10 cases. Erosion due to the corrosive action was present in the oral mucosa, tongue, esophagus, and stomach. Mainly all three vital organs were affected (lungs, liver, and kidneys). Histopathological analysis revealed changes like ulceration of the gastric mucosa, pulmonary edema in the lungs, centri-lobular necrosis in the liver, and acute tubular necrosis in the kidneys.

Figure 9. Time Onset from Ingestion and Admission.

Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]

Figure 10. Clinical Presentations.

Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]

Figure 11. Period of Survival.

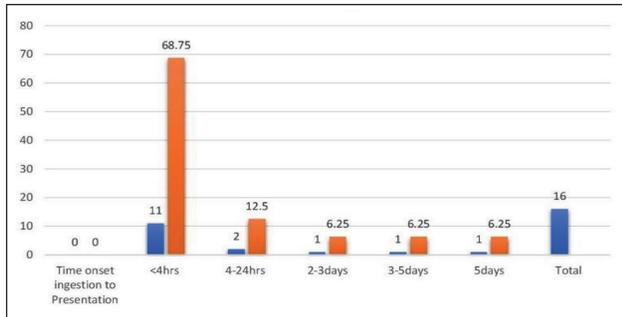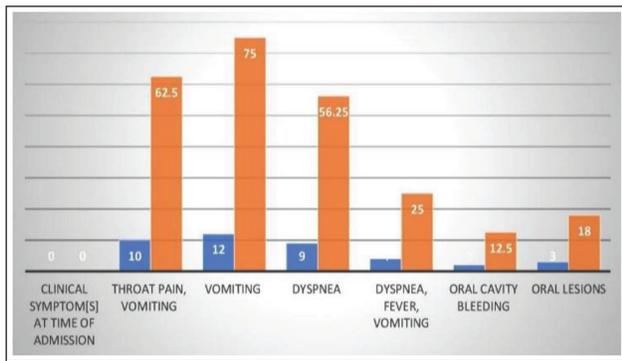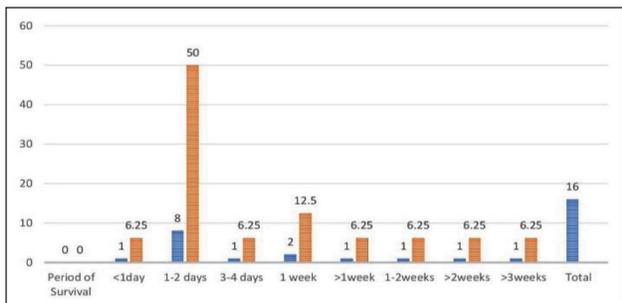**Source:** Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]

Discussion

In the present study, a total of 16 paraquat cases were admitted during the study period, which confirmed paraquat poisoning was included in the present study. The incidence of paraquat poisoning is 16 (15.68%). Similar observations were noted by other studies.[3–5] The incidence of paraquat poisoning revealed that there has been a threefold increase, compared to past studies. This increase has to be considered as the poison is easily available over the counter, with unrestricted access, and the fatality of the poison is much higher.

Most of the victims of paraquat poisoning were young adults between 21 and 30 years of age, 10 (62.75%) in both
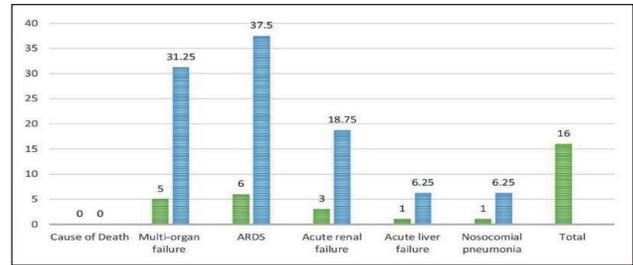

Figure 12. Underlying Cause of Death.

Source: Sahu et al.[4]; Kumar et al.[7]; Birdar et al.[19] and Ravichandran et al.[21]

genders, followed by 31–40 years 5 (31.75%), and 1 (6.25%) case reported in the age between 41 and 50 years. No cases were reported between 10 and 20 years or more than 50 years. These are consistent with the author's studies.[4–6] Young men married who encounter hardship in their lives, and if they fail to achieve the required goals, consume poison and end their lives. Similar results were seen in other studies too.

In the present study, the paraquat poisoning cases where males predominate 12 (75.00%) than females 4 (25.00%). These are consistent with other studies.[4–6] The male-to-female ratio was found to be 3:1.

The present study showed that most of the victims are from the rural population 12 (7500%) than the urban population 4 (25.00%), supported by authors' studies.[5,6]

In the present study, most patients are married people 12 (75.00%) compared to unmarried people 4 (25.00%), who encounter hardship in their lives. These findings were similar to those of other studies.[6,7]

A maximum number of paraquat victims 10 (62.50%) belonged to the nuclear family when compared to the joint family 5 (31.25%). Similar findings are observed by Indian authors.[6–8]

In the present study, most of the victims 8 (50.00%) were farmers and the remaining were students 3 (18.00%), 2 (12.05%) housewives, and laborers 2 (12.05%). These findings are consistent with other author studies.[7–9] This percentage is higher than in other parts of the country, such as Meerat and Punjab.

The present study showed that out of 16 cases, the maximum number of cases reported during winter was 7 (43.75%) followed by the rainy season 5 (35.21%) and 4 (25.00%) cases reported during summer. These observations are like the other studies.[8,9] Month-wise, cases reported most cases were during the last quarter of the year, that is, October to December months, 7 (43.75%) cases, and each month one case only reported from January to September months. Similar observations are made in studies carried out by authors.[8–10]

The highest number of patients who consumed paraquat in the daytime was 10 (62.50%) while the nighttime 6 (37.50%). These findings were like the other studies.[9–11] Most of the victims consumed paraquat at their residence 9 (56.25%) as compared to outdoor 5 (31.25%). These are consistent with the authors.[9–11]

The exact dose of paraquat ingested in the present study was noted in detail. Based on the history given by patients/attendants, the amount consumed was approximately 20–30 ml in 10 (62.50%) cases, 10–20 ml in 3 (18.75%) cases, 40–50 ml in 2 (12.50%) cases, and more than 50 ml in 1 (6.25%) case, respectively. This was similar to the study of the authors.[10–12]

In our study, we observed that the amount of ingested paraquat was stated by patients/relatives as a mouthful, cap of a container, and all or part of a mug or cup. We consider the volume of a mouthful amount equal to 30, a normal mug, and a cup equal to 150–250 ml, respectively. These findings are like other studies.[11–13] The volume of a sample of 1 l paraquat container cap was measured as 25 ml. In the existence of a remainder of ingested poison, we estimated the ingested volume by directly measuring the residual volume and asking for recent or previous use of poison. The concentration of paraquat present in the consumed liquids ranged from 5% to 30%. We observed that the majority of paraquat victims consumed a fatal dose between 20 and 30 ml of paraquat. The prognosis of the patient hugely depends on the amount of paraquat poison consumption. Although the WHO has estimated the lethal dose of paraquat for humans to be 30–50 mg/kg, even lower doses may be fatal among children.

The present study noted that the common presenting symptoms after ingestion of paraquat poison included vomiting in 9 (75.00%) patients, followed by difficulty in breathing in 4 (25.00%) patients. One patient (6.25%) was presented with febrile at the time of admission. On clinical examination, the present study showed oral cavity lesions in 1 (6.25%) patient and icterus in 1 (6.25%) patient. Paraquat, when consumed, causes ulceration and erosion of the oral mucosa, tongue, esophagus, and stomach. These are consistent with many Indian authors.[12–14]

Our study observed that ingestion of paraquat was for deliberate self-harm or suicide in 15 (93.75%), and accidental in 1 (6.25%). The present study observed that almost all patients ingested paraquat orally, and other routes of paraquat poisoning were not shown. These are similarly supported by studies carried out by authors.[12–15]

We observed that the overall survival period of post-paraquat consumption ranged between 10 hours and 25 days. Of the total fatalities, eight patients (50.00%) survived in 24–48 hours, at least two patients (12.50%) one week. Similar findings are made by other studies.[16,17] For the surviving patients, the average amount of ingested paraquat is 25 ml. Prolonged exposure can cause gastric/esophageal perforations and pancreatitis. Paraquat is exceedingly toxic to humans, and as little as one teaspoonful of the active ingredient may be fatal, with death known to occur as late as 30 days after ingestion.

The present study outcome of the victims showed that almost all 16 (100.00%) patients died. Paraquat toxicity at a cellular level is due to redox cycling and intracellular oxidative stress generation by the accumulation of superoxide anion, hydrogen peroxide, and hydroxy radicals. These are consistent with other studies.[17–19] The corrosive action is not present in other pesticides, as a result, gastric lavage is not routinely performed in such cases. The prognosis of the patient hugely depends upon the amount of consumption.

On analysing the cases for organs involved, the stomach was affected in 15 (93.75%) cases, the lungs were affected in 15 (93.75%) cases, the liver in 14 (87.50%) cases, and kidneys in 10 (62.50%) cases. Similar observations are made by many studies.[17–20] On ingestion, paraquat is rapidly but incompletely absorbed and is rapidly distributed to the lungs, liver, kidneys, and muscles. Due to corrosive action, erosion was present in the oral mucosa, tongue, esophagus, and stomach. It also causes acute tubular necrosis in the kidneys and thereby causes acute kidney injury. It affects the liver and causes centrilobular necrosis and ischemic changes. In the lungs, it causes pulmonary edema and later stages fibrosis.

The present study showed that most patients died from organ failure in 6 (37.50%) cases, followed by acute respiratory distress syndrome in 5 (31.25%) cases, acute renal failure in 3 (18.74%) cases and the remaining cases were acute liver failure in one case and nosocomial pneumonia one case. Ingestion at high doses is known to injure other organ systems like the kidneys, liver, and heart, with death in most cases resulting from respiratory or multi-organ failure. Which are supported by studies carried out by authors.[18–21]

On autopsy, the brain was congested and edematous, and visceral organs showed marked congestion in all cases. Lungs were congested with marked pulmonary edema in 10 (62.50%) cases. Due to corrosive action, erosion was present in the oral mucosa, tongue, esophagus, and stomach. Similar findings are made by the authors' studies carried out in India.[19–22] All fatal cases had many similarities including the history of consumption of large amounts, ventilator support from day one, and all three vital organs were affected (lungs, liver, and kidneys). Histopathological analysis revealed similar changes like ulceration of the gastric mucosa, pulmonary edema in the lungs, centrilobular necrosis in the liver, and acute tubular necrosis in the kidneys.

In all the cases, viscera were sent for analysis, and out of 16 reports obtained,16 were positive. These are consistent with other studies.[20–23] Hemodialysis and hemoperfusion can be done, and Immunosuppressive drugs and opiates may also be given. Emetics, cathartics, and oxygen are contraindicated.

Conclusion

All the paraquat poisoning cases should be treated as medical emergencies. When compared to other pesticides, paraquat is the most dangerous of all, with a maximum fatal rate.

Treatment protocol for paraquat poisoning should be framed, and it is better to implement stringent rules in the sales than to struggle in the treatment part of it.

There must be further research to develop adequate tests to determine the presence of paraquat toxicity in live or deceased patients, as the postmortem features are grossly vague and resemble multi-organ failure. Paraquat toxicity should be

considered in case of an unexplained combination of respiratory, and gastrointestinal symptoms and acute renal damage, even in the absence of a proper history of paraquat consumption.

Declaration of Conflicting Interests

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

Ethical Approval

Informed consent statements have been taken from all the patients and were submitted to Institutional Ethics Committee and got approval (Ref. No. IEC/IRB/MMC/25/22).

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Informed Consent

Informed consent statements have been taken from all the patients.

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Tracing Resilience: A Forensic Examination of Pesticide Stability in Beverages

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Abstract

The phenomenon of crime is not ordinary; behind every criminal act lies a motive, and after every crime, there exists a trail or clue. These traces are crucial for investigators and forensic scientists in establishing the perpetrator and linking them to the crime. With the advancement of technology, the methods employed in committing crimes have also evolved, and the ready availability of poisons has made the act of killing distressingly simple. Poisons, whether organic or inorganic compounds originally intended for eradicating insects, pests, or rodents, are unfortunately misused to end human lives. In cases where poisons are employed, tracing the specific poison to determine the cause of death is imperative. However, when poisons are mixed with other substances, such as liquids, the task of tracing them becomes significantly challenging. One such medium where poisons can be surreptitiously introduced is beverages. The focus of this study is to trace poisons mixed in beverages containing citric acid and to ascertain their stability period, during which the presence of the poison can be detected—a critical timeframe within which poison traces can be identified. To conduct this study, pesticides including cypermethrin, chlorpyrifos, and phenthoate were chosen and mixed with beverages containing citric acid. Ultraviolet spectroscopy was employed to analyze the samples. The study's findings indicate that, with the exception of cypermethrin, the stability of the other two pesticides, chlorpyrifos, and phenthoate, was compromised, leading to chemical changes and loss of stability over time.

Keywords

Toxicology, pesticide, cypermethrin, chlorpyrifos, phenthoate, beverages

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Introduction

Crime is a universal phenomenon, yet the methods employed by criminals vary widely and are often unique to each individual case.[1,2] While understanding the motive behind a crime is crucial for its resolution, evidence holds paramount importance in convicting the perpetrator in a court of law. In this context, forensic science plays a pivotal role, with forensic toxicology being a crucial subsection that specializes in analyzing both organic and inorganic poison substances to determine the cause of death.[3–6]

In recent times, there has been a surge in reports of pesticides being mixed into soft drinks or beverages by perpetrators.[7,8] Pesticides are readily accessible substances that can be easily misused for nefarious purposes. A plethora of pesticides are available in the market, with organophosphate-based pesticides being among the most common.[9–12] Therefore, for the this study, several organophosphate-based pesticides were selected:

1. Cypermethrin: Known as a central nervous system (CNS) inducer and neuro-degenerator, as documented.[13]
2. Chlorpyrifos: This pesticide affects the nervous system by overstimulating neuron cells.[14,15]
3. Phenthoate: It impacts inhibition and affects the neurotransmitter system.[16]

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These pesticides were chosen for their known effects on the nervous system and their potential lethality when ingested.[17]

Objectives

The main aim of this is to determine the rate and extent of pesticide degradation in various types of acidic beverages.

Materials and Methods

The objective of this research is to assess the stability of pesticides, specifically cypermethrin, chlorpyrifos, and phenthoate, in carbonated beverages like 7UP and Sprite. These pesticides, known as organophosphate-based insecticides, are commonly utilized in agricultural practices. The choice of carbonated beverages such as 7UP and Sprite is motivated by their colorless nature, which facilitates the detection of any changes resulting from the addition of pesticides. Ethical clearance is obtained by IEC Order No. KARE/CEC/MOM/2023-24/02Dated:05-03-2024.

Before commencing the testing, the concentrated pesticides were appropriately diluted to ensure that the concentrations were within a manageable range for analysis. The dilution was carried out using a ratio of 10:90 with water, effectively reducing the concentration of the pesticides. Subsequently, the diluted pesticides were mixed with the beverage according to a specific ratio. The mixture consisted of 85% beverage, 10% citric acid, and 5% diluted pesticide. This formulation ensures a consistent composition for testing while also incorporating citric acid, which may influence the stability of the pesticides in the beverage. Following this preparation, the beverage was ready for testing, and daily observations were conducted over a period of 10 continuous days using ultraviolet (UV) spectroscopy. This methodology allows for a comprehensive examination of how these pesticides interact with carbonated beverages over time. By conducting daily assessments using UV spectroscopy, researchers can identify any degradation or changes in the pesticides' concentrations, shedding light on their stability in this specific matrix.

Results and Discussion

Initially before analyzing the sample, a baseline reading was taken. This established the absorbance of the solvent or blank solution. The absorbance of the sample was then measured at specific wavelengths between 200 and 250. Any increase in absorbance compared to the baseline indicates absorption by the sample components.

Based on the absorbance of UV spectroscopy analysis conducted between wavelengths of 200 and 250 nm, the stability of the pesticides in the beverages was assessed as follows:

Cypermethrin (Figure 1):

- Absorbance readings for cypermethrin did not show significant changes over the 10-day period compared to the baseline.
- This suggests that cypermethrin did not degrade in the beverages containing citric acid. The absence of notable changes indicates the stability of cypermethrin under the conditions tested.[18]

Phenthoate (Figure 2):

- Phenthoate exhibited noticeable degradation over the first seven days of analysis, as evidenced by a decrease in absorbance compared to the baseline.
- However, after seven days, the degradation of phenthoate diminished, and the absorbance readings stabilized.
- This indicates that while phenthoate initially degraded in the beverages, its degradation slowed down and reached a stabilized state by the end of the 10-day period.[19]
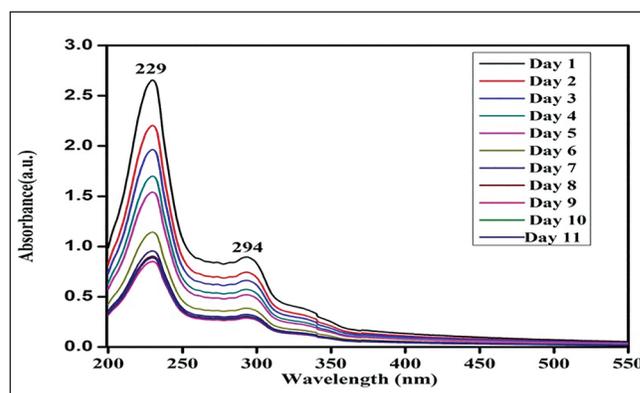

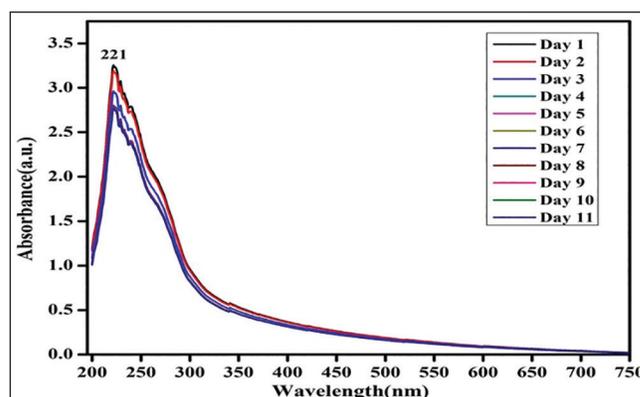**Figure 1.** Stability of Cypermethrin.

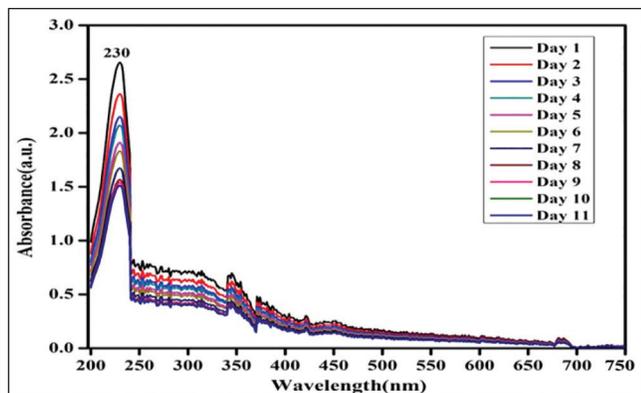**Figure 2.** Stability of Phenthoate.

Figure 3. Stability of Chlorpyrifos.

Chlorpyrifos (Figure 3):

- Chlorpyrifos showed a considerable amount of degradation on the initial day, as indicated by a decrease in absorbance compared to the baseline.
- However, the level of chlorpyrifos degradation gradually decreased over time, with absorbance readings dropping further.
- By the end of seven days, chlorpyrifos degradation diminished, suggesting that its degradation process slowed down and stabilized.[20,21]

Overall, these findings suggest varying degrees of stability and degradation for the pesticides analyzed in the beverages containing citric acid. Cypermethrin showed stability, while phenthoate and chlorpyrifos exhibited degradation, albeit with different degradation profiles. These results provide valuable insights into the behavior of these pesticides in beverage matrices, which is essential for assessing their potential impact.[22]

Discussion

Based on the stability assessment of the pesticides in the beverages over the 10-day period, it is evident that traces of the pesticides can be detected even after this duration. This finding suggests that if a deceased individual had consumed these beverages containing the pesticides within the past 10 days, it may be possible to detect traces of the pesticides in their body.[23]

In forensic investigations involving suspected poisoning cases, analyzing body tissues or fluids for the presence of pesticides can provide crucial evidence to determine the cause of death. If the deceased had ingested beverages containing cypermethrin, phenthoate, or chlorpyrifos, the presence of these pesticides in post-mortem samples could indicate poisoning as the cause of death.[24,25]

Analyzing extracts from the body tissues or fluids using appropriate analytical techniques, such as chromatography or mass spectrometry, can help detect and quantify the pesticides present. The results of these analyses, combined with other investigative findings, can contribute to determining the circumstances surrounding the individual's death.[26,27]

Conclusion

The accessibility of pesticides and insecticides in the market raises concerns about their potential misuse in criminal activities, including poisoning cases. In forensic investigations, the timely analysis of liquids found at crime scenes or recovered from victims' bodies is critical for identifying potential poisons and determining the cause of death.

This study plays a crucial role in aiding forensic investigations by providing insights into the time frame during which specific chemical compounds, such as pesticides, can be reliably traced in beverages. By understanding the degradation patterns of these compounds, particularly in beverages containing citric acid, forensic analysts can better prioritize and expedite the analysis of liquid evidence. Identifying poisons and toxic substances is a primary task of toxicology divisions within forensic laboratories. The study's findings help to establish a time frame within which these chemical compounds can be detected before degradation occurs. This understanding is essential for ensuring that forensic analyses are conducted within a critical window of time to maximize the chances of identifying the poison or toxic substance responsible for an individual's illness or death.

Furthermore, the study underscores the importance of considering the law of progressive change in forensic investigations. As chemical compounds degrade over time or interact with other substances, the ability to detect and identify traces of poisons may become increasingly challenging. By recognizing the time-sensitive nature of toxicological analyses, forensic scientists can adjust their protocols and prioritize cases accordingly to optimize the chances of successful detection and identification of poisons.

Authors' Contribution

Sanjana G, Krishnapriya R, Lavanya N and Vijjurothi Madhav Manikanta helped in acquisition of data or analysis and interpretation of data.
Rudrank Shukla was involved in drafting the article or revising it critically for important intellectual content.
M C Janaki helped in conception and design of the study and final approval of the version to be published.

Declaration of Conflicting Interests

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

Ethical Approval

This study did not involve human participants or animal subjects. Therefore, ethical approval was not required in accordance with institutional and national guidelines.

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Informed Consent

Not applicable as this study did not involve human participants, and no personal data were collected.

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Rodenticide Poisoning: A Case Series of Deliberate Self-harm Admitted to a Tertiary Health Care Hospital in Northern Karnataka

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Abstract

Rodenticides or 'rat poisons' are mixture of compounds to eradicate rodents. They are the most toxic compounds with various chemical compositions, mechanisms of action, toxic doses and lethal effects. Coumarins, aluminium phosphide, zinc phosphide and yellow phosphorous are the commonly used rodenticides for deliberate self-harm (DSH). The use of pesticides as agents of deliberate self-poisoning (DSP) is on the rise, with more than 500,000 cases reported worldwide annually. The National Poison Information Centre (NPIC) is a round-the-clock telephone service meant for the dissemination of information regarding the symptoms and management of various poisonings. It is managed by the Department of Pharmacology at the All India Institute of Medical Sciences. In a retrospective study, data over 13 years were analysed from the NPIC. Of 14,867 cases reported to the NPIC, 17.06% were due to rodenticides. Rats are the most destructive pests damaging crops and for preventing these pests, rodenticides are commonly used in agricultural sector and homes. In the absence of a definite antidote, mortality in patients with rodenticide consumption is high. The rapid action, easy availability and high toxicity for the target species at an economic deal have made this compound an ideal agent with misuse for suicidal poisoning. This case series presents four cases of rat poisoning admitted to a tertiary health care hospital which helped us in identifying the clinical features of certain rat poisons and diagnosing the rat poison by means of poison detection centre and which will help the treating physician to reduce the mortality in future.

Keywords

Rodenticide poisoning, zinc phosphide, bromadiolone, deliberate self-harm, suicide

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Introduction

Rodenticides, commonly referred to as 'rat poisons', are chemical agents aimed at eliminating small rodents. The common targets for their use are household rodents, that is, rats/mice, squirrels and gophers. Controlling rodents is imperative as they are vectors for the spread of disease, destroy crops/grains and multiply rapidly. In India, being a primarily agrarian country, rodenticides are widely used and also commonly available in almost every household, to prevent their stored grains from rodents. They are available in various formulations, such as powders, pastes, pellets, cereal baits or blocks.[1] Since it is easily available and cheaper than other pesticides in the market, it is often taken with suicidal intent or ingested accidentally by children.[2]

Deliberate self-harm (DSH) is a problem that is increasing in prevalence with time. Since the ancient times to the post-modern era, people have deliberately tried and at many instances succeeded in taking their own life. The population is varied and not restricted to any socioeconomic class of people. Various methods of DSH are used across the world with rodenticides being one of the most common methods used in the Indian subcontinent.[3] The global burden of

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rodenticide poisoning varies from region to region. In the United States, as per the American Association of Poison Control Centres, rodenticides accounted for 0.3% of 2.3 million human exposures as reported to the regional poison control centres. There are no definite data from Asia describing the prevalence of the various rodenticide poisonings. However, the National Poison Information Centre (NPIC) is a round-the-clock telephone service meant for dissemination of information regarding the symptoms and management of various poisonings. It is managed by the Department of Pharmacology at the All India Institute of Medical Sciences (AIIMS). In a retrospective study, data over 13 years were analysed from the NPIC. Of 14,867 cases reported to the NPIC, 17.06% were due to rodenticides.[1]

Rodenticides are of following common types—anticoagulants, metal phosphides (aluminium phosphide, zinc phosphide) and yellow phosphorus. Other types include calciferols, barium carbonate and alpha-naphthylthiourea (ANTU). Each one of them has different methods of action. Hence, they have different toxicological profiles with variable fatality rates in humans when consumed by accident or intentionally.[3] As a result, the toxidrome produced by one rodenticide is largely different from that produced by another rodenticide. In addition, there is also a vast difference in the immediate and long-term outcomes based on the type of rodenticide consumed.[1] Since almost every system is affected in rodenticide poisoning and also there in no definite treatment guidelines available, we have taken up this study to identify the specific clinical features, and course and to diagnose the poisoning using 1,2-dichloropropane (PDC) as soon as possible to start the specific treatment.

Materials and Methods

We present a case series of four patients, consecutively admitted to the medical ward with rat poisoning in a tertiary care hospital over a period of six months from May 2023 to November 2023. After obtaining approval from the institutional ethical committee and written informed consent of patients' relatives, the case records of patients with rodenticide poisoning were retrieved from the medical records department. The diagnosis was made from the patient's clinical signs and symptoms, local examination, investigations like laboratory parameters and most importantly from PDC as well as history from patient bystanders. Treatment histories from other hospitals were obtained from reference letters. After the death of the patient, we have involved the findings of post-mortem examinations, histopathology and Regional Forensic Science Laboratory (RFSL) report.

Results

There was a total of four patients who were admitted with rodenticide poisoning during the one-year study period. The age of the patients ranged between 20 and 30 years of age and the gender of all four patients was female. Among four cases, case 1, 2 and 3 were referred from other hospitals. The intent for ingestion of rodenticide in all four cases was suicide and we were able to find the exact quantity of ingested rodenticide only in two cases based on the history. Soon after the ingestion, patients developed gastrointestinal symptoms like nausea, vomiting and diarrhoea. Despite treatment like Ryle's
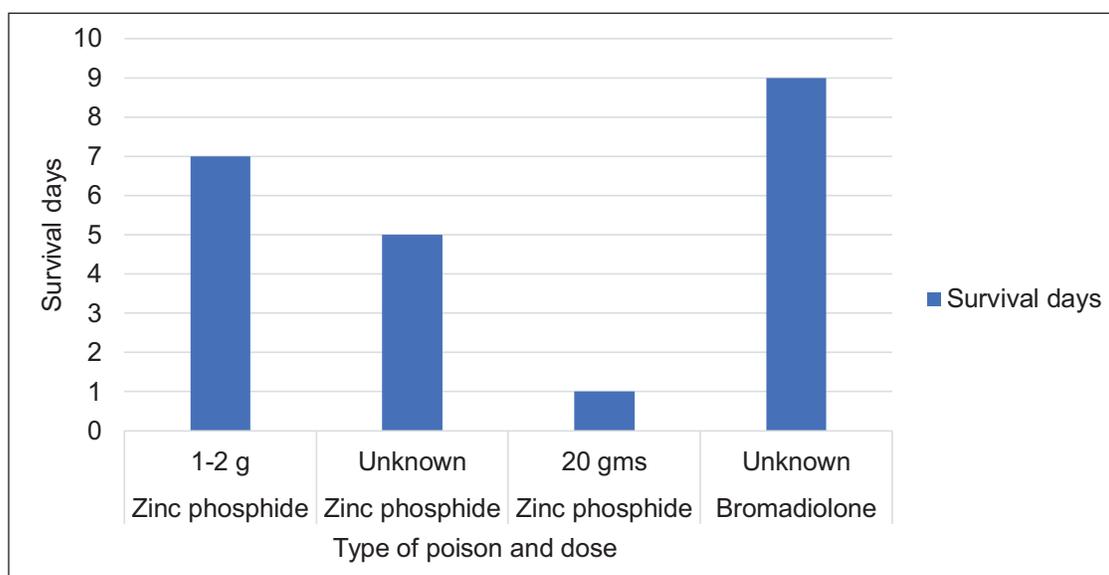

Figure 1. Distribution of Types of Poisons, Dosage, and the Survival Days.

Table 1. Case Details.

Case No	DOA and Time of Admission	Age/Sex	DOI	Compound Name	Quantity Ingested	Intent	Referred from Y/N	Clinical Features	Investigation	Cause of Death	Treatment	DOD	DOA	Survival Period	PDC Report	RFSL Report	HPE Report
1	31 May 2023 10 AM	22/female	25 May 2023 3 pm	Zinc phosphide (Ratol)	1–2 grams	Suicide (family problem)	Civic hospital (after 5 days) AMA	Vomiting, abdominal pain, altered sensorium	LFT and RFT elevated	Acute renal failure	N-acetyl cystine, IV fluids, antibiotics, Inotropes, vitamin K, mechanical ventilation, ICU care	1 June 2023	01 June 2023	7 days	Nil	Negative for phosphorus	Uterus-menstrual phase
2	17 June 2023 10 AM	29/female	13 June 2023 10 PM	Zinc phosphide	Unknown	Suicide (family problem)	Venugram hospital (after 4 days) AMA	Vomiting, abdominal pain, altered sensorium	LFT and RFT elevated	Acute renal failure	NAC regimen, IV fluids, inotrope, mechanical ventilation, ICU care	18 June 2023	19 June 2023	5 days	Nil	Negative for phosphorus	Uterus-menstrual phase
3	24 November 2023	30/female	24 November 2023 at 1.30 PM	Zinc phosphide	20 grams	Suicide (family problem)	Local hospital	Vomiting, abdominal pain	LFT and RFT elevated	Respiratory failure	N-acetyl cystine, IV fluids, antibiotics, inotropes, vitamin K, mechanical ventilation, ICU care	25 November 2023 10.39 PM	26 November 2023	1 day	Zinc phosphide	Positive forphosphine	Uterus-menstrual phase
4	30 November 2023	30/female	29 November 2023 at 10 PM	Bromadiolone	Unknown	Suicide (family problem)	No	Vomiting, abdominal pain, loose stools	LFT and RFT elevated	Multi-organ Failure	Vitamin K, hydrocortisone, N-acetyl cystine	8 December 2023	09 December 2023	9days	Bromadiolone +ve	Negative for phosphorus	Uterus-menstrual phase

Notes: DOA: Date of admission; DOI: Date of ingestion of poison; AMA: Against medical advise; DOD: Date of death (DOD); DOA: Date of autopsy.

tube aspiration and other non-specific treatments since there is no specific antidote available, patients progressed to hepatic, renal and pulmonary dysfunction.

Based on the PDC reports, case 4 consumed a rodenticide called bromadiolone and case 1, 2 and 3 had consumed zinc phosphide. Investigations were undertaken and all the cases had raised liver function test (LFT), renal function test (RFT) levels suggesting multiorgan dysfunction with severe hypoglycaemia and metabolic acidosis. Treatments like N-acetyl cysteine regimen, vitamin K, sodium bicarbonate and other supportive care and treatment were given according to patient's symptoms. Cases 1 and 2 ended up with acute renal failure, case 3 with respiratory failure and case 4 with multiorgan dysfunction. All the four cases expired despite the required treatment. The survival period of these patients ranged from 24 hours to 9 days (Table 1 and Figure 1).

Discussion

Rodenticides have a wide range of toxicity, fatality and modes of action. Studying each poison independently and examining its different modes of action, organ involvement, toxicity and deadly effects will provide you the most thorough understanding of the rodenticides. Compounds with a single-dose LD50 less than 50 mg/kg of body weight are included in this group. This group of compounds consists of zinc phosphide and aluminium phosphide. The poison that causes both types is phosphine, which has been considered hazardous due to its inhibition of cytochrome c oxidase. Zinc phosphide toxicity has a few days latent phase, but aluminium phosphide toxicity manifests as systemic poisoning right away. Appropriate treatment with necessary antidote must be given as early as possible within 12 hours.[4]

Due to its extended half-life, bromadiolone, which is categorized as a 'super coumarin', may need to have the prothrombin time (PT) and international normalized ratio (INR) monitored often for several days.[5] Even though the risk of bromadiolone poisoning has increased, only limited number of published articles are available till now. Early supportive treatment would definitely help to recover sooner.

Intentional self-harm through the use of rodenticide is a serious global health issue that has a significant influence on family and societal dynamics. So, the need to study about the rodenticide poisoning plays a significant role. In our study, all the patients who consumed poison were in the age group of 20–30 years. A study was conducted by Vignesh et al. in Chidambaram also had the majority of 20–30 age group.[6] Our case series was female predominant and mode of poisoning was suicidal. Another study conducted by Lokesh et al. in Mandya, Bangalore, with found majority of females had suicidal intension.[7] In our case series, all the four patients were females and the histopathological examination of these four patients had revealed they were in their menstrual phase. This reveals there was a significant association between suicidal attempts and menstrual cycle. The menstrual cycle is associated with nonfatal suicidal behaviour; attempts at suicide tend to happen more frequently during the cycle's lowest oestrogen (and serotonin) stages. A study conducted by Leenaars et al. revealed that women who had committed suicide were menstruating at the time of event.[8]

PDC plays a vital role in detecting type of poison ingested which helps the treating physician to provide appropriate treatment with specific antidote and helps in reducing the mortality. Treatment for each case of rat kill poisoning involves a thorough clinical examination, progressive monitoring of the coagulation profile and LFTs.[9] Due to the abundant availability of rodenticides and for the rural population involved in agriculture, it is accessible at a lower cost. For the peripheral hospitals treating a case of rodenticide poisoning without the proper availability of antidote poses a great challenge.

Conclusion

Rodenticide poisoning is an important health problem with a high case fatality rate especially with metal phosphides. Easy availability, over-the-counter or on e-commerce websites and a lack of antidotes for rodenticides in our country pose an important health problem. Early gastric lavage and symptomatic treatment were key in the management of rodenticide poisoning. Still, universal guidelines are needed for proper management. Prognosis mainly depends upon the type of chemical compound and amount of compound consumed, the time interval between intake and first aid treatment and early treatment with magnesium sulphate and acetylcysteine. Early magnesium sulphate therapy may be useful in aluminium phosphide poisoning patients and acetylcysteine therapy may prevent hepatic complication. In our case series, PDC helped us in confirming the diagnosis and we started treatment at the earliest. However, delayed presentation, an unknown quantity of ingestion and no specific antidote are the drawbacks which led to the patient's demise. It was also observed that all four cases in our case series were females between the ages of 20 and 30 years old who committed suicide during or near their menstruation period, as evidenced by an HPE examination of the uterus, implying that the patients may have had premenstrual dysphoric disorder (PMDD). People with PMDD will have PMS symptoms (bloating, headache and breast tenderness) along with extreme irritability, anxiety or depression. Therefore, family issues, PMMD, easy access and availability to rodenticide could all have contributed to the suicides in these four cases. Therefore, improving public awareness regarding the lethality of rodenticides, strict monitoring of sales and usage of rodenticides, family support, proper counselling against suicide and awareness on PMMD will help to avoid indiscriminate use and poisoning with rodenticides, as well as potentially lowering suicidal rates in the near future.

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Reconstruction of Stature by Per-cutaneous Measurement of Parts of Upper and Lower Limbs (Distal Part of Upper Limb [Forearm and Hand], Hand, Leg and Foot)

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Abstract

Stature is one of the important criteria for establishing identification of unknown person/dead body. It is measured as standing height of the person but reconstruction of stature becomes difficult when dead bodies are mutilated, burnt or skeletonized. Anthropologists throughout the world have tried to estimate stature from bones and mutilated and dismembered remains of dead bodies. Authors under this project tried to reconstruct the stature of 200 healthy students (100 males and 100 females) between 19 and 25 years of age by measuring parts of their upper and lower limbs such as distal part of upper limb (forearm including hand), hand, leg and foot. Standing height and per-cutaneous length of these parts were analysed statistically by using (a) formula $y - \overline{y} = byx(x - \overline{x})$, that is, $y = \pi \dfrac{\delta y}{\delta x}(x - \overline{x}) - \overline{y}$ where *y* stands for standing height and *x* for length of part of limb and regression equations are derived separately in males and females for all the body parts and (b) multiplication factor, that is, ratio of standing height and length of limb part.
Regression equations and multiplication factors of parts of limbs are summarized as follows:

Body parts	Regression Equation		Multiplication Factor	
	Male	Female	Male	Female
Forearm and hand	2.42x + 56.64	2.31x + 59.5	3.67	3.73
Hand	5.1x + 67.9	4.8x + 70.2	8.5	8.7
Leg	2.34x + 63.9	2.17x + 65.4	3.73	3.73
Foot	3.35x + 82.6	3.42x + 75.8	6.49	6.65

Stature calculated by regression equations and multiplication factors were compared by the actual standing height and it was found that the results of regression equation are close to the actual height that is, ±3 cm. In reconstruction with multiplication factors, the calculated heights were more than ±5 cm in a large number of cases. This shows that multiplication factors are less reliable than regression equation.

Introduction

Reconstruction of stature from bones and mutilated remains is always a challenge for forensic pathologist. Anthropologists, all over the world, are trying to develop a simple and accurate formula for estimation of stature.[1–6] Authors, in a project, tried to reconstruct stature from the parts of upper and lower limbs, that is, from (a) distal part of upper limb (combined length of forearm and hand), (b) hand, (c) leg and (d) foot[7–10] separately in males and females from same participants. A direct correlation was observed between standing height and per-cutaneous length of distal part of upper limb, hand, leg and foot and

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multiplication factors and regression equations were derived. The authenticity of these formulae was assessed by reconstructing the stature by putting the value of length of respective body parts in regression equation or by multiplying with multiplication factors and compared with actual height.

Materials and Methods

After ethical approval of pilot project, 200 healthy students (100 males and 100 females) of Meerut between 19 and 25 years of age were selected for this study irrespective of their caste, religion, dietary habits and socioeconomic status. Students having significant growth disorders, deformities, bony anomalies and fracture/amputation were excluded to rule out any abnormal result.

After taking consent, the standing height and length of both side of distal part of upper limb (forearm including hand), hand, leg and foot of all the participants were measured. The stature was measured on stadiometer without shoes as a distance between standing surface to the highest point on the head in mid-sagittal plane. The combined length of forearm and hand was measured as distance between the tip of olecranon process and the tip of middle finger by sliding calliper.

The length of hand was measured between the midpoint of wrist to tip of middle finger for which students were requested to put their hand on plane white paper on which tip of styloid process of radius and ulna and tip of middle finger were marked with pencil. A line was drawn between the tips of two styloid processes and the length of hand was measured as the distance between the mid-point of line to tip of middle finger.

For the length of leg, the subject was requested to put his/her leg on a table/stool and distance between the table top to the most prominent point of medial condyle of tibia was measured. The length of foot was measured between the most prominent point of heel to tip of great toe by marking these points on white paper. These measurements were compiled on master chart and also on excel format in computer.

Regression equation was derived by using the formula

$$y - \overline{y} = byx(x - \overline{x})$$

$$= \pi \frac{\delta y}{\delta x}(x - \overline{x})$$

$$y = \pi \frac{\delta y}{\delta x}(x - \overline{x}) + \overline{y} \text{, where}$$

y = Standing height (stature)
$\overline{y}$ = Average (mean) of standing heights
x = Length of body part (forearm and hand, hand, leg or foot)
$\overline{x}$ = Average (mean) of length of body part (forearm and hand, hand, leg or foot)
δy = Standard deviation of standing height
δx = Standard deviation of length of body part (forearm and hand, hand, leg or foot)
π = Co-relation coefficient between standing height and corresponding length of body part

The mean and standard deviation of standing height and mean and standard deviation of length of right and left side of body parts and average of both sides were calculated, from which their correlation coefficient with standing height was derived. Practically there was no significant difference in the lengths of right and left side body parts, and regression equation for the estimation of stature was derived from the average length of both sides separately in male and female. The stature was estimated with the formula $y = \pi \frac{\delta y}{\delta x}(x - \overline{x}) + \overline{y}$ as discussed above. Multiplication factor is a ratio of stature and length of body parts (distal part of upper limb, hand, leg and foot). It is calculated separately in male and female. For a particular part of limb multiplication factor is derived by dividing average of standing height with average of length of the part of limb (distal part of upper limb, hand, leg and foot).

Observation and Results

All the measurements were compiled on master chart and also on excel format in computer to calculate minimum, maximum, mean and standard deviation of stature and also of average of length of both side body parts and their correlation coefficient with stature. The data for male and female are summarized in Tables 1 and 2.

The regression equations for estimation of stature from different body parts, distal part of forearm (forearm and hand), hand, leg and foot in male and female were derived by

Table 1. Measurement of Stature and Body Parts in Male.

Measurements	Stature (cm)	Average of Length of Bilateral Forearm Including Hand (cm)	Average of Length of Bilateral Hands (cm)	Average of Length of Bilateral Legs (cm)	Average of Length of Bilateral Feet (cm)
Minimum	158.5	41.6	18.05	41.1	22.35
Maximum	184	51.75	22.4	50.50	29.9
Mean	170.9	46.799	20.2	45.74	26.397
Standard deviation	6.00673	2.246602	0.912594	2.3593	1.64135
Correlation coefficient with stature	–	0.904695	0.776181	0.91856	0.914287

Table 2. Measurement of Stature and Body Parts in Female.

Measurements	Stature (cm)	Average of Length of Bilateral Forearm Including Hand (cm)	Average of Length of Bilateral Hands (cm)	Average of Length of Bilateral Legs (cm)	Average of Length of Bilateral Feet (cm)
Minimum	147.5	38.0	16.1	38.1	21.3
Maximum	167.5	45.15	20.3	46.25	26.1
Mean	156.6	41.9825	18	42.009	23.5775
Standard deviation	4.73963	1.777218	0.79	1.823837	1.146434
Correlation coefficient with stature	–	0.87992	0.79966	0.83531	0.829467

Table 3. Regression Equation for Body Parts in Male and Female.

Body Parts	Regression Equation	
	Male	Female
Forearm and hand	2.42x + 56.64	2.31x + 59.5
Hand	5.1x + 67.9	4.8x + 70.2
Leg	2.34x + 63.9	2.17x + 65.4
Foot	3.35x + 82.6	3.42x + 75.8

Table 4. Variations in Calculated Stature from Real Standing Height by Regression Equations.

Subject	Standing Height	Body Parts	Corresponding Length (cm)	Regression Equation	Calculated Stature (cm)	Variation in cm
Male	Min. 158.5 cm	Forearm and hand	41.6	2.42x + 56.64	157.3	−1.2
		Hand	18.05	5.1x + 67.9	160.0	+1.5
		Leg	41.1	2.34x + 63.9	160.1	+1.6
		Foot	22.35	3.35x + 82.6	157.5	−1.0
	Max. 184 cm	Forearm and hand	51.75	2.42x + 56.64	181.9	−2.1
		Hand	22.4	5.1x + 67.9	182.7	−1.3
		Leg	50.5	2.34x + 63.9	182.1	−1.9
		Foot	29.9	3.35x + 82.6	182.8	−1.2
Female	Min. 147.5 cm	Forearm and hand	38	2.31x + 59.5	147.3	−0.2
		Hand	16.1	4.8x + 70.2	147.5	0.0
		Leg	38.1	2.17x + 65.4	148.1	+0.6
		Foot	21.3	3.42x + 75.8	148.5	+1.3
	Max. 167.5 cm	Forearm and hand	45.15	2.31x + 59.5	163.8	−3.7
		Hand	20.3	4.8x + 70.2	167.6	+0.1
		Leg	46.25	2.17x + 65.4	165.8	−1.7
		Foot	26.1	3.42x + 75.8	165.1	−2.4

using formula $y = \pi \dfrac{\delta y}{\delta x}(x - \bar{x}) + \bar{y}$ which is shown in Table 3.

By putting the value of x in different situations, statures were calculated and compared with the corresponding real standing height. The calculated height in all the four parameters was found close to real standing height, ±3 cm in majority of the cases (Table 4).

Table 5. Multiplication Factor for Body Parts in Male and Female.

Body Parts	Regression Equation	
	Male	Female
Forearm and hand	3.67	3.73
Hand	8.5	8.7
Leg	3.73	3.73
Foot	6.49	6.65

Table 6. Variations in Calculated Stature from Real Standing Height by Multiplication Factor.

Subject	Standing Height	Body Parts	Corresponding Length (cm)	Multiplication Factor	Calculated Stature (cm)	Variation in cm
Male	Min. 158.5 cm	Forearm and hand	41.6	3.67	152.67	5.83
		Hand	18.05	8.5	153.43	5.07
		Leg	41.1	3.73	153.30	5.20
		Foot	22.35	6.49	145.05	13.45
	Max. 184 cm	Forearm and hand	51.75	3.67	189.92	−5.92
		Hand	22.4	8.5	190.40	−6.40
		Leg	50.5	3.73	188.37	−4.37
		Foot	29.9	6.49	194.05	−10.05
Female	Min. 147.5 cm	Forearm and hand	38	3.73	141.74	5.76
		Hand	16.1	8.7	140.07	7.43
		Leg	38.1	3.73	142.11	5.39
		Foot	21.3	6.65	141.65	5.85
	Max.167.5 cm	Forearm and hand	45.15	3.73	168.41	−0.91
		Hand	20.3	8.7	176.61	−9.11
		Leg	46.25	3.73	172.51	−5.01
		Foot	26.1	6.65	173.57	−6.07

The multiplication factor is calculated as ratio of average of standing height with average length of the parts of both side limbs (distal part of upper limb, hand, leg and foot). It is derived separately in male and female. Multiplication factors of above four parts are shown in Table 5.

Statures were calculated from the per-cutaneous measurements of part of limbs by multiplying the multiplication factor and compared with the corresponding real standing height. The calculated height in all the four parameters was more than ±5 cm to real standing height in large number of cases (Table 6). Thus, regression equations are more reliable in reconstruction of stature than the calculation done by using multiplication factors, which is less consistent with actual height.

Discussion

Estimation of stature is a crucial requirement in post mortem examination of dead bodies especially when they are un-identified and badly decomposed, mutilated or skeletonized. A direct relationship was observed between length of different part of upper and lower limbs and standing height by different workers.[11–13] A direct relationship was observed between standing height and the length of distal half of upper limb (combined length of forearm and hand) in a study by Sushil et al.[14] and multiplication factor is nearly similar to our study. The similar results were also observed in other studies observed for the estimation of stature from dimensions of hand and foot.[15–19] Regression equations and multiplication factors are derived separately for males and females. The

length of right and left side of limbs or their parts are almost the same in most of the cases and so are the regression equations and multiplication factors for both side arms. So, the role of right and left side measurements in determination of stature is statistically insignificant. The calculated stature from regression equations of body parts was close to actual height, less than +/−3 cm in most of the cases. With multiplication factors, when statures were calculated, the errors varied from −10.05 cm to +13.45 cm, of which the difference of more than +/−5 cm was seen in large number of cases. Hence, multiplication factors are statistically inferior and less reliable than regression equations.

Conclusion

- There is a direct relationship between standing height and length of upper and lower limbs in both the sexes.
- Regression equations and multiplication factors are most often used to reconstruct stature.
- Regression equations and multiplication factors are derived separately in male and female for the reconstruction of stature from the length of distal part of arm (combined length of forearm and hand), hand, leg and foot.
- Calculated statures from regression equations are close to the actual height, less than +/−3 cm in most of the cases.
- Calculated statures from multiplication factors, the errors vary from −10.05 cm to +13.45 cm, of which the

difference is more than +/−5 cm in large number of cases.

- Regression equations are statistically superior and more reliable than multiplication factors.

Declaration of Conflicting Interests

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Ethical Approval

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Informed Consent

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Intermediate Syndrome After Chlorpyrifos and Cypermethrin Poisoning

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Dear Editor,

Acute organophosphate (OP) poisoning is a significant cause of morbidity and mortality in developing countries including India. It is action on the enzyme acetylcholinesterase (AChE) is of most clinical significance. These compounds bind to the esteratic site on the AChE molecule phosphorylating the enzyme, leading to inhibition of its normal action. Studies have shown that a phenomenon of enzyme ageing occurs which involves cleavage of a radicle from the inhibited enzyme, making it resistant to rephosphorylation. The net result is the accumulation of excess acetylcholine (ACh) at the cholinergic nerve endings all over the body resulting in the characteristic clinical manifestations. Following inhibition, recovery of this enzyme occurs at a rate of about 1% per day.[1]

Case Study

A 43-year-old alcoholic and depressed person drank a bottle of Hamla 550 (probably about 60 mL) containing Chlorpyrifos and Cypermethrin on 17/6/2023. He was hospitalized in Baramati, Pune and treated with gastric lavage, intravenous atropine, pralidoxime (PAM), intubated, mechanical ventilation, supportive treatment, and extubated on 23/6/23. After three to four days, he developed respiratory weakness and was unable to lift his head. On the eighth day, his vital capacity fell, facial muscles were weak, as was shoulder abduction and hip flexion. The distal muscles were normal. He had normal reflexes and no sensory deficit.[2] He was referred to private hospital in Pune. Serum cholinesterase levels measured 1722.8 U/L on 26/6/23. After clinically corelating symptoms to intermediate syndrome (IMS), treatment with atropine and PAM was restarted. Neurophysiological studies were carried out on 14th day. Results from motor and sensory nerve conduction studies on the median nerve on 14th day were normal. His muscle strength slowly improved and by 15th day he was neurologically normal. He recovered completely after three weeks. It shows that downregulation of acetylcholine receptors (AChRs) could explain the IMS and neurophysiological findings. These receptors have a half-life of 10 days.

Discussion

The IMS is comprised of characteristic symptoms and signs occurring after apparent recovery from the acute cholinergic syndrome. As the syndrome occurs after the acute cholinergic syndrome but before OP-induced delayed polyneuropathy, the syndrome is called "Intermediate Syndrome" (IMS).[2] The IMS occurs in approximately 20% of patients following oral ingestion of OP pesticides, with no clear association between the type of OP compound involved and the development of the syndrome.

With appropriate therapy, complete recovery occurs 5–18 days later. The treatment of IMS is mainly supportive; early aggressive decontamination, appropriate antidote therapy, and prompt institution of ventilatory support should be helpful in ameliorating the magnitude and/or the incidence of IMS. Although IMS is well recognized as a disorder of neuromuscular junctions, its exact etiology, incidence, and risk factors are not clearly defined because existing studies are mostly the small-scale case series and do not employ a consistent and rigorous definition of IMS.[3] The prognosis of IMS is likely to be favorable if respiratory failure can be promptly recognized and treated accordingly.

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Mysterious Death of a Woman Under the Guise of COVID-19 Pandemic: An Exhumation Case Report

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Abstract

Exhumation plays a crucial role in forensic investigations, particularly in cases where the cause of death remains uncertain or suspicious. This study examines the medico–legal significance of exhumation in uncovering concealed homicides, with a focus on a rare case of fatal head injury identified post-exhumation. Exhumation, derived from the Latin term meaning "from the ground," is a legally regulated process requiring judicial authorization under Bhartiya Nagarik Suraksha Sanhita (BNSS), previously governed by Section 176 of the Criminal Procedure Code (CrPC).

A unique case is discussed where a 30-year-old woman was secretly buried during the coronavirus disease 2019 (COVID-19) pandemic without a post-mortem examination. Upon exhumation two months later, autopsy revealed an extradural hematoma despite significant decomposition and an absence of cranial fractures. This highlights the importance of meticulous autopsy examination, even in cases of advanced decomposition. Comparative data from studies on exhumation cases indicate that determining the cause of death becomes increasingly challenging as the post-burial interval extends.

This case underscores the necessity of strict regulations regarding death certification, particularly during public health crises, and the role of forensic medicine in ensuring justice. It reinforces the need for exhumation in unresolved or suspicious deaths, demonstrating its potential in revealing hidden forensic evidence and aiding legal proceedings.

Keywords

Exhumation, COVID-19 pandemic, head injury, decomposition

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Introduction

The term *Exhumation* is derived from the Latin words *ex* (out of) and *humus* (ground), meaning "to bring to light," especially after a period of obscurity or burial.[1] Exhumation is a Latin word, which means "from the ground." Exhumation, which means "from the ground," requires authorization from a judicial magistrate or an appropriate authority.[2]

Exhumation is carried out for various religious, cultural, and social reasons in different parts of the world.[3] It is a complex, costly, and time-consuming process, requiring official permission from legal authorities. As such, it is performed only when a specific need arises. The process is strictly regulated and follows vigilant procedures. First, legal authorization must be obtained from the District and Sessions Judge, Additional District and Sessions Judge, or Judicial Magistrate under Section 196 of Bhartiya Nagarik Suraksha Sanhita (BNSS) previously it was done under Section 176 of the Criminal Procedure Code (CrPC).

The process of exhumation is not only significant from a legal perspective but also plays a key role in forensic investigations. It often serves as a vital tool for uncovering the truth in cases where the cause of death remains unclear or suspicious. Forensic experts utilize exhumation to collect crucial evidence that may be pivotal for solving a case, such as identifying poison or toxins in the body or examining trauma that was not immediately apparent at the time of death. In certain instances, advanced techniques like DNA analysis, toxicology reports, and histopathology can only be performed on remains exhumed after a long period of burial, making this process crucial for obtaining a comprehensive understanding of the deceased's condition at the time of death.

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This case report is unique because findings related to exhumation and decomposition are rarely observed. In our case, even after two months of exhumation, evidence of intracranial hemorrhage was found despite the absence of any bony fractures. Such cases are extremely rare and have been reported in only a few instances worldwide.

Case History

In April 2020, at the peak of the coronavirus disease 2019 (COVID-19) pandemic, a 30-year-old woman died under mysterious circumstances, reportedly following a fall in her home. Her husband took her to a private practitioner, where she was declared dead, and the cause of death was deemed natural, leading to the decision not to conduct a post-mortem examination. That night, he buried her in a cemetery without informing the police or involving any of her close relatives.

Two months later, as the lockdown restrictions began to ease, the woman's brother, who lived in Uttar Pradesh, visited her husband to offer condolences. While speaking with neighbors and relatives, he learned that they had photographs of her head showing visible injuries at the time of her death (Figures 1 and 2). Suspicious after seeing the images, he

Figure 1. Head Showing Signs of Injury.

Figure 2. A Closer Look from Different Angle Showing Blood in Hair.

immediately filed a complaint at the local police station, leading to the registration of an ADR (Accidental Death Report).

Following this, the Sub-Divisional Magistrate issued an exhumation order. The body was subsequently exhumed in the presence of the Sub-Divisional Magistrate, doctors, and police officers. It was then transported to the mortuary, where a post-mortem examination was conducted.

Post-mortem Findings

The body was recovered in an advanced state of decomposition, enshrouded in a dirt-laden, tattered white cloth heavily contaminated with mud and organic debris. The remains exhibited extensive post-mortem changes, with near-complete soft tissue loss over the craniofacial region, leading to exposure of the underlying skeletal structures, including the ribs, chest, and facial bones. The presence of long, black, curly hair, still adherent to the partially decomposed scalp, suggested female sex. Marked skeletonization was observed, particularly in the head and thoracic regions, with remnants of desiccated soft tissue clinging to the bones. The scalp hair exhibited easy pluckability, and a strong putrefactive odor was emanating from the remains, indicative of advanced decomposition (Figure 3).

Upon cleansing and removal of extraneous debris, external examination confirmed extensive decomposition with partial preservation of soft tissue in select regions. The skull demonstrated brownish–black discoloration over the frontal bone (Figure 4). Internally, the visceral organs had undergone complete autolysis, appearing as an amorphous, black decomposed mass with no discernible anatomical features. Post-exhumation radiographic imaging did not reveal any skeletal fractures (Figures 5 and 6).

However, upon opening the cranial cavity, the dura mater was found to be intact, underlying which a well-demarcated, brownish-black semisolid mass measuring approximately 7 cm × 4 cm and weighing 110 grams was firmly adherent, consistent with an extradural hematoma (Figure 7). Further dissection of the dura mater revealed semisolid cerebral

Figure 3. Exhumed Body Showing Signs of Decomposition and Skeletonization.

Figure 4. Brownish Black Discoloration Over Frontal Region of Skull.

Figure 5. Lateral View of X-ray Skull.

Figure 6. Anteroposterior View of X-ray Skull.

matter with diffuse brownish-black infiltration within the brain parenchyma, suggestive of significant post-mortem decomposition changes (Figure 8). Based on the collective findings, the cause of death was opined to be a fatal head injury.

Discussion

The exhumation of human remains plays a critical role in forensic investigations, particularly in cases where the cause and manner of death remain uncertain. In the present case, the exhumation of a 30-year-old female who was clandestinely buried during the COVID-19 pandemic revealed crucial forensic evidence that contradicted the officially recorded

Figure 7. Brownish Black-colored Semisolid Mass Firmly Adherent to Dura Mater.

Figure 8. Brownish-black Infiltration of Brain Parenchyma.

cause of death. This underscores the importance of forensic re-examination in instances of suspicious deaths, particularly those occurring under exceptional circumstances such as a pandemic-induced lockdown.

In a retrospective study conducted by Rajesh Bardale et al., total 24 cases of exhumation were analyzed over a period of 10 years, out of which in 16 cases (66.6%) the cause of death was clearly determined at exhumation. Out of these 24 cases, in 5 cases the first autopsy was not conducted and the bodies were buried by criminals after killing the individuals.[4]

One of the primary challenges in exhumation cases is the degree of decomposition, which can obscure or destroy important forensic evidence. In this case, despite the significant decomposition observed after two months of burial, key findings such as an extradural hematoma remained identifiable. The presence of such findings in the absence of any cranial fractures is a rare but documented phenomenon. This highlights the importance of careful examination of soft tissue remnants and skeletal remains, even in advanced decomposition states.

Another critical aspect of this case is the issuance of a false death certificate without a post-mortem examination. The deceased's husband exploited the pandemic situation to avoid legal scrutiny, emphasizing the need for stricter regulations regarding the issuance of death certificates, particularly during public health crises. This case also illustrates how relatives' suspicions and circumstantial evidence, such as photographic documentation, can prompt intervention by police and uncover the actual cause of death.

In a study by Shala Imran et al., 95 exhumations were conducted over two years. Among cases exhumed within three months, the cause of death was determined in 18 instances (18.95%) but remained undetermined in 27 cases (28.42%). For exhumations occurring between four and six months, the cause of death was identified in 15 cases (15.79%), while it remained unknown in 16 cases (16.84%). In the 7- to 12-month period, the cause of death was established in three cases (3.16%) and remained undetermined in eight cases (8.42%). When exhumation took place more than 12 months after death, the cause was determined in just one case (1.05%), with seven cases (7.37%) remaining unresolved. Overall, out of 95 cases, the cause of death was identified in 37 cases (38.95%), while it remained undetermined in 58 cases (61.05%).[5]

In another report, the body of a 10-year-old girl was exhumed two years after burial. She had been sexually assaulted and strangled before being buried. The remains were recovered from a location identified by the accused, who had confessed to the crime. A detailed examination of the skeletal remains concluded that they belonged to a female aged 10–12 years, with an estimated height of 138–140 cm. DNA profiling confirmed her identity.[6]

Similarly, in another case report the cause of death of a 73-year-old woman was initially certified as natural. The exhumation was ordered three weeks after the burial. At autopsy, there were findings suggestive of blunt force impact to occiput, thorax, and upper extremities and compression of neck. The findings at autopsy proved foreign intervention and suggested death due to suffocation. Exhumation and further autopsy contradict natural death established the cause of death beyond further suspicion. An obvious lack of meticulous and thorough post-mortem examination was probably the main reason for the misjudgment in this case.[7]

From a medico–legal perspective, the present case reinforces the necessity of exhumation in cases where the cause of death is doubtful. The judicial authorization of exhumation under BNSS, previously under Section 176 of the CrPC, remains a crucial provision for ensuring justice.

The findings also highlight the forensic significance of examining all body cavities, as external examination alone may not always reveal the cause of death, particularly in cases involving closed head injuries. Furthermore, this case contributes to forensic literature by demonstrating that even after prolonged burial, intracranial pathology may persist in identifiable form, aiding in establishing the cause of death.

Conclusion

In conclusion, this exhumation case underscores the indispensable role of forensic medicine in criminal investigations, particularly in detecting concealed homicides. It highlights the medico–legal implications of fraudulent death certifications and the need for vigilance in death investigations, especially during public emergencies. The findings emphasize the necessity of thorough forensic examinations and reinforce the importance of exhumation as a tool for establishing the truth in suspicious deaths.

Declaration of Conflicting Interests

Ethical Approval

The ethical approval is taken from Institutional Ethical Committee of Rajiv Gandhi Medical College, Thane. The identity of the deceased was not revealed in the manuscript.

Funding

Informed Consent

The identity of the deceased has been anonymized and no identifiable personal information has been disclosed. Informed consent was not required for this case report as it involves a deceased individual and the information was obtained from medicolegal autopsy records.

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Accidental *Jatropha curcas* Poisoning in Six Childrens: A Case Report

Manish Nigam[1], Narendra Singh Patel[2], Vivek Kumar Chouksey[2], Vaibhav Agrawal[2], Nikhil Sabu[2], Amar Singh Manjhi[2] and Sawan Verma[2]

Abstract

Jatropha curcas, a member of the Euphorbiaceae family, is a widely distributed plant with highly toxic seeds. The primary toxic compounds—phorbol esters and curcin—induce severe gastrointestinal distress upon ingestion. Accidental ingestion of these seeds, particularly in children, is a frequent yet underreported cause of poisoning in regions where the plant grows abundantly. Here, we present a case of six children (aged 8–15 years) who developed acute gastrointestinal symptoms after ingesting *Jatropha curcas* seeds while playing in a garden. The children experienced multiple episodes of vomiting and diarrhea but remained hemodynamically stable. Immediate medical intervention, including gastric lavage and intravenous (IV) fluid therapy, led to full recovery. This case highlights the toxicity of *Jatropha curcas* seeds, its clinical presentation, and the importance of public awareness and preventive measures.

Keywords

Jatropha curcas, plant poisoning, pediatric toxicology, gastrointestinal toxicity, accidental ingestion

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Introduction

Jatropha curcas is a large, glabrous shrub belonging to family Euphorbiaceae, with greenish white, smooth bark that peels off in thin flakes. Leaves measured up to 15 mm in diameter, and are entirely or palmately lobed. Flowers are yellowish green in color (Figure 1).[1] *Jatropha curcas*, also known as the physic nut, Barbados nut, or purging nut, is a drought-resistant plant used in biodiesel production, medicinal applications, and traditional remedies. Despite its economic value, the plant contains toxic compounds, including phorbol esters, curcin (a ribosome-inhibiting protein), diterpenes, and lectins, which contribute to its acute toxicity in humans and animals.[2] Children are particularly susceptible to accidental ingestion due to the attractive appearance of the seeds and their initially sweet taste. Reports from India,[3] South Africa,[4] Kenya,[5] and other regions indicate that *Jatropha curcas* poisoning is a growing concern. The primary clinical manifestations of poisoning include gastrointestinal distress (vomiting, diarrhea, abdominal pain), dehydration and electrolyte imbalance, and rare systemic complications (hepatic, renal, and central nervous system involvement).

Previous studies highlight mass poisoning incidents involving children who unknowingly consumed the seeds, necessitating urgent medical intervention.[6–8] This case report adds to the growing body of literature by documenting a cluster of *Jatropha curcas* poisonings in India and emphasizing the need for preventive strategies and public health awareness.

Case Details

Patient Demographics and History

Six children (male and female, aged 8–15 years) were playing in a garden around 4:00 PM when they discovered groundnut-like fruits and seeds. Upon tasting them, they found the seeds

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Figure 1. *Jatropha curcas* (A) Mature Plant; (B) Seedling; (C) Inflorescence with Male and Female Flowers; (D) Fruits at Different Stages of Ripeness; and (E) Mature Fruit with Seeds.

Source: Abdelgadir and Van Staden.[10]

sweet and proceeded to consume two to five seeds each. Approximately 30 minutes postingestion, all six children developed the following symptoms: Multiple episodes of vomiting (5–7 episodes per child), loose stools (watery, nonbloody), and mild epigastric discomfort. The vomitus was nonprojectile and nonbilious. Importantly, the children exhibited no fever, loss of consciousness, altered sensorium, or respiratory distress. Concerned parents brought them to the emergency department for evaluation. They also brought the fruits for identification which helped us in diagnosing the cases.

Clinical Examination

Upon arrival, the children were assessed for vital signs, hydration status, and systemic involvement. General condition: Mild dehydration was noted in some children and mild congestion in eyes was present. Vital signs: pulse were increased, blood pressure was stable, respiratory rate was normal, temperature was afebrile. Abdominal examination: Soft, nontender, mild discomfort in some cases. Neurological examination: No altered sensorium, normal reflexes.

Management and Treatment

Prompt supportive treatment was initiated: gastric lavage, intravenous (IV) fluids, and other supportive measures like antiemetic and oral rehydration solution (ORS) were given and then were kept in close observation for 24 hours.

Outcome and Follow-up

All six children recovered within 24–36 hours, with symptoms resolving completely. Parents were educated about *Jatropha curcas* toxicity and advised to remove the plant from the vicinity.

Discussion

Jatropha curcas seeds contain phorbol esters, which act as potent gastrointestinal irritants, leading to vomiting and diarrhea.[9,10] Curcin, a toxic lectin, has cytotoxic effects, inhibiting protein synthesis and potentially damaging liver and kidney cells.[11] Several studies have reported *Jatropha curcas* poisoning in children, emphasizing similar clinical manifestations and outcomes: Gupta et al. (2016)[3]—Mass poisoning in North India; severe gastrointestinal distress required hospitalization. Moshobane et al. (2017)[4]—Cases in South Africa highlighted the need for early fluid replacement therapy; Joubert et al. (1984)[6]—Early documentation of Jatropha poisoning in children, stressing the purgative effects; Mukungu et al. (2015)[5]—Kenyan case series demonstrating successful gastric lavage and IV fluid therapy; Choudhary et al. (2022)[8]—Family-wide Jatropha poisoning in rural India, reinforcing the need for community education. Though self-limiting in most cases, *Jatropha curcas* poisoning can lead to severe dehydration and electrolyte imbalance, metabolic acidosis (in rare cases), liver and kidney involvement (if large quantities are consumed). Fortunately, early medical intervention significantly improves outcomes, with most patients recovering fully within 24–48 hours.[7]

Conclusion

Jatropha curcas poisoning remains an underrecognized public health concern, especially in tropical and subtropical regions. This cluster of pediatric poisonings highlights the toxicity of *Jatropha curcas* seeds and the importance of early supportive management. Education, awareness, and preventive strategies are key to reducing future poisoning incidents. Given the growing number of *Jatropha curcas* poisoning cases, the public health and preventive strategies that can be taken into consideration can include public awareness campaigns—educating communities on the toxicity of Jatropha curas, eradication of Jatropha plants—especially in school gardens and playgrounds, and supervised outdoor play—preventing accidental ingestion of toxic plants.

Declaration of Conflicting Interests

Ethical Approval

Ethical approval for this study was obtained from the College Ethical Review Committee prior to its commencement.

Funding

Informed Consent

Informed consent was obtained from the parents/guardians of the children before conducting the examinations.

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Bee Sting: Autopsy of an Anaphylactic Death—A Case Report

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Abstract

Bee stings are the most common among insect emergencies. Bee venom contains dopamine, histamine, neurotoxin enzymes, melittin, hyaluronidase, and phospholipase-A. Hypersensitivity varies from mild urticaria to severe anaphylaxis leading to even death. We report a case of a 72-year-old man attacked by a swarm of bee and sustained multiple bee stings all over his face, head, neck, chest, and both arms causing massive envenomation following which he managed to walk home following which he developed systemic symptoms such as vomiting, weakness, fatigue, dizziness, gasping, and chest pain. He was brought dead to the casualty and hence was taken up for medicolegal autopsy. Postmortem examination revealed congestion of all internal organs including classical signs of anaphylaxis leading to respiratory distress and death. Multiple bee stings envenomation can end up in anaphylactic shock and death. Therefore, patients who have sustained multiple bee stings have to be rushed to the hospitals at the earliest and receive prompt treatment to avoid fatal complications. Purpose of this article is to highlight the symptomatology and gross changes noted in the autopsy are signs of anaphylaxis as a result of allergy to honeybee venom.

Keywords

Honeybee, bee sting, allergic reaction, norepinephrine, first aid, anaphylaxis, death, case report

List of Abbreviations

ACTH—adrenocorticotropic hormone, IgE—immunoglobulin E, PLA2—phospholipase-A2, RAST—Radio allergo sorbent test.

Background

Insects that sting to defend their colonies are included in the order Hymenoptera in the taxonomy of animals. Notable Hymenoptera groups in medicine are the Apoidea (bees), Vespoidea (wasps, hornets, and yellow jackets), and Formicidae (ants). A bee sting is a wound and discomfort brought on by a bee stinger puncturing skin. In contrast to insect bites, bee stings are caused by venom that varies greatly in composition. Bee sting casualties are the commonest among insect sting/ bite emergencies.

From 2000 to 2017, hornet, wasp, and bee stings resulted in 1,109 deaths among US citizens, or an average of 62 deaths each year. The number of deaths varied, peaking at 89 in 2017 and falling to 43 in 2001.[1] Bees are typically 10–15 mm long, with a barbed sting, and brilliant yellow bodies with black markings on the abdomen. While wasps and hornets can sting repeatedly, bees can sting only once since their sting becomes embedded in the flesh.[2] The bee sting apparatus consists of three functionally independent parts: the motor part, the piercing part, and the venom-related area.[3] Honeybee venom contains dopamine, histamine, neurotoxin enzymes, melittin, hyaluronidase, and phospholipase-A.[4] The severity of reactions to bee sting hypersensitivity can vary from mild skin rashes/hives to fatal anaphylaxis leading to death. Anaphylactic reactions can happen instantly or within 20 minutes. There is breathing difficulty, dizziness, and unconsciousness. The number of stings has a direct bearing on the severity and outcome of the envenomation. Consequently,

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50–500 stings can result in an adult man dying.[5] In 2–15 minutes, death could happen.

Case Presentation

A 71-year-old man, who was returning from his friend's funeral, was attacked by a swarm of bees on 25 September 2022 at 8 am, on Nittur Road, Belagavi, Karnataka. He sustained multiple bee stings all over his face, head, neck, chest, and both arms causing massive envenomation following which he managed to walk home, but he felt intense pain during and immediately after getting stings all over his wounds and before reaching home, within minutes after the incident he started developing all local symptoms such as urticaria, redness, local pain, and burning sensation, following which just within 5 minutes he had started to develop systemic symptoms such as weakness, nausea, vomiting, disorientation, chest pain, and respiratory discomfort with gasping. However, he managed to reach home by a walk, and informed his family regarding the incident vaguely and they initiated some home remedies like the application of tobacco, manual attempts to remove the stings, and ice packs before rushing to the emergency room. All these home remedies were on target towards the local symptoms, whereas no remedy was started for the silently developing systemic symptoms. Hence, his condition started to deteriorate and before leaving to the hospital, he went unconscious, and so he was declared to be brought dead in the casualty at 9.30 AM, that is, within a short time of less than two hours, and hence was taken up for medicolegal autopsy on the same day at 4 PM.

External Examination

On the autopsy table, the length of the victim measured 160 cm; he was moderately built and nourished. Rigor mortis had developed over the upper part of the body. Postmortem staining was present over the back of the body and was not fixed. Multiple bee stings were present over the scalp, face, both arms, and forearms, front of the chest, outer aspect of both sides of chest, and below axilla, in total accounting for 106 bee sting injuries with a surrounding zone of inflammation around each sting (Figures 1–3). Thirty-six dead honeybees were collected from the body of the victim, from the scalp hair, within pockets, folding of full sleeve cuffs, within his tank and shirt, from nostril and mustache.

Internal Examination

Autopsy examination revealed certain findings suggestive of anaphylactic reactions.

1. Few honeybees were removed from the laryngeal lumen.

2. Grossly larynx and trachea were intact, edematous, and congested, with obstruction of the laryngeal lumen (Figure 4), which was in concordance with a case report by Sethi and Jena.[6] Histopathology of the larynx confirmed the same (Figure 5).
3. Both lungs—Hyper expansion of the lungs and mucus clogging was present, which went in favor of asthmatic crisis.
4. Anaphylactic asthma fatality—Lungs were heavy and diffusely congested on cut section. Blood with copious froth exuded on compression (right—511g, left—436 g) (Figure 6).

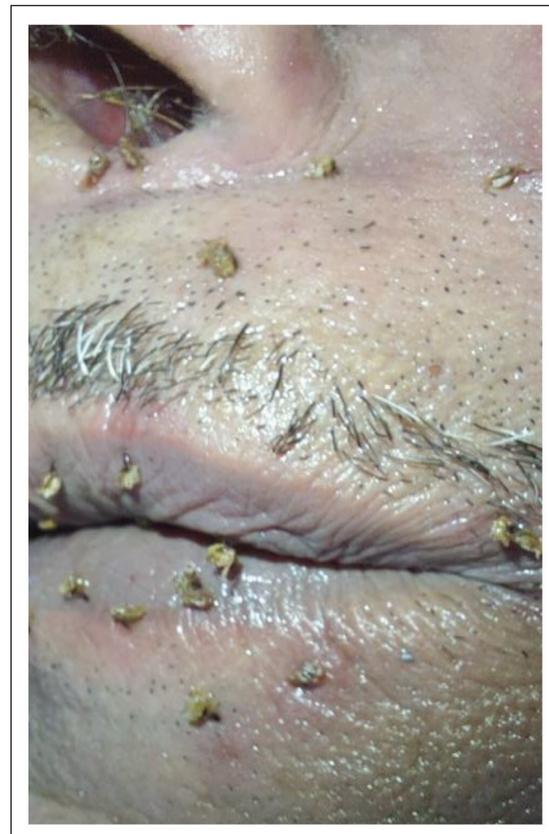**Figure 1.** Dead Honeybee Recovered from the Dead Body.

Figure 2. Bee Stings Struck in Skin of Face.

Figure 3. Removed Stingers.

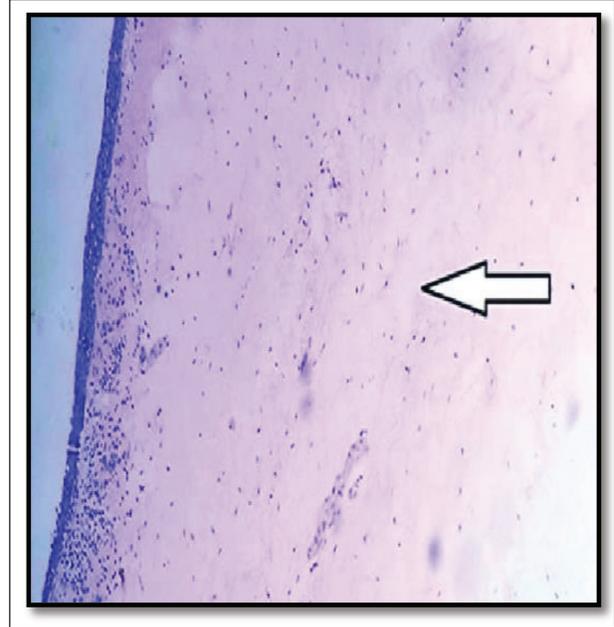**Figure 4.** Gross Laryngeal Edema and Congestion.

Figure 5. Histology of Laryngeal Edema.

Figure 6. Heavy and Diffusely Congested Lungs with Mucous Plugs.

5. The bronchial lumen was filled with mucus (Figure 7) and at high magnification, the numerous eosinophils were prominent (Figure 8).
6. Chronic congestive splenomegaly was incidentally found even with neither any past medical history/ condition nor with history of any addictions.

Anaphylactic shock from numerous bee stings was determined to be the cause of death based on the results of the postmortem examination and the histology report.
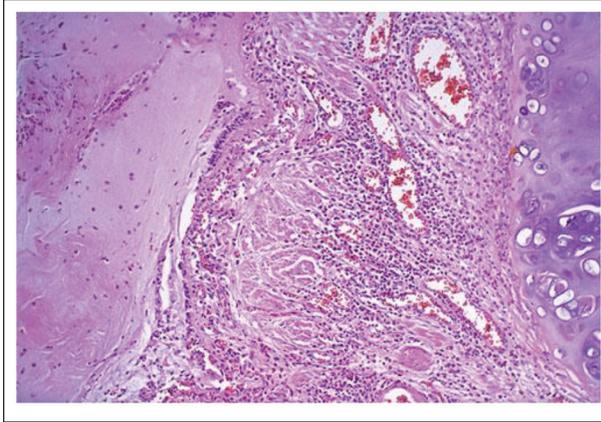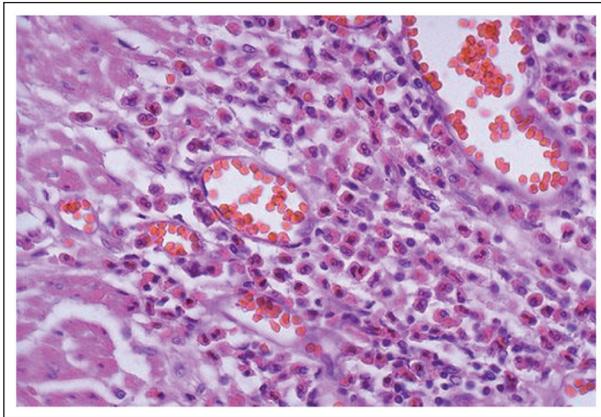
Figure 7. Microscopy of Bronchial Lumen.

Figure 8. Microscopy of Bronchial Lumen at High Magnification.

Discussion

Honeybee venom, enzymes (hyaluronidase, phospholipases), and biological amines (norepinephrine, serotonin, dopamine, histamine, and acetylcholine) are just a couple of the chemicals that make up stings and lead to the clinical picture.[7]

A honeybee sting can present in either or all of the four modes of presentations as follows. *Dermal reaction symptoms* (urticaria, erythema, and angioedema), *cardiovascular* (acute coronary syndrome, hypotension, and shock), *respiratory system* effects (laryngeal edema and bronchospasm), and events involving the *digestive system* (vomiting and incontinence).[5]

The melittin protein, which hydrolyzes cell membranes, modifies cell permeability, and releases histamine, is the primary cause of localized discomfort. Additionally, it releases catecholamines and in concert with phospholipase-A2 (PLA2), it facilitates intravascular hemolysis. Histamine and other vasoactive peptides are released from mast cells by the mast cell degranulating peptide (peptide 401). PLA2, which together with melittin causes intravascular hemolysis, is bee venom's primary allergenic element. Another is hyaluronidase, which is thought to be the main "spreading factor" since

it alters cell membranes. Additionally allergic is hyaluronidase and vasoactive amines, such as dopamine, noradrenaline, and histamine.[8]

Management Considerations

In case of attack by a swarm of bees, the treatment should be immediately started without any delay, which includes ligature above the site of the sting, removal of the stinger and venom sac with a blade, or with a forceps, following the administration of the lifesaving drug, that is, an intramuscular shot of adrenaline also known as epinephrine.[9] Delivery of adrenaline must not be delayed by even a few minutes to prevent hypoxia or death. This can be followed by all the other first aid measures such as iodine or local antihistamine and local ice application, and adrenocorticotropic hormone (ACTH) 25 mg in a liter of normal saline can be given by intravenous infusion.[10]

If there are pertinent clinical or postmortem signs, serum tryptase values of more than 100 µg/L in a postmortem sample would be compatible with anaphylaxis being the cause of death or contributing to it.[11]

In addition to routine toxicological screening, serum should be submitted for radio allergo sorbent test (RAST) testing for serum tryptase level and immunoglobulin E (IgE) specific to bee venom.[12] These simple, low-cost tests might be able to rule out anaphylaxis as the cause of death.

In case of suspicion, a scene investigation has to be done to know whether the victim has used any strong scents, and wearing brightly colored clothing may make it easier for insects to find them. The presence of any biological or inorganic stains or trails must be noted and sampled. Interviews with parents, relatives, and other witnesses are required at all times. The location, month, and time of year at the moment of death must be taken into consideration, and they must be contrasted with the local geographic latitude's pollen calendar.[11]

Mass envenomation-related deaths are thought to be caused by three main processes: direct venom toxic consequences, intravascular hemolysis mediated by melittin and PLA2, and significant hypotension resulting from excessive histamine release.[13]

Particularly in cases when there are no visible stings, a serum tryptase and specific IgE to bee venom on serum taken at autopsy might help identify anaphylactic reaction to bee venom as the cause of death.[10] Such testing and investigation were not done in our case, since multiple bee sting injuries, autopsy findings, and the cause of death were evident.

Parenteral antihistamines, fluid resuscitation, bronchodilators, supplemental oxygen, intubation, vasopressors, tetanus booster, and pain relievers may be required. Patients should be observed for 24 hours for recurrent anaphylaxis. Rarely, symptoms of bee stings include vasculitis, rhabdomyolysis, widespread alveolar hemorrhage, and thrombocytopenic purpura. The case in point showed the signs of itching, urticaria, hypotension and shock, nausea, vomiting, laryngeal edema; that is, the symptoms included involvement of all the above-mentioned systems. Deaths due to bee sting are quite avoidable deaths with

prompt action. Immediate resuscitation and care would have saved the patient if he would have been ushered to the casualty.

Conclusions

Therefore, this article highlights the clinical manifestations and fatal outcomes of mass honeybee envenomation including the autopsy findings of anaphylaxis to bee venom and the need for initiating immediate resuscitation by anticipating the unwanted fatal outcomes including death.

Declaration of Conflicting Interests

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

Ethical Approval

Ethical approval has been obtained for the conductance of the study.

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Informed Consent

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Journal of Indian Academy of Forensic Medicine

Aims and Scope

Journal of Indian Academy of Forensic Medicine (JIAFM) is a quarterly peer-reviewed specialty medical journal which is the official publication of the Indian Academy of Forensic Medicine. The Journal covers all technical, medico-legal and clinical aspects of the Specialty including the Ethical and Social issues. JIAFM presents a comprehensive and meticulous exploration of the intricate facets within the realm of Forensic Medicine. It serves as a pivotal platform for scholarly investigations, discussions, and insights into ethical and social dimensions that intersect with Forensic Medicine.

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Journal of Indian Academy of Forensic Medicine **(JIAFM)** is a quarterly peer-reviewed specialty medical journal which is the official publication of the Indian Academy of Forensic Medicine. The basic ideology of publication of this journal is based on the objectives of Indian Academy of Forensic Medicine (IAFM). It is a quarterly published, multidisciplinary, Multispeciality, international, peer reviewed IAFM (society) journal published by SAGE as a medium for the advancement of scientific knowledge of Forensic Medicine, Medical Ethics, Medical Education, Law and allied sciences.

The Journal covers all technical, medico-legal and clinical aspects of the Specialty including the Ethical and Social issues. JIAFM presents a comprehensive and meticulous exploration of the intricate facets within the realm of Forensic Medicine. It serves as a pivotal platform for scholarly investigations, discussions, and insights into ethical and social dimensions that intersect with Forensic Medicine.

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From Editor's Desk

Dear All,

You have my sincere gratitude for believing in me and giving me this distinguished role as the Editor-in-Chief of Journal of Indian Academy of Forensic Medicine. Big thanks to all IAFM members and Esteemed voters. Words cannot describe how grateful I am. I am grateful to the former IAFM President - Dr Mukesh Yadav Sir and former IAFM Secretary- Dr Manish Kumath Sir for their kind blessings and continued support. With blessings and support from current IAFM President- Dr C B Jani Sir and IAFM Secretary- Dr Rajesh Dere Sir, I will prove myself with continued hard work, dedication and constant efforts towards upliftment of the journal status.

I am well aware of the obligations that you have placed on me. With your ongoing assistance, I hope that everyone will have a great time for their own academic upliftment, including upgradation of the journal quality and indexing status at par excellence. I will strive to improve the calibre and standard of JIAFM publications. Throughout the trip, I ask for your participation, understanding, and direction as needed. I would like to express my sincere gratitude to all of our past editors and co-editors who have distinguished this journal via their tireless efforts and dedication, which has allowed JIAFM to grow every year.

Being the Editor-in-Chief, on the behalf of my new editorial team including officially elected Joint Editor Dr Mohammed Ziyauddin G. Saiyed, I assure you a hassle-free and user friendly manuscript submission, handling and management system via SAGE platform for speedy process and final decision through editorial team. A few highly active national and international faculties with outstanding knowledge in a range of subspecialties have also been added as National, international editorial board and reviewer board panels, and they will be able to provide constructive criticism to help us get better.

Additionally, by including case series, research briefs, brief communications, book reviews, and letters to the editor, we intend to improve the publication sections. We genuinely anticipate our fraternity's academic advancement through high-calibre publications with your help.
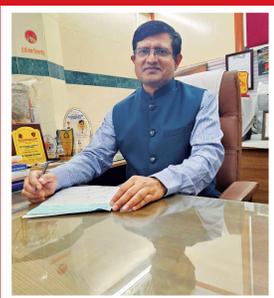
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