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An Autopsy based Study of Atherosclerosis of Cerebral Arteries: A Case Report

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Abstract

Cerebral artery atherosclerosis is a major risk factor for ischemic stroke and sudden natural death. In Forensic practice, significant intracranial atherosclerosis can be unnoticed unless observed and demonstrated carefully. This case report is an autopsy based study of diseased with known history of stroke. Examination of brain and intracranial vessels revealed advanced atherosclerotic changes with critical narrowing in middle and posterior cerebral arteries. Autopsy based confirmation helps in clinicopathological correlation and assists in accurate certification of cause of death in Forensic Practice.

Keywords: atherosclerosis, stroke, autopsy, cerebral artery

Introduction

Stroke is one of the leading causes of disability and death worldwide. Intracranial atherosclerosis is one of the main risk factors for the development t of ischemic stroke.

A stroke or cerebrovascular accident is defined as the abrupt onset of a neurologic deficit that is attributable to focal vascular cause. Cerebral ischemia is caused by reduction in blood flow that lasts longer than several seconds. If this lasts more than minutes, infarction or death of brain tissue occurs [(1)]. Atherosclerotic cerebrovascular disease is frequently associated with systemic diseases such as hypertension and diabetes [(2)]

Patients with previous history of stroke are at increased risk of recurrent ischemic events and sudden death. Stroke is diagnosed as a clinical entity and imaging studies are only supportive, hence a meticulous autopsy plays an important role in establishing the exact cause of death in such cases. This case highlights the importance of detailed

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postmortem examination in confirming death due to advanced atherosclerotic cerebrovascular disease.

Case History

A male adult aged 59 years with a known history of stroke was brought dead to KR Puram General Hospital, Bengaluru following sudden collapse while going to the rest room of his residence. The deceased was also a known case of chronic hypertension. The deceased was later brought for autopsy in East Point medical college and Research Centre. As per history given by relatives, the deceased had been bedridden after the episode of stroke. There was no history of trauma, poisoning etc.

External Examination

The body was of an adult male, moderately built and nourished. Pressure sores were present over the buttocks. Postmortem changes were consistent with time since death. No demonstrable external injuries were present over the body.

Internal Examination

Brain: the brain was edematous. Yellowish golden coloured fluid was present in the subdural spaces. On examination of cerebral vessels. Approximately 90-95 % of narrowing with calcification was present in the middle and posterior cerebral arteries and its branches on both sides. (fig 1).

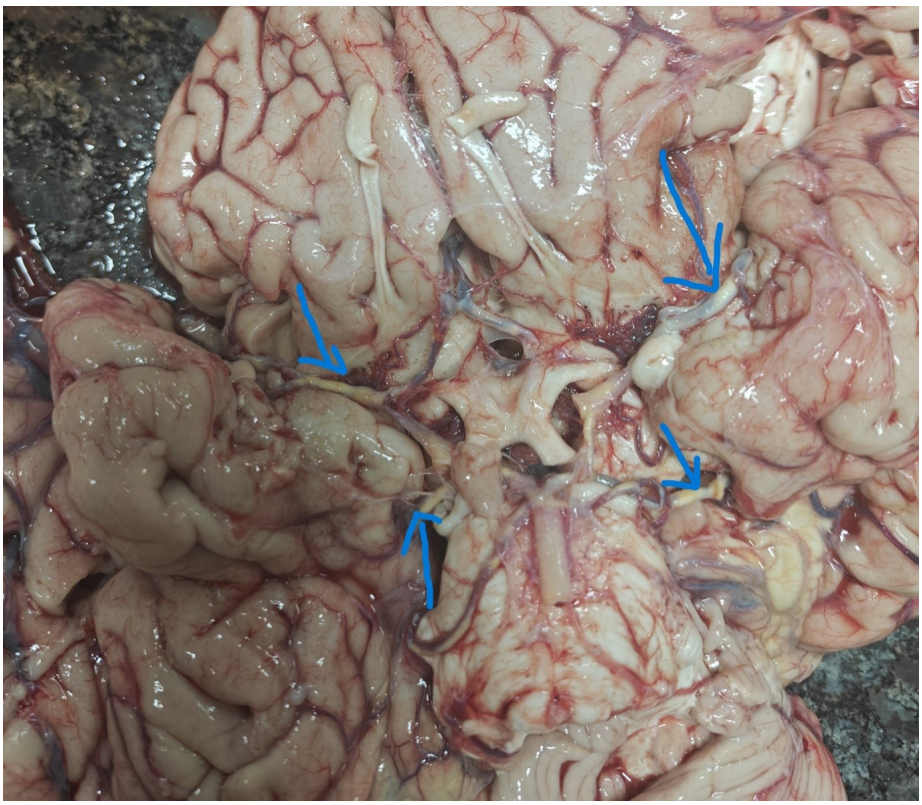


Figure 1: Photograph of the brain depicting circle of willis and atherosclerotic cerebralarteries.

Liver: the surface of liver showed features of cirrhosis with multiple yellowish colourednodules and firm consistency.

Heart: pericardium was intact. Heart weighed 340 grams. Coronary arteries showed atherosclerotic calcification of approximately 45 % to 55 %.

Blood and routine viscera were sent for chemical analysis at Forensic Science Laboratory. The chemical analysis reports were negative for any detection of poisons.

Opinion on Cause of Death

Death is due to Ischemic cerebrovascular disease due to atherosclerosis of bilateral cerebral arteries.

Discusssion

Sudden and unexpected death is death occurring within 24 hours of the onset of symptoms in an individual who was not known to be suffering from any disease, injury or poisoning. The term is applied to deaths occurring due to natural causes rather than polytrauma or poisoning.[3]. The cardiovascular system constitutes the leading cause of sudden death (45 – 50 %). The central nervous system constitutes 10- 20 % of the total incidence of sudden deaths. The Central Nervous System causes, that lead to sudden death include intracerebral hemorrhage, cerebral thrombosis, embolism, tumor, idiopathic epilepsy etc. [4]

The major arteries supplying the cerebrum get interconnected at the base of the brain to form a six legged polygon of arteries called as Circle of will is. It is the arterial anastomotic ring at the base of brain formed by anterior cerebral artery, anterior communicating artery, posterior cerebral artery, posterior communicating artery, and right and left internal carotid artery. If one of the major arteries forming circle of will is is blocked, the circle of willis provides alternative roots for collateral circulation like an arterial traffic circle.[5]

The middle cerebral artery is the largest terminal branch of internal carotid artery. It supplies about two thirds of super lateral surface and temporal pole. Posterior cerebral artery is the branch of basilar artery, it passes laterally parallel to superior cerebellar artery and curves around to reach the medial surface of cerebral hemisphere.[5]

Most common form of stroke occurs due to infarction in the middle cerebral artery.[1]. Risk factors of intracranial atherosclerosis include diabetes, high blood pressure, high cholesterol, cigarette smoking, increasing age, family history of stroke etc. grossly there is minimal changes in appearance during first 6 hours of injury. By 48 hours, the tissue become pale, soft and swollen. As time progresses, infarcted tissue liquifies, eventually leaving fluid filled cavity.[2] The most common investigations to detect stroke are CT and MRI. These radiographic investigations show damage in brain that happens because of stroke or atherosclerosis.[6]

A study done by wolk off noted that lipid plaques in the arterial lumen first began to occur in the fourth decades of life. Lipid plaques represent the first stage of arterial narrowing. He also found that large arteries at their base of the brain developed atherosclerotic changes earlier than the more distal branches[7]. This finding is similar to the finding in the present case. Large artery atherosclerosis (> 50 % stenosis or complete occlusion of a major cerebral artery or a branch of cortical artery) presents with Clinical features including aphasia, neglect, motor or sensory deficits.[8]

A postmortem examination in a patient with suspected cerebrovascular disease should be performed in the standard way with removal of the brain and spinal cord. In cerebrovascular disease, there may be non specific abnormalities that are commonly found. Patients may show muscle wasting linked to loss of motor function, Immobility predisposes them to pressure sores[9]. The deceased in the present study had developed pressure sores over posterior part of the body due to prolonged immobility.

An Autopsy based study done by Asha S Shenoy et al, in 2022 in 50 cases aged above 60 years of age found that intracranial anterior circulation was affected more than other vessels. The most common nature of plaques was found to be fibro fatty in this study. The present study showed more advanced stage of plaque formation with increased component of calcification along with fibro fatty deposits. [10]

In a case control study done by M Aighi et al found that there were significant prevalence of intracranial plaques and stenosis in ischemic stroke patients which is similar with the comorbidity of the deceased in the currently reported study. The gradual loss of elastic fibres and medial muscular elements with increase in collagen tissue were the reasons attributed to the development of atherosclerosis with increasing age. [11]

In an hospital based autopsy proven study done by Archana Hinduja, Harsh Gupta, Daniel Dye in 58 patients who died with a diagnosis of stroke that was done to find out the discrepancies between the clinical diagnosis and autopsy findings have found that in three cases, prognosis altering discrepancies were found. The brain finding sat autopsy in the present case could not be correlated with the clinical diagnosis as the patient was brought dead.[12]

The autopsy based study done by Sreekanth S Nair, Nikhil Lakhmanan in keralam in persons of age above 30 years found that the atherosclerosis was more significantly progressed in middle cerebral arteries and posterior cerebral arteries as compared to anterior cerebral arteries. This is in contrast with the result of the study dine by Asha Shenoy[10]. The pattern of atherosclerosis is similar to the present case where middle and posterior cerebral arteries have higher grade of luminal narrowing (90 – 95 %) as compared to (60 - 65 %) narrowing found in the anterior cerebral arteries [13]

Conclusion

This case demonstrates that advanced bilateral atherosclerosis can lead to fatal ischemic cerebrovascular disease. Autopsy findings of severe narrowing of cerebral arteries, edematous brain and absence of external injuries establish natural cause of death. The yellowish brown coloured fluid in subdural space is consistent with the old (chronic) subdural hematoma with breakdown of hemoglobin breakdown components.[3] Severe bilateral calcification of lumens of cerebral arteries leads to compromised perfusion of vital centers of brain. This case reinforces early detection and timely preventive measures to prevent fatal outcome.

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Informed Written Consent: had been obtained from the next of kin (son) along with signature.

Conflict of Interest: there is no conflict of interest.

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Review Article

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Use of Smartwatches as A Medical Device and Security Concerns: A Comparative Regulatory Perspective from The EU, US, India, and Russia

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Abstract

Background: Smartwatches are rapidly evolving into medical devices capable of conducting electrocardiograms (ECGs), measuring blood oxygen saturation, and detecting arrhythmias and sleep apnea. Their clinical usage facilitates lifelong disease management, the early detection of anomalies, and remote patientcare. However, there are legal and cybersecurity issues that lie deep in this transformation. Risks of insecure wireless connections, weak encryption, and re-identification make sensitive health information vulnerable to unauthorized access.

Methods: The Present work uses a scoping review approach to assess the medical use of smartwatches and related regulatory and security concerns. Although the European Union has implemented privacy protection through the General Data Protection Regulation (GDPR), and the U.S. has developed regulations through the Health Insurance Portability and Accountability Act (HIPAA), a fragmentation of rules still exists. The Medical Device Rules (MDR 2020) in India are not very clear regarding AI-enabled wearables, whereas Russia has recently updated rules regarding the registration and post-market surveillance of medical devices, including specialized software and smartwatches, under Government Decree No. 1684 (2024).

Conclusion: The article will contribute to the legal literature by providing a comparative overview of smartwatch regulation in various jurisdictions, highlighting how disjointed regulation and inadequate cybersecurity practices can compromise the security of patients and hinder medical innovation. It claims that harmonizing legal provisions, adopting strong encryption algorithms, and recognizing AI-based capabilities are key to the success of smartwatches as reliable instruments of personalized medicine today.

Keywords: Smartwatch; Medical device; Security Concerns; Regulations; Healthcare.

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Introduction

Medical smartwatches evolved from fitness tracking to monitoring physiological parameters, such asmeasuring heart rate, blood oxygen saturation, and electrocardiogram data (ECG).[1],[2] The medical integration of smartwatches enables real-time patient tracking, chronic disease care, and early health anomaly detection, making them innovative personalized medicine solutions.[3] Technological devices appear on the market too fast compared to how long it takes for researchers to analyze their digital security risks. Research reveals that unsecured Bluetooth and Wi-Fi connections breach smartwatch health data, including GPS locations, sleep patterns, and cardiac rhythms.[4] The studies conducted by Zhang et al. (2019) established that hackers exploit Apple Watch and Fitbit data breaches to retrieve personal IDs or manipulate test results.[5]

Smartwatch producers prioritize user convenience over encryption standards because this vulnerability allows attackers to exploit system weaknesses.[6] It analyzes how smartwatches are dualistic in terms of medical innovation and security risk, and then protective measures that bridge wearable devices to medical security requirements.

The Smartwatch has immensely developed, with basic step counts developing to multifaceted medical devices that can conduct a single-lead electrocardiogram (ECGs), detecting atrial fibrillation, and screening sleep apnea or Parkinson's disease.[73], [7] It puts smartwatches at the intersection of biomedical innovation and digital health law and calls into question not only the validity of the offered diagnosis but also the level of security in cyberspace and adherence to laws.

This study is two-fold in its exclusive nature:

1. Medical functions- the use of smartwatches as a productive screening and monitoring tool, supported by apps approved by the FDA and validated research, aiding in timely diagnosis.
2. Regulatory and security concerns: how a deficit of encryption, unauthorized presence of data, and disjointed legal frameworks jeopardize patient privacy and safety?[55],[80]

The paper is separated into four parts. First, it provides a general overview of the clinical applications of smartwatches with respect to the accuracy of screening and their integration into healthcare systems. Second, it analyzes erroneous design and communications protocols that expose sensitive health information to attack. Third, it addresses the appropriateness of the current regulatory frameworks, including the Russian federal law, the GDPR, the HIPAA, and the MDR 2020 in India, that can be used to safeguard wearable medical technologies. Finally, it also includes recommendations in accordance with the centralized regulation and secure deployment of health applications based on smartwatches.

This article is a contribution to the existing body of literature about digital health law, as it combines medical, technical, and legal perspectives on the best approach to establishing a balance between the protection of patients and their innovation. In this manner, it reminds us of the need to have a holistic approach to the law that would anticipate the threats of emerging technologies and establish the circumstances under which their application is secure.

Materials and Methods: A Scoping Review

The given research utilized a scoping review to assess the medical use of smartwatches and the security issues of the latter. The methodology used involved the following stages:

1. *Literature Search Strategy*:
   a. The research used four key terms, which included "smartwatch for disease detection" and "medical uses of smartwatches," along with "wearable security vulnerabilities" and "medical device regulations."

   b. This research utilized four database tools, namely PubMed, IEEE Xplore, Scopus, and SciSpace, to locate peer-reviewed articles from the years 2014 through 2024.

2. *Data Extraction and Synthesis:*
   a. Information extracted included objectives of the studies, types of devices (e.g., Apple Watch, Fitbit), and diagnostic functionalities (e.g., ECG accuracy), as well as vulnerabilities in terms of security (e.g., Bluetooth exploits).

   b. Case studies: The FDA-cleared applications were reviewed by means of metrics such as the sensitivity (71-98%) and specificity (82-99%) through case studies (Table 2).[7],[71]

3. Security and Regulatory Analysis:
   a. Cybersecurity breaches were assessed by several studies of the data breach risks, insufficient encryption method usage,[8] and re-identification attacks.[9]

   b. Regulatory frameworks (Russian federal law, GDPR, HIPAA, and India's MDR 2020) were compared to identify gaps in data protection and compliance.[81],[80]

4. Limitations:
   a. Reliance on existing studies may introduce publication bias.

   b. Variability in device-specific validation metrics limits generalizability.

A narrative review design was chosen, considering the heterogeneity of evidence that moves across both clinical validation and cybersecurity studies and legal literature. It is suitable for mapping changing regulatory and technological backgrounds in which standardized outcome measures have not been established. [10]

Uses of Smartwatch as A Medical Device

Smartwatches function as devices that can provide ongoing clinical data to reveal medically important events. Research shows smartwatches provide better accuracy in predicting blood and urine clinical laboratory results than standard vital signs assessed by clinicians, as per Picard R. W. & Boyer E. W., 2021.[11] These devices help patients interact with medical staff more effectively while allowing remote disease tracking, leading to improved medical treatment and disease prevention goals.[12] Simultaneously, they function as systems for digital health applications to support better medical results, together with general patient wellness.[13]

Screening, Risk Detection, and Diagnosis: Conceptual Boundaries

When assessing the smartwatch capabilities, it is necessary to make a distinction between screening, risk detection, and clinical diagnosis. The majority of the smartwatch applications that have been passed by regulatory bodies are geared towards screening or risk notification, but not conclusive diagnosis. Namely, notifications related to atrial fibrillation displayed through photoplethysmography detect unusual rhythms that should be further assessed clinically, though not substituting physician-signified ECG diagnostics.[7] [70] Exaggerating the diagnostic ability may confuse both patients and the regulators.

Table 1. Scoping overview of reported clinical use of smartwatches

Clinical use of smartwatches		Regulatory Status	Reference
Heart condition	To detect atrial/cardiac arrhythmias	FDA-cleared for AF screening (selected devices)	[14], [15], [16], [17], [18],[19], [20], [21], [22], [23]
	Assist in screening and diagnosing acute ischemic heart disease (IHD) (narrowed coronary arteries) through ECG tracing.	Not approved for standalone diagnosis	[24]
	Smartwatch electrocardiograms (ECGs) can detect sudden cardiac arrest.	Not approved for clinical diagnosis	[25]
	To detect Brugada syndrome (severe arrhythmias)	No regulatory clearance	[26]

Continue....

Recording multichannel ECGs and detecting ST-segment changes in acute coronary syndromes	Not approved for clinical diagnosis	[27]
Screening obstructive sleep apnea	FDA-cleared (screening only)	[74]
Measuring movement disorder severity, effectively classifying simulated myoclonus	Research use only	[28]
Early detection and monitoring of COVID-19	No diagnostic approval	[29], [30]
Identifying Parkinson's through biophysical signals (analysis of sleep pattern/stages)	Research use only	[29], [73] , [31]
Identify Alzheimer's disease by analyzing non-speech sounds and daily activities.	Research use only	[32], [33].
Asthma Detection	No regulatory clearance	[34]
Physical activity and weight loss in chronic disease management programs	Wellness / adjunctive use	[35]
Predicting diabetes (by monitoring mobility, heart rate, and skin moisture)	Research use only	[36]

Note: Smartwatches primarily support screening, monitoring, and risk stratification, not definitive diagnosis. Clinical confirmation by healthcare professionals remains essential.

With the ability to track physiological signs, such as heart rate and ECG, these devices stand out as important tools in healthcare. However, they show promise, and their integration into clinical practice needs to be carefully considered, including their limitations, as well as further validation.

Case Studies

A summary of case studies depicting the use of smartwatches for varied medical applications has been provided as follows**;**

Table 2. Case studies on the use and efficiency of smartwatches as medical devices

Medical Application	Device Example	Use Case	Supporting Evidence	Performance metrics	Regulatory Status	References
Atrial Fibrillation (AF) Detection	Apple Watch Series 4+	Irregular rhythm notifications using photoplethy-smography (PPG).	Apple Heart Study demonstrated irregular rhythm notifications prompting medical evaluation	Sensitivity 71%, specificity 98%	FDA-cleared for AF screening	[7]

Continue....

ECG Monitoring	Apple Watch Series 4+	Single-lead ECG for detecting AF and other arrhythmias.	Single-lead ECG validated against clinician-read ECGs	Sensitivity 98%, specificity 99% (AF)	FDA-cleared (specific indications)	[71]
Fall Detection	Apple Watch, Samsung Galaxy Watch	Accelerometer and gyroscope data to detect falls and alert emergency contacts.	Accelerometer-based fall detection with emergency alerts	~95% sensitivity for hard falls	FDA-cleared (Apple Watch)	[37]
Blood Oxygen Monitoring	Apple Watch Series 6+, Fitbit Sense	SpO2 measurement via PPG sensors.	Compared against pulse oximeters under controlled conditions	Mean error <2%	Wellness feature (non-medical)	[38], [39].
Sleep Apnea Detection	Fitbit devices	PPG and motion data to screen for sleep-disordered breathing.	Detection of sleep-disordered breathing events	Sensitivity 88%, specificity 82%	FDA-cleared for screening	[40]
Diabetes Management	Dexcom G6 + Apple Watch	Continuous glucose monitoring (CGM) integration for real-time glucose trends.	CGM integration improves glycemic awareness	Reduction in hypoglycemia events	FDA-cleared CGM (not watch alone)	[41]
Hypertension Monitoring	Samsung Galaxy Watch	PPG-based blood pressure estimation.	Calibration-dependent PPG-based estimates	Mean error <5 mmHg	Region-specific clearance	[42]
Mental Health Tracking	Fitbit, Apple Watch	Heart rate variability (HRV) and activity data to assess stress and anxiety.	HRV and activity correlated with stress indicators	~85% classification accuracy	Research/ wellness	[43]

Note: "Reported sensitivity and specificity values derive from controlled validation studies and do not imply standalone diagnostic equivalence to clinical gold standards."

From Table 2, it can be concluded that People commonly use smartwatches as devices for early warning indications as well as persistent disease supervision applications. The FDA has approved specific roles, yet developing countries like India remain unclear about the necessary approvals for these systems. The medical regulatory bodies need to determine and clarify what approvals are required for smart wearable devices.

Screening Capabilities aiding in Diagnosis

ECG tracing can be performed on smartwatches and is correlated strongly with conventional ECGs when used to diagnose ischemic heart disease (IHD).[44] However, as pointed out by Pasli et al.,[45] smartwatches are capable of recognizing several cardiac dysrhythmias, but with further studies, they work to widen their range of screening. As stated by Nazarian S. et al. (2021),[46] smartwatches have high screening capabilities, aiding in the diagnosis of cardiac arrhythmias with 93% sensitivity and 83% specificity. The self-screening happens in 30 seconds using photoplethysmography (a combination of photosensors to determine heart rhythm). Monitoring various health indicators, such as stress levels and sleep patterns, and early signs of diseases like COVID-19, wearable devices have been used by them.[49] Atrial fibrillation (AF) has a high screening accuracy with a pooled sensitivity and specificity of 94% and 97%, respectively, by smartwatches.[47] AI-enabled algorithms in smartwatches got FDA clearance for atrial fibrillation detection, and they are quite capable of detecting atrial fibrillation. Early detection is enabled by their widespread use, ease of use, and potential cost-effectiveness, which enhances stroke prevention and minimizes heart complications associated with stroke.[82]

So far, smartwatches have demonstrated a promising use for assessing the impact of Parkinson's Disease, demonstrating balanced accuracy of 74.1% for distinguishing Parkinson's Disease and other disorders.[73] The screening capabilities of smartwatches have shown early detection, disease monitoring, and even health status assessment and continuous physiologic information capturing in a non-invasive way by enabling real-time health status assessment and continuous physiological information gathering through biophysical signals of COVID-19 and Parkinson's.

Integration with Healthcare Systems

Smartwatch monitors the physiological health parameters like heartbeat, blood pressure, and body temperature, and relays the data through to the IoT to the cloud platform, which allows one to remotely access and continuously monitor the health of patients. [48]

The integration of smartwatch data with Electronic Medical Records (EMR) is essential for enhancing clinical decision-making and reducing healthcare provider workloads.[77] Challenges such as data interpretation and algorithm reliability must be addressed to ensure effective use in clinical settings.[76], [49] Applications designed for smartwatches facilitate remote monitoring, particularly beneficial for geriatric patients.[76]

Design and Functionality

Smartwatch technology advances include the utilization of multiple sensors so that health monitoring can be achieved, including temperature and oxygen.[50] With the presence of multiple sensors like ECG, PPG, heart rate, temperature, and SpO2 sensors, smartwatches monitor vital signs continuously.[51] OLED displays that can provide real-time data visualization add to user interaction and accessibility. While they are potential, there are obstacles such as battery life, user comfort, and application development that need to be overcome to make smart watches commonplace.[76] Also important is sensor integration, power management, and data security in developing such devices.[52]

Smartwatch and Security Concerns

By integrating smartwatches into healthcare and daily life, there are many safety concerns related to electromagnetic interference (EMI) and the security of the data that is collected from the smartwatches. Recent studies show that modern smart watches do

not cause a problem when used along with cardiac implantable electronic devices (CIEDs);[53] however, there are still severe issues regarding data security, and there are still vulnerabilities.

Cybersecurity Vulnerabilities

About 60% of the identified vulnerabilities in medical devices are a result of unauthorized access.[54] For smartwatches, the analysis of authors reveals many vulnerabilities within the Bluetooth communication protocols used by them.[56] These vulnerabilities can be abused in the process of pairing, and manufacturers should ensure that such security vulnerabilities are addressed. The vulnerability of Bluetooth communication protocols is very high and can be exploited by attackers because of the exposed security and authentication keys that can be used.[78], [55] Timko et al. (2024)[78] reveal the vulnerability of Wearable Smart Health Devices (WSHD), which includes unsecured security keys, authentication keys, and API endpoints. Such vulnerabilities will result in the threat of information leakage and the unauthorized alteration of information. The medical smartwatches tend to transmit sensitive health data via wireless networks, which can be easily hacked and accessed by unauthorized third parties.[59], [56] The vulnerability of working with data has been revealed through the discovery of a new kind of attack that can identify individuals using health data even when there are no personal identifiers, which indicates the fundamental flaws of working with data.[9] Numerous smartwatches used in the medical field have weak encryption, which makes them vulnerable to information leakage.[57]

For a medical smartwatch to be an integral part of personalized medicine, such smartwatches must have robust security, such as disruption-tolerant networking, anonymization of data, and secure authentication to avoid attack effectively.[83]

Data security & Privacy Risks

Smartwatches operate under risk from security threats that involve both illegal device pairing and insecure code attacks because these threats can breach personal health data, according to Lee et al. (2016).[58] According to Kaur et al. (2024),[59] Data transmission over wireless networks exposes these devices to interception and cyber-attacks, yet users express that half of them will not share data.[60]

Large-scale collection of personal health data becomes problematic because it leads to security issues and unauthorized access to information, according to Venkatachalam et al. (2023).[61] Users could unintentionally endanger their sensitive health information, so it becomes vulnerable to misuse and discriminatory practices.[62] Supporters of real-time health monitoring, along with patient engagement benefits, argue that proper safeguards would address these important concerns.[63]

Regulatory Challenges

Comparative analysis of the regulatory framework was performed using three analytical dimensions such as (1) definition of medical device, (2) coverage of software and AI-based functionality, and (3) effectiveness of post-market surveillance and cybersecurity requirements. It is a framework that allows not only during the identification of the formal compliance requirements but also during the monitoring of the enforcement gaps.

The privacy rights security framework defends personal privacy, yet many wearable devices exhibit insufficient security systems, resulting in possible data exposure incidents.[64], [65] The EU Medical Device Regulation (MDR) enforces tighter standards than those of the FDA, thus creating obstacles for companies conducting multinational product deployments.[80] Meanwhile, in the U.S., numerous wearable devices escape HIPAA protections, which exposes patient healthcare information to possible misuse by insurers and employers.[66] Although HIPAA addresses the information that has been guarded among the covered entities, the majority of consumer smartwatch data is outside its jurisdiction. It poses a structural regulation black hole that is in stark contrast with the risk-based and technology-agnostic protections offered by the GDPR.[80]

Alongside the already documented systems of the European Union General Data Protection Regulation (GDPR) and the U.S. Under the Health Insurance Portability and Accountability Act (HIPAA), Russia has enacted detailed legislation addressing medical devices, which clearly covers wearable technologies. In Russian Federal Law No. 323-FZ On the Fundamentals of Public Health Protection in the Russian Federation, the definition of medical devices is quite broad, i.e., any instruments, apparatuses, equipment, or specialized software, the main purpose of which is not pharmacological or genetic.[67]

Software, such as mobile and web applications, can be considered a medical device under the conditions that it independently processes physiological information, helps make clinical decisions, and is directly advertised for use in medicine.[68] The new state registration of medical devices is regulated by new rules, which were introduced by the recent regulatory changes, especially by Government Decree No. 1684 of November 30, 2024, which came into force on March 1, 2025. According to these regulations, smartwatch manufacturers who want to use the products in a medical context must pass clinical trials, technical testing, and official registration before commercialization.[84]

Moreover, Russia has enhanced its post-market surveillance, which makes it compulsory to report adverse events and safety problems in line with Order No. 980n of 2020.[85] Meanwhile, the practice of Russian regulatory registration indicates discrepancies: several consumer wearables with medical-quality sensors (e.g., heart rate or SpO2) are not registered as a medical device, provided that manufacturers do not explicitly state that they are intended to diagnose.[86]

Russia has started standardizing artificial intelligence (AI) based medical software with technical standards, including GOST R 59921.1-2022, which concerns the clinical assessment of AI in medicine.[69] This focus on AI is especially topical because AI algorithms are used in smartwatches to detect arrhythmias and other screening options.

Therefore, the Russian practice demonstrates the scope and lack of clarity of regulating smartwatches: the legal definitions are broad, but the application of the law has been based primarily on professed medical intent instead of technical potential, and this leaves possible loopholes in protecting the patient.

Smaller medical device businesses across India find it challenging to implement regulations stipulated by the Medical Device Regulation (MDR) 2020 due to inconsistent procedural conformity,[70] while standalone SaMD is explicitly mentioned under Medical Devices Rules (MDR) 2020, but combined devices lack specific guidelines.[81] The regulatory framework lacks clarification about Artificial Intelligence-based SaMD, specifically due to its importance for smart watches, which employ AI for health tracking purposes.[81]

Findings

Smartwatches have shown a lot of promise to transform healthcare by facilitating uninterrupted coverage of chronic illnesses, early identification of cardiovascular abnormalities, and incorporation into healthcare systems. As one case in point, the smartwatch apps in the detection of atrial fibrillation were tested in large-scale clinical trials (such as the Apple Heart Study), and their application has been proven to have a high sensitivity and specificity.[7], [71] Similarly, the latest meta-analyses affirm that smartwatches are diagnostic of arrhythmias, and the combination of sensitivity and specificity is over 90 percent.[72] Smartwatch software has also shown potential in identifying the tremors of Parkinson's and sleep apnea in addition to COVID-19, besides cardiology [73], [74], [75]

It has been noted that the incorporation of smartwatch data into electronic medical records (EMR) can be used as a means of improving clinical decision-making and reducing provider workloads, especially when working with geriatric populations and remote-location patients.[76], [77] Nevertheless, research indicates that there are still weaknesses. One of the most widespread threats includes weak Bluetooth protocols, a lack of encryption, and vulnerable authentication tokens.[78], [55] In addition,

health data anonymized for protection purposes can be disclosed due to re-identification attacks, and significant privacy concerns may arise.[9]

From a Regulatory perspective, jurisdictional differences pose several challenges. The GDPR in the European Union sets strong data protection regulations,[79] whereas HIPAA in the United States provides partial protection of health data but excludes much of the consumer wearables.[80] The Medical Device Rules (MDR 2020) in India provide guidelines on Software as a Medical Device (SaMD), although they do not explicitly address concepts related to AI-driven applications.[81] Recently, Russia has made some reforms, and under Government Decree No. 1684 (2024), wearable devices are to be state-registered and subject to post-market supervision as medical devices, such as those involving software-based diagnostics.[84] However, a significant number of consumer smartwatches in Russia are not considered medical devices without clear implications of their use in a clinical setting. [86]

In general, the results indicate a two-fold trend. On the one hand, smartwatches are characterized by high accuracy of screening and integrative healthcare. Contrarily, they are at risk of not being adopted safely due to fragmented regulatory regimes and chronic cybersecurity vulnerabilities. Stakeholders need to focus on end-to-end encryption, robust authentication, and aligned international regulatory frameworks to ensure that these devices achieve their full medical potential.[82], [83]

Conclusion

Currently, smartwatches are mainly adjunctive screening and monitoring activities, aiding in timely diagnosis, and their safe connection with healthcare can be determined solely by regulatory clarity, cybersecurity resilience, and the control of clinicians. The Smartwatches exemplify the two-sidedness of technological advancement in healthcare: they promise the opportunities of personalized and real-time medical surveillance unprecedented before, and at the same time, create a gap in patient privacy and cybersecurity. In different jurisdictions, regulation is still not evenly managed. The GDPR of the European Union and the HIPAA of the United States provide partial protection, and the MDR 2020 of India does not include direct references to the AI-based wearable technologies. In contrast, Russia has recently extended its regulatory framework to demand compulsory registration of medical devices, including wearable software, under the Government Decree No. 1684, which is to take effect in March 2025, and to impose post-market surveillance with the help of Order No. 980n.[84], [85] However, there are still loopholes in practical enforcement because there are numerous consumer wearables that are not considered medical devices. After all, manufacturers do not use direct medical assertions.[86]

The comparative analysis illustrates that in the absence of international harmonization, the legal frameworks will tend to leave key blind spots, especially when it comes to AI-inspired diagnostics and cross-border data flows. To move smartwatches beyond being vulnerable consumer electronics and secure medical devices, three priorities can be identified: strong security architecture, harmonization of regulatory and compliance requirements across jurisdictions, and making AI and software a core part of the definition of medical devices. The dynamic nature of the Russian strategy highlights the opportunities and threats of national regulation of a fast-globalizing health technology market. Finally, to enable smartwatches as trusted and dependable medical devices, the balance between innovation and enforceable guidelines that anticipate patient rights and data integrity is the key to the future of smartwatches.

Future Work

Further research should undertake continuous data collection over time to establish superior screening and diagnostic methods across different racial groups and investigate any algorithmic discrimination. Smartwatches will be sustainably incorporated into medical practices when medical professionals establish a balance between technological development and stringent measures for privacy protection and patient welfare safeguards. Smartwatches will transform from consumer devices

into dependable, secure healthcare elements by solving their present obstacles.

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Analysis of Alleged Manner of Death in Firearm Autopsy cases Conducted at Tertiary care Centre in Malwa Region of Punjab

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Abstract

Firearm injuries represent a significant cause of violent deaths worldwide and pose major medico-legal challenges for forensic experts. Determining the manner of death in firearm cases—whether homicidal, suicidal, or accidental—is crucial for criminal investigations and judicial proceedings. The present study was undertaken to analyze the alleged manner of death in firearm autopsy cases conducted at a tertiary care centre in the Malwa region of Punjab and to evaluate their demographic and medico-legal characteristics.

This descriptive autopsy-based study was carried out in the Department of Forensic Medicine and Toxicology at Guru Gobind Singh Medical College and Hospital, Faridkot, Punjab. The study included 50 consecutive autopsy cases of alleged firearm injuries examined over a period of 18 months. Data regarding age, sex, marital status, occupation, residence, alleged manner of death, and autopsy findings such as the presence and type of foreign body were collected and analyzed.

The majority of victims belonged to the 31–40 years age group (32%), followed by the 21–30 years age group (30%). Males constituted 86% of the cases, showing a clear male predominance. Most victims were married (68%). The most common alleged manner of death was homicidal (64%), followed by suicidal (30%), while accidental deaths accounted for only 6% of cases. Foreign bodies such as bullets or pellets were recovered in 56% of cases, while 44% of cases showed no retained projectile. Bullets were more commonly associated with both suicidal and homicidal cases.

The findings indicate that firearm fatalities predominantly affect young adult males and are largely homicidal in nature, particularly in rural populations where firearm accessibility and interpersonal conflicts may contribute to such incidents. Autopsy examination plays a critical role in confirming the nature of firearm injuries and correlating the alleged manner of death with scientific findings.

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The study highlights the importance of regional epidemiological data in understanding firearm-related fatalities and emphasizes the need for effective preventive strategies, stricter firearm control, and improved medico-legal investigation.

Keywords: Firearm injuries; Alleged manner of death; Forensic pathology; Medico-legal investigation.

Introduction

Firearms are among the most lethal weapons capable of producing severe injuries and fatalities. A firearm is essentially a thermodynamic device that converts the chemical energy of gunpowder into the kinetic energy of a projectile, which when discharged can cause extensive tissue damage and destruction of vital organs[1]. The injuries caused by firearms depend on several factors including the type of weapon used, the velocity and trajectory of the projectile, firing distance, and the anatomical structures involved. These injuries often lead to death due to massive hemorrhage, shock, or damage to vital organs such as the brain, heart, and lungs[2].

Globally, firearm-related violence has emerged as a major public health and medico-legal concern. The World Health Organization recognizes firearm injuries as a significant contributor to mortality and morbidity worldwide[3]. In India, firearm deaths continue to represent an important component of violent deaths. According to the National Crime Records Bureau (NCRB), firearm-related incidents account for a considerable number of deaths each year. Recent statistics indicate that more than one thousand deaths due to firearms were reported nationally, reflecting the persistent problem of gun violence in the country[4].

The problem is particularly relevant in certain regions where socio-economic factors, availability of illegal firearms, and interpersonal conflicts contribute to firearm-related crimes. In northern states such as Punjab and Haryana, a significant number of gunshot deaths are reported annually. The NCRB data for recent years highlight the regional burden of firearm violence and the need for systematic medico-legal analysis[4].

From a forensic perspective, firearm deaths present unique challenges during autopsy. The forensic pathologist must carefully examine and document the characteristics of gunshot wounds, including entry and exit wounds, abrasion collars, tattooing, blackening, and other associated features. These observations help determine the direction, range, and type of weapon used[5]. Moreover, such findings are crucial in establishing the manner of death, which may be classified as homicidal, suicidal, accidental, or undetermined. Accurate determination of the manner of death plays a vital role in criminal investigations and judicial proceedings[6].

Previous studies conducted in various parts of India and abroad have shown that firearm deaths predominantly occur among young adult males, often between the ages of 20 and 30 years[7]. Many studies also report that homicide constitutes the most common manner of firearm deaths, followed by suicide and accidental injuries[8]. The frequent use of unlicensed or country-made firearms in developing countries has been identified as a major factor contributing to such fatalities[9].

In addition to determining the cause of death, forensic examination provides insights into epidemiological patterns such as demographic distribution, occupation, location of injuries, and socio-economic background of the victims. Such data help identify risk factors and trends in firearm-related violence[10]. Studies have also indicated that rural populations may experience a higher incidence of firearm-related deaths due to factors such as easy availability of weapons, land disputes, socio-cultural conflicts, and limited law enforcement presence[11].

Despite the seriousness of the problem, region-specific data regarding firearm autopsy cases remain limited in many parts of India, including the Malwa region of Punjab. Local epidemiological studies are essential to understand the patterns of firearm deaths, the alleged manner of death reported by investigating agencies, and their correlation with autopsy findings.

Therefore, the present study was undertaken to analyze the alleged manner of death in firearm autopsy cases conducted at a tertiary care centre in the Malwa region of Punjab. By examining demographic characteristics, injury patterns, and medico-legal findings, the study aims to provide a comprehensive understanding of firearm-related fatalities in this region and to contribute to the existing body of forensic research.

Research Gap

Despite a substantial body of literature on firearm fatalities globally and within India, several important gaps remain—particularly in the medico-legal interpretation of the alleged manner of death:

1. Lack of Region-Specific Data (Malwa Region, Punjab):- Most Indian studies on firearm fatalities are concentrated in regions such as Delhi, Uttar Pradesh, Rajasthan, and metropolitan cities. There is a notable absence of systematic autopsy-based data from the Malwa region of Punjab, which has distinct socio-cultural dynamics, including:
    - High rural population density
    - Easy availability of licensed and illicit firearms
    - Land-related disputes and interpersonal violence
2. Limited Correlation Between Alleged and Autopsy Findings

    Previous studies predominantly focus on:
    - Pattern of injuries
    - Demographic distribution
    - Type of weapon

However, very few studies critically analyze the relationship between the *alleged manner of death* (as reported by police/investigators) and *objective autopsy findings*. This creates a crucial gap in medico-legal validation.

3. Inadequate Analysis of Socio-Demographic Determinants: - Although demographic data are reported, integrated analysis linking factors like occupation, marital status, and residence with the manner of death is insufficiently explored.
4. Scarcity of Data on Projectile Recovery and Its Medico-Legal Relevance The presence, absence, and deformation of bullets/pellets are often documented, but their correlation with manner of death (suicidal vs homicidal vs accidental) is rarely emphasized.

Justification and Need for the Study

This study was necessary to address the above gaps and strengthen medico-legal practice in the following ways:

1. Medico-Legal Accuracy in Determining Manner of Death-Determining whether a firearm death is homicidal, suicidal, or accidental is crucial for:
    - Criminal investigation
    - Judicial outcomes
    - Insurance and compensation claims

This study provides objective autopsy-based evidence to validate or question alleged histories, reducing reliance on potentially biased or incomplete police narratives.

2. Regional Epidemiological Insight - Punjab, particularly the Malwa belt, has:
    - High firearm accessibility
    - Unique socio-economic stressors (agrarian conflicts, financial burden, interpersonal disputes)

Materials and Methods

This study employed a quantitative, descriptive, autopsy-based research design, focused on analyzing the epidemiological, medico-legal, and pathological characteristics of fatal firearm injuries. Autopsy data were used to interpret wound morphology, injury mechanisms, and correlating socio-demographic variables.

The study was conducted in the Department of Forensic Medicine & Toxicology at Guru Gobind

Singh Medical College & Hospital, Faridkot (Punjab), a tertiary care government medical institution serving a largely rural population.

Study Period

The study was carried out over 18 months, during which 50 consecutive autopsy cases with alleged firearm injuries were examined.

Study Population

All deceased individuals brought to the mortuary during the study period with a documented or alleged history of firearm injury were included.

Inclusion Criteria

- All deceased individuals with suspected or confirmed firearm injuries, irrespective of:
  - Type of firearm
  - Weapon recovery
  - Distance of fire
  - Circumstances of death
  - Time elapsed between injury and death

Exclusion Criteria

- Bodies decomposed to a degree that firearm injury assessment was impossible
- Cases where firearm injury was secondary or incidental (e.g., postmortem animal scavenging)
- Explosion-related deaths not involving firearm discharge

Results

Out of 50 deceased cases studies, 47 (94%) have been identified, while 3 (6%) have not been identified and were 31-40 age group with 16 cases (32.0%), followed by the 21-30 age group with15cases (30.0%). The 51-60 age group has 9 cases(18.0%),the61-70group has 5 cases (10.0%), and the 41-50 group has 4 cases (8.0%). The 10- 20 age group has the fewest cases with 1 (2.0%). Males account for the majority of cases, with 43 cases (86.0%), while females account for 7 cases (14.0%). The majority of cases involve married individuals, with 34 cases (68.0%), majority of cases are homicidal, with 32 cases (64.0%). Suicidal cases account for 15 cases (30.0%), while accidental cases are the least common, with 3 cases (6.0%). Foreign bodies (either bullets or pellets) were present in 56.0% of the firearm autopsy cases, with the remaining 44.0% showing no foreign body. In 19 cases (32.0%), the foreign bodies were deformed. In 9 cases (18.0%), the foreign bodies were not deformed.

Table 1. Association of alleged Matter of Death with age of patients in firearm autopsy cases

	Alleged Manner								Chi-square	P-value
	Suicidal		Accidental		Homicidal		Total			
	N	%	N	%	N	%	N	%		
10-20	1	6.70%	0	0.00%	0	0.00%	1	2.00%	10.872	.368
21-30	5	33.30%	0	0.00%	10	31.30%	15	30.00%		
31-40	5	33.30%	0	0.00%	11	34.40%	16	32.00%		
41-50	1	6.70%	1	33.30%	2	6.30%	4	8.00%		
51-60	1	6.70%	1	33.30%	7	21.90%	9	18.00%		
61-70	2	13.30%	1	33.30%	2	6.30%	5	10.00%		
Total	15	100%	3	100%	32	100%	50	100%		

The age of patients in firearm autopsy cases, with no significant statistical association (Chi-square: 10.872, P-value: 0.368). Suicidal cases were most common in 21-30 and 31-40 age groups. Homicidal cases were spread across all age groups, most frequent in 31-40. While accidental cases were few and spread evenly. Males constituted 86.70% of suicidal cases, 66.70% of accidental cases, and 87.50% of homicidal cases, making up 86.00%.

The association between the alleged nature of death (suicidal, accidental, homicidal) and the gender of patients in firearm autopsy cases, showing no significant statistical association (Chi-square: 0.997, P-value: 0.608). Females comprised of 13.30% of suicidal cases, 33.30% of accidental cases, and 12.50% of homicidal cases, accounting for 14.00%.

The association between the alleged nature of death (suicidal, accidental, homicidal) and the marital status of patients in firearm autopsy cases, indicating no significant statistical association (Chi-square: 11.039, P-value: 0.087). Married individuals constituted 60.00% of suicidal cases, 66.70% of accidental cases, and 71.90% of homicidal cases, making up 68.00%. Unmarried individuals comprised of 40.00% of suicidal cases and 12.50% of homicidal cases.9.40% of homicidal cases, making up 6.00% of the total cases. 33.30% of accidental cases, and 6.30% of homicidal cases, comprising 6.00%.

A significant association between the alleged nature of death and the occupation of patients in firearm autopsy cases (Chi- square: 23.524, P-value: 0.024). With private jobs, 20.00% were suicidal, 33.30% accidental, and 15.60% homicidal, comprising 18.00%. Government employees showed a high incidence of suicidal cases at 46.70% and 6.30% homicidal, 18.00%. Farmers/zamindars had 26.70% suicidal, 33.30% accidental and 40.60% homicidal cases. Unemployed individuals accounted for 21.90% of homicidal cases. Laborers 9.40% were homicidal. Those with unknown occupations accounted for 33.30% of accidental cases and 6.30% of homicidal cases, making up 6.00% of the total. Students had 6.70%.

The association between the alleged nature of death (suicidal, accidental, homicidal) and the residence of patients in firearm autopsy cases, showing a significant statistical association (Chi-square: 11.514, P-value: 0.021). In urban areas, 46.70% of the cases were suicidal, 66.70% were accidental, and 18.80% were homicidal, making up 30.00%. In rural areas, 53.30% of the cases were suicidal and 75.00% were homicidal. For those with an unknown residence, 33.30% were accidental and 6.30% were homicidal.

Table 2. Association of alleged nature of death with a type of foreign body of patients in firearm autopsy cases

	Alleged nature								Chi-square	P-value
	Suicidal		Accidental		Homicidal		Total			
	N	%	N	%	N	%	N	%		
Bullet	7	46.7%	0	0.0%	11	34.4%	18	36.0%	4.760	0.313
Pellets	3	20.0%	0	0.0%	7	21.9%	10	20.0%		
Absent	5	33.3%	3	100.0%	14	43.8%	22	44.0%		
Total	15	100.0%	3	100.0%	32	100.0%	50	100.0%		

No significant association between the nature of death and the type of foreign body in firearm autopsy cases (Chi-square: 4.760, P-value: 0.313). Bullets are found in 46.7% of suicidal cases and 34.4% of homicidal cases. Pellets are found in 20.0% of suicidal cases and 21.9% of homicidal cases. Noforeign body is foundin33.3% of suicidal cases, 100.0% of accidental cases, and 43.8% of homicidal cases.

Discussion

In the present study, 16 cases (32.0%), followed by the 21-30 age groupwith15cases (30.0%). The 51-60 age group has 9 cases (18.0%), the 61-70 group has 5 cases (10.0%), and the 41-50 group has 4 cases (8.0%). The 10- 20 age group has the fewest cases with 1 (2.0%). These results align with the study conducted by Pargi et al.[29] which showed that out of 103 cases of firearm autopsies, the majority were from the 20-39 years age group (67.96%), with the peak incidence in the 20-29 years age group (40.78%). This age range encompasses the productive and active members of society. Similarly, other studies have reported a peak incidence between 21-40 years of age, including those by Patowary AJetal.,[30]SachanRetal.,[14]and KumarKetal[18].

Males account for the majority of cases, with 43 cases (86.0%), while females account for 7 cases (14.0%). In the study by Vergia et al.,[25] males (88.75%) out numbered females (11.25%) with a male-to-female ratio of about8:1. Similarly, Dutta et al. found that males (89.57%) outnumbered females (10.43%) with a male-to-female ratio of about 8.9:1 [31]. Patowary et al[30] reported 88.9% males, and Kumari et al[17] reported 90% males, showing similar results. Males are society's active participants and are more commonly involved in outdoor activities. In addition, they are more prone to rage and revenge episodes, which explains the preponderance of males in all studies.

Males account for the majority of cases, with 43 cases (86.0%), while females account for 7 cases (14.0%). This indicates a significantly higher occurrence of firearm autopsy cases among males compared to females. In the study by Vergia et al.,[25] males (88.75%) out numbered females (11.25%) with a male-to-female ratio of about8:1. Similarly, Dutta et al. found that males (89.57%) outnumbered females (10.43%) with a male-to-female ratio of about 8.9:1[31]. Patowary et al[30] reported 88.9% males, and Kumari et al[17] reported 90% males, showing similar results. Males are society's active participants and are more commonly involved in outdoor activities. In addition, they are more prone to rage and revenge episodes, which explains the preponderance of males in all studies.

The majority of cases involve married individuals, with 34 cases (68.0%). Unmarried individuals account for 10 cases (20.0%). Both divorced individuals and those with unknown marital status have 3 cases each (6.0%). This indicates that married individuals constitute the largest group among firearm autopsy case. In the study by Dutta et al[31] about 80 per cent of victims of firearms of both sexes were married. It bears no correlation with such incidences but any type of outrageous behavior is more common after marriage because of the burden of responsibilities that come with it.

The victims of firearm injuries showed a rural preponderance (88.70 percent) while the urban population accounts for 11.30 percent of the victims.

The majority of cases involve married individuals, with 34 cases (68.0%), majority of cases are homicidal, with 32 cases (64.0%). Suicidal cases account for 15 cases (30.0%), while accidental cases are the least common, with 3 cases (6.0%) the study by Dutta et al[31] about 80 per cent of victims of firearms of both sexes were married. It bears no correlation with such incidences but any type of outrageous behavior is more common after marriage because of the burden of responsibilities that come with it.

In the present study, the research observed a higher frequency of suicidal cases among younger and middle-aged individuals, whereas homicidal cases were evenly distributed across age groups. Interestingly, age itself did not significantly influence the alleged nature of death in these cases. Males accounted for a substantial majority across different categories: 86.70% in suicidal cases, 66.70% in accidental cases, and 87.50% in homicidal cases, making up 86.00%of all cases combined.

These findings align with previous studies, such as the one conducted by Foote et al.[31] in the USA, where the suicide group primarily consisted of older white males. Another relevant study by Branas et al.[33] highlighted that suicides were predominantly among older (>35 years), white, unmarried males.

In the current study, the prevalence of suicide among young and middle-aged males could be attributed to their roles as heads of households, their accessibility to firearms, and their higher tendency towards impulsivity and anger. Additionally, their involvement in firearm-related activities may further exacerbate these risks. The difference in age groups in males with previous study could be attributed to different study population and different pressures faced by population in different geographical locations.

Females comprised of 13.30% of suicidal cases, 33.30% of accidental cases, and 12.50% of homicidal cases, accounting for 14.00% of the total cases. Overall, the majority of cases for all types of death are males, with no significant difference in the distribution of the alleged nature of death between genders.

Overall, farmers/zamindars have the highest proportion of homicidal cases, while government job holders have a significant portion of suicidal cases. This distribution shows a significant association between occupation and the alleged nature of death in firearm autopsy cases. Farmers and rural landowners in Northern India often have higher rates of firearm ownership, primarily due to the need for crop protection, which is facilitated by the Crop Protection Act. This easy access to firearms can lead to impulsive and violent actions during disputes. Additionally, property and financial disputes are common among farmers and landowners in this region, further contributing to the high proportion of homicidal cases. Studies, such as those reviewed by Branas et al. (2017), highlight that rural areas with greater firearm accessibility correlate with increased rates of firearm-related homicides. Studies, such as research reviewed by Branas et al. (2017), highlight that rural areas with higher firearm ownership correlate with increased rates of firearm-related deaths, including homicides[34].

Overall, suicidal cases are almost evenly distributed between urban and rural areas, while homicidal cases are predominantly found in rural areas. Accidental cases are more common in urban areas and among those with unknown residences. This distribution indicates a significant correlation between residence and the alleged nature of death infirearm autopsy cases. Rural areas generally have higher rates of firearm ownership for purposes such as crop protection and personal safety. Also, unlicensed weapons are common among the rural population. Additionally, improper placement of the weapon is also responsible for the same. The ease of access to firearms increases the likelihood of their use in suicides.

Novel Findings and Key Insights

This study contributes several important and relatively underreported findings:

1. Predominance of Homicidal Deaths (64%)
    - Confirms that firearm fatalities in this region are primarily homicidal, unlike some Western data where suicides predominate.
    - Reflects regional socio-cultural dynamics, especially rural conflict and firearm accessibility.
2. Strong Rural–Homicide Association
    - 75% of homicidal cases occurred in rural areas
    - Suggests a significant correlation between rural residence and firearm-related violence

This is a key epidemiological insight, reinforcing:

- Role of land disputes
- Availability of firearms in agrarian communities

3. Occupational Correlation with Manner of Death
    - Farmers/zamindars → highest proportion of homicidal cases
    - Government employees → higher proportion of suicidal cases

This is a novel socio-occupational correlation, indicating:

- Economic and land-related conflicts → homicide
- Occupational stress and psychosocial factors → suicide

4. Age-related Trends Without Strong Deterministic Influence
    - Suicidal deaths cluster in 21–40 years, but
    - Homicidal deaths span all age groups

Age alone is not a decisive determinant, suggesting that environmental and social factors outweigh biological age in firearm deaths.

5. Male Predominance Across All Manners (86%)
    - Consistent across suicidal, homicidal, and accidental cases
    - Reinforces gender-based risk exposure:
        - Greater outdoor activity
        - Aggression and conflict involvement
        - Access to firearms
6. Projectile Findings as Medico-Legal Indicators
    - Bullets more common in suicidal and homicidal cases
    - Absence of projectile in 100% of accidental cases

Important forensic implication:

- Absence of foreign body may raise suspicion regarding alleged accidental manner
- Projectile recovery can aid in:
    - Reconstruction of events
    - Weapon identification

7. Significant Correlation Between Residence and Manner of Death
    - Rural → more homicidal
    - Urban → relatively more accidental/ suicidal

Indicates environmental influence on violence patterns, a relatively underexplored domain.

8. Marital Status Trend (68% Married)
    - Higher involvement of married individuals
    - Possibly linked to:
        - Family responsibilities
        - Financial and interpersonal stress

Conclusion

A firearm is a deadly weapon and is responsible for committing heinous crimes such as murder. It can irreversibly injure any vital organ post which the probability of surviving is merely minimal. Preventing firearm deaths requires a multi-faceted approach involving policy, community, and individual actions. Strengthening gun laws is a critical step. Implementing comprehensive background checks for all firearm purchases ensures that guns do not end up in the hands of individuals who pose a risk to public safety. Mandatory waiting periods between the purchase and possession of a firearm can provide a crucial cooling- off period, reducing impulsive acts of violence. Additionally, enforcing laws that restrict access to firearms for high-risk individuals, such as those with a history of violence, mental illness, or substance abuse, is essential in preventing potential tragedies.

Education and awareness play a significant role in firearm safety. Educating gun owners on the importance of safe storage, including using gun safes and locks, can prevent accidental shootings and unauthorized access to firearms. Public awareness campaigns that highlight the risks and responsibilities of firearm ownership can help foster a culture of safety and responsibility. By promoting safe storage practices and raising awareness about the potential dangers of firearms, communities can work together to reduce the incidence of gun-related injuries and deaths.

Law enforcement and policy enforcement are necessary to ensure that existing gun laws are effectively implemented. Strict enforcement of gun laws can prevent illegal possession and trafficking of firearms, reducing the availability of guns to those who should not have them. Implementing laws that remove firearms from individuals involved in domestic violence incidents can protect potential victims and prevent lethal outcomes. Consistent and rigorous enforcement of these policies is essential for reducing firearm-related violence.

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Medico-legal Study of Carbon Monoxide in Deaths due to Burns

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Abstract

Background: Burn deaths constitute an important component of medico-legal autopsies, particularly in developing countries such as India, where thermal injuries are associated with accidental, suicidal, and homicidal circumstances. In fire-related deaths, inhalation of toxic combustion products, especially carbon monoxide (CO), plays a major role in mortality in addition to thermal injury. Carbon monoxide binds with haemoglobin to form carboxyhaemoglobin (COHb), producing tissue hypoxia and contributing significantly to death. Detection of COHb in postmortem blood also serves as an important indicator of vitality during fire exposure and assists in differentiating antemortem burns from postmortem burning.

Methods: The present descriptive study was conducted in the Department of Forensic Medicine and Toxicology, G.G.S. Medical College and Hospital, Faridkot, Punjab, over a period of 18 months from 15.07.2024 to 15.01.2026. All medico-legal autopsy cases of flame burns fulfilling the inclusion criteria were included. Carbon monoxide in blood was analysed using Kunkle's test, Hoppe–Seyler's test, and potassium ferrocyanide test. Demographic profile, manner of death, burn distribution, survival duration, and association with COHb positivity were evaluated.

Results: The majority of burn victims belonged to the 41–50 years age group (40%), followed by 31–40 years (30%), with males constituting 65% of cases. Accidental burns accounted for 55% of deaths, followed by suicidal (35%) and homicidal burns (10%). Trunk and lower limbs were the most commonly affected regions (35% each). Most victims survived for 24–72 hours (55%). Carbon monoxide blood tests were positive in 55% of cases across all three testing methods. Positive COHb tests were predominantly associated with deaths occurring within 24–72 hours, whereas cases surviving beyond 72 hours were largely test-negative.

Conclusion: The study highlights the medico-legal significance of carbon monoxide estimation in burn deaths. Detection of carboxyhaemoglobin provides supportive evidence of inhalational injury and vitality during fire exposure and aids in accurate interpretation of cause and manner of death. The findings reinforce the importance of toxicological analysis as an integral component of forensic investigation in burn fatalities.

Keywords: Burn deaths; Carbon monoxide; Carboxyhaemoglobin; Antemortem burns; Burn fatalities

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Introduction

Burns are classified according to their causative agent into thermal, chemical, electrical, and radiation burns. Thermal burns, especially those caused by flames, hot liquids, steam, and hot solids, are most frequently encountered in medico-legal practice [1,2].

In India, burn injuries are of particular importance because they occur in a wide range of settings including domestic accidents, occupational exposure, self-harm, and homicidal violence. Burn deaths among married women may also assume special legal significance in the context of dowry death, where death due to burns or bodily injury within seven years of marriage under suspicious circumstances attracts medicolegal investigation under relevant law. Thus, every fatal burn case requires careful examination not only to establish cause of death, but also to determine the manner of death—accidental, suicidal, or homicidal [1,3].

In charred bodies, the pathologist must determine whether burning occurred before death or after death, because this distinction is crucial in reconstructing the events surrounding death. Antemortem burns usually show signs of vital reaction such as soot in the airways, congestion, inflammatory response, and evidence of inhalation of combustion products, whereas postmortem burns may mimic similar external destruction without corresponding internal vitality markers. Other autopsy findings such as pugilistic attitude, heat ruptures, heat hematoma, and cherry-red coloration of blood may complicate interpretation unless correlated with scene findings, history, and toxicological analysis. Therefore, medico-legal evaluation of burn deaths requires a multidisciplinary approach integrating gross findings, histopathology, toxicology, and circumstantial evidence [2].

An important contributor to death in fire-related burns is not thermal injury alone, but inhalation of smoke and toxic gases generated during combustion. Victims may succumb to asphyxia even before extensive external burns develop. Among the toxic gases associated with fires, carbon monoxide is the most significant and frequently encountered asphyxiant. It is produced during incomplete combustion of carbon-containing materials such as wood, cloth, paper, and household furnishings. Carbon monoxide is colourless, odourless and non-irritant, which makes it particularly dangerous and difficult to detect without laboratory analysis. Once inhaled, it rapidly diffuses across the alveolar membrane and binds to haemoglobin with an affinity more than 200 times greater than that of oxygen, forming carboxyhaemoglobin. This reduces oxygen transport, interferes with oxygen release to tissues, and causes tissue hypoxia, particularly in highly oxygen-dependent organs such as the brain and heart [3,6].

The medicolegal importance of carbon monoxide in burn deaths is considerable. Detection of carboxyhaemoglobin in postmortem blood supports the inference that the victim was alive during the fire and inhaled smoke before death. Higher levels may indicate significant inhalational exposure and may contribute directly to death. Carbon monoxide poisoning may also coexist with other fire-related toxicants such as cyanide and irritant gases, further worsening hypoxia and survival. Typical symptoms of carbon monoxide exposure range from headache, dizziness, and nausea at lower levels to confusion, syncope, coma, and death at higher concentrations. At autopsy, findings such as cherry-red blood, congestion of organs, pulmonary oedema, and soot in the respiratory passages may suggest inhalation injury, but toxicological confirmation remains essential.[2]

In this context, the study of carbon monoxide in deaths due to burns is highly relevant. It helps in assessing vitality, clarifying the role of inhalational injury, and improving the accuracy of forensic opinions regarding cause and manner of death. A systematic evaluation of burn patterns, autopsy findings, and carboxyhaemoglobin presence can therefore strengthen medicolegal interpretation and contribute to better forensic practice.

Aims and Objectives

All the cases will be studied having the following aims and objectives: -

1. To study the demographic profile of burn victims.
2. To determine the presence of carboxy haemoglobin in deaths due to burns.
3. To identify the association between occurrence and presence of carboxy haemoglobin in blood.
4. To determine burns seen on a body are ante mortem or postmortem in nature.

Material and Methods

Study Area

The study will be conducted in Mortuary under the Department of Forensic Medicine and Toxicology, G.G.S. Medical College and Hospital, Faridkot, Punjab.

Study Design: Descriptive study

Study Period: 18 Months

SAMPLE SIZE: As per previous year total recorded cases of burns were 23. The sample size of this study will be all cases of burns within 18 months of study.

Sample Technique

From the point of view of feasibility, a convenient non-random sampling technique will be used here and eligible cases satisfying the criteria for inclusion and not liable for exclusion will be subjected for the study.

Limitation: Presence of carboxy haemoglobin only analysed.

Inclusion Criteria

I. Those cases which have history of death due to Burn.

II. All deaths due to burns, died in hospital.

Exclusion Criteria

I. Putrefied body with burns.

II. Burns due to hot liquid, electric and corrosive burns.

Methodology

The presence of carboxy haemoglobin in cases of, death due to burns analysed with:

1. **Kunkle's Test –** In this test a sample of suspected blood was diluted with four times its volume of water and few drops of 3% aqueous tannic acid solution was added to it and shaken well. In cases with more than 10%carbon monoxide were present, a pinkish white precipitate will appear [5].
2. **Hoppe Seyler's Test –** In this test a suspected blood sample was diluted with about 20 times of volume of water and 10 % caustic soda was added to it. Normal blood became reddish brown but blood containing more than 10% carbon monoxide remained bright red in colour as no methaemoglobin was formed [5].
3. **Potassium ferrocyanide Test –** In this test 15cc of blood was mixed with equal amount of 20% ferrocyanide solution and 2cc of dilute acetic acid and shaken gently, a bright red coagulum formed in the cases of normal blood [5].

By enquiry and with the inquest report, the particulars are collected and correlated with the presence of carboxy haemoglobin. The particulars collected are age, sex, percentage of burns, death interval, circumstantial evidence, and manner of death. The data was entered in computer and analysed statistically.

Data Analysis Plan

The collected data was entered in MS Excel and statistically analysed.

Ethical Considerations

Written informed consent was taken from the relatives of deceased.

Observations and Results

In the present study on burn cases, all post-mortem cases done in the mortuary of G.G.S. Medical College, Faridkot, from 15.07.2024 to 15.01.2026, i.e., 18 months were considered. Burn cases were predominantly observed in the 41–50 years age group (40%), followed by the 31–40 years group (30%). Collectively, individuals between 31 and 50 years constituted 70% of the total cases, with predominance of males (65%) among burn cases, with females constituting 35% of the total cases. Accidental burns constituted the majority of cases, accounting for 55% of burn-related deaths, followed by suicidal burns (35%), while homicidal burns formed the smallest proportion (10%). Trunk and lower limbs were the most commonly involved body regions, each affected in 7 cases (35%). The upper limbs were involved in 4 cases (20%). Head and neck involvement was observed in 2 cases (10%). Burns involving the genitalia were noted in 1 case (5%). The survival pattern across all categories of burn distribution, namely localised burns, extensive burns, and whole-body burns. In each category, the majority of cases survived for 24–72 hours (55%), followed by survival beyond 72 hours (35%), while early mortality within 24 hours accounted for only 10% of cases, with male victims constituting the majority of burn cases across all survival durations. Total 20 cases were studied (The preview of study was not for closed and open space.)

Table. Distribution of Carbon Monoxide Blood Tests in Burn Cases.

Test Name	Positive cases	Percentage (%)	Negative cases	Percentage (%)
Kunkle's test	11	55.0	09	45.0
Hoppe–Seyler's test	11	55.0	09	45.0
Potassium ferrocyanide test	11	55.0	09	45.0

As per table, carbon monoxide (CO) blood tests were positive in 55% of burn cases across all three chemical methods employed, namely Kunkle's test, Hoppe–Seyler's test, and the potassium ferrocyanide test.

Table. Incidence of Chemical Tests with Survival Duration

Chemical test	<24 hrs	%	24–72 hrs	%	>72 hrs	%
Kunkle's test (+)	2	10	9	45	0	0.0
Kunkle's test (-)	0	0.0	2	10	7	35
Hoppe–Seyler's test (+)	2	10	9	45	0	0.0
Hoppe–Seyler's test (-)	0	0.0	2	10	7	35
Potassium ferrocyanide test (+)	2	10	9	45	0	0.0
Potassium ferrocyanide test (-)	0	0.0	2	10	7	35

Kunkle's Test

Among cases positive for Kunkle's test, 2 cases (10%) died within 24 hours, while 9 cases (45%) survived for 24–72 hours. No positive case survived beyond 72 hours. In contrast, among Kunkle's test–negative cases, no deaths occurred within 24 hours; 2 cases (10%) survived for 24–72 hours, and 7 cases (35%) survived for more than 72 hours.

Hoppe–Seyler's Test

A similar pattern was observed with Hoppe–Seyler's test. Among positive cases, 2 cases (10%) died within 24 hours, and 9 cases (45%) survived for 24–72 hours, with no survival beyond 72 hours. Among negative cases, no deaths occurred within 24 hours; 2 cases (10%) survived for 24–72 hours, and 7 cases (35%) survived for more than 72 hours.

Potassium Ferrocyanide Test

In potassium ferrocyanide test–positive cases, 2 cases (10%) died within 24 hours, and 9 cases (45%) survived for 24–72 hours, while no cases survived beyond 72 hours. Among test-negative cases, no deaths occurred within 24 hours; 2 cases (10%) survived for 24–72 hours, and 7 cases (35%) survived for more than 72 hours.

Discussion

In the present study, burn cases were predominantly observed in 41–50 years of age group (40%), followed by the 31–40 years group (30%), together constituting 70% of the total cases. On the same lines as observed by **Popovic VM et. al (2009) and Feng Li et. al (2015)** reported mean ages closer to the fourth and fifth decades, particularly in cases involving carbon monoxide exposure and fire-related deaths. The higher proportion of middle-aged victims of the present study may be attributable to occupational exposure, domestic responsibilities, and prolonged exposure to fire sources in enclosed spaces (7,8). In the present study, demonstrated a male predominance (65%) among burn victims. This finding is same as observed with studies by **Popovic VM et. al (2009), Büyük Y et. al (2009), Ketenci et al. (2018), Aydogdu HI et. al (2021), and Davies B et. al (2024)**, which reported higher burn incidence among males, often attributed to occupational exposure and risk-taking behaviour. The male predominance of this present study may reflect, regional sociocultural and occupational patterns [7,9,10,11,12].

In the present study, Accidental burns constituted the majority (55%) in the present study, followed by suicidal (35%) and homicidal (10%) burns. This pattern aligns with findings by **Jaiswal KA et. al (2007), Büyük Y et. al (2009), Ketenci et al. (2018), Kumar R et. al (2024), and Davies B et. al (2024)**, where accidental burns predominated. The relatively higher proportion of accidental burns in the present study suggests increased exposure to domestic and occupational fire hazards [13,9,10,14,12].

In the present study, the trunk and lower limbs were the most commonly involved regions (35% each), followed by upper limbs (20%). Similar distribution patterns were reported by **Jaiswal KA et. al (2007), Yadav PK et. al (2020), and Manoj TM et. al (2024),** where extensive involvement of trunk and limbs was associated with higher TBSA and mortality. The involvement of vital body regions contributes significantly to poor prognosis [13,16,15].

In the present study, survival pattern across all categories of burn distribution, namely localised burns, extensive burns, and whole-body burns. In each category, the majority of cases survived for 24–72 hours (55%), followed by survival beyond 72 hours (35%), while early mortality within 24 hours accounted for only 10% of cases, with male victims constituting the majority of burn cases across all survival durations, a similar survival pattern was observed across all burn distribution categories, with most cases surviving 24–72 hours. This observation supports findings by **Yadav PK et. al (2020) and Ajid A et. al (2019),** indicating that survival is influenced not only by burn extent but also by inhalation injury and systemic complications (16,17). **Ketenci et al. (2018) and Davies B et. al (2024),** where males showed higher early mortality, possibly due to occupational[10,12].

In the present study, carbon monoxide (CO) blood tests were positive in 55% of burn cases across all three chemical methods employed, namely Kunkle's test, Hoppe–Seyler's test, and the potassium ferrocyanide test. In the remaining 45% of cases, these tests yielded negative results. Kunkle's test: Among cases positive for Kunkle's test, 2 cases (10%) died within 24 hours, while 9 cases (45%) survived for 24–72 hours. No positive case survived beyond 72 hours. In contrast, among Kunkle's test–negative cases, no deaths occurred within 24 hours; 2 cases

(10%) survived for 24–72 hours, and 7 cases (35%) survived for more than 72 hours. Hoppe–Seyler's test: A similar pattern was observed with Hoppe–Seyler's test. Among positive cases, 2 cases (10%) died within 24 hours, and 9 cases (45%) survived for 24–72 hours, with no survival beyond 72 hours. Among negative cases, no deaths occurred within 24 hours; 2 cases (10%) survived for 24–72 hours, and 7 cases (35%) survived for more than 72 hours. Potassium ferrocyanide test: In potassium ferrocyanide test–positive cases, 2 cases (10%) died within 24 hours, and 9 cases (45%) survived for 24–72 hours, while no cases survived beyond 72 hours. Among test-negative cases, no deaths occurred within 24 hours; 2 cases (10%) survived for 24–72 hours, and 7 cases (35%) survived for more than 72 hours. These findings correlate strongly with **Yeoh MJ (2004), Popovic VM et. al (2009), Ketenci et al. (2018), and Liu Z et. al (2021),** who demonstrated that elevated COHb levels are associated with early death and poor prognosis [19,7,10,18].

Conclusion

This study confirms that carbon monoxide inhalation is a critical factor in 55% of burn deaths, with COHb positivity serving as a reliable marker for antemortem burns and vitality during fire exposure.

Key Findings

- Middle-aged males (31–50 years, 65%) are most affected, with accidental burns dominating (55%)
- COHb-positive victims predominantly died within 24–72 hours (45%), while COHb-negative cases survived beyond 72 hours (35%)
- Trunk and lower limbs (35% each) were most commonly injured, correlating with higher mortality

The consistent 55% positivity across all three chemical tests (Kunkle's, Hoppe–Seyler's, potassium ferrocyanide) validates their reliability for forensic use. COHb estimation is indispensable for distinguishing antemortem from postmortem burns, determining vitality, and accurately establishing cause and manner of death—especially critical in legal contexts including dowry death investigations. Routine toxicological analysis should be standard in all burn autopsies to improve forensic accuracy and legal outcomes.

Conflict of Interest: Nil

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Ethical Considerations: This study is approved by Thesis & Ethical Committee of Baba Farid University of Health Sciences, Faridkot and GGS Medical College, Faridkot is the constituent college of the university and the Institutional ethical committee is approved by COSCO Reg. No. ECR/836/inst./PB/2016/RR-25 and NECRBHR, DHR Reg. No. : EC/NEW/INST/2023/PB/0219ICMR, the copy of ethical approval is attached here with.

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Correlation of Development of The Third Molar Tooth with Age in Medicolegal cases brought to a Tertiary Healthcare Center

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Abstract

Introduction: The significance of third molars (wisdom teeth) in medicolegal age estimation is based on the principle that these teeth have a relatively predictable pattern of development and eruption. Age holds medicolegal importance in determining criminal responsibility, consent, and eligibility for marriage, employment, and voting. It is crucial in juvenile justice, sexual assault, and medical consent. This study was conducted at a tertiary health care facility.

Aims & Objectives: To correlate third molar tooth eruption with age in medicolegal age estimation cases.

Materials and Methods: Method –Cross-sectional study, Sample size – 161, Inclusion criteria – children and adults brought for examination of Medicolegal cases like physical and mental capacity, Accused of rape for medical examination, Injury certificate, etc, between the estimated ages of 11 to 25 years. Exclusion criteria: 1) Children below the age of 11 years and adults above the age of 25 years. 2) Those with a history of dental extraction of the third molar tooth. 3) Previous history of surgery in the posterior jaws. 4) Previous history of any pathology or developmental anomalies like cleft palate and syndromes. 5) Congenitally missing third molars were not included.

Observation & Results: In the present study, the eruption of the third molar was noted between 16 and 22 years. Crown formation was reported from 11 years onwards. In almost all cases, individuals above 22 years of age exhibited third molar development, characterised by physical eruption and crown formation. Variability in the development of the third molar at different stages and ages is noted.

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Conclusion: The third molar tooth eruption is one of the key factors involved in the estimation of age, which is to be correlated with the other parameters.

Keywords: ***Third Molar, crown formation, eruption, Adolescence, Medicolegal age.***

Introduction

Age estimation in medicolegal cases is a critical process used to determine an individual's age, often in the context of legal proceedings, immigration, or forensic investigations. It is particularly important when the exact age of a person is unknown, disputed, or difficult to ascertain, such as in cases involving minors, unidentified bodies, or individuals without birth records.

Age estimation in medicolegal cases relies on a combination of biological and radiological methods, with each offering valuable insights into an individual's age, especially when conventional birth records or documentation are not available. The methods include general examination, secondary sexual characters development, dental development, and skeletal maturity. Examination of dental status is important, especially when the radiological facilities are not available or contraindicated due to the physiological status of the subject.

High correlation of age with the development of third molars is observed in different studies. The correlation between age and third molar development is often used in the dental and medical fields for various diagnostic and forensic purposes.

Generally, the stages of third molar development progress as follows:

1. **Crown Formation**: Begins around 7-10 years of age. [2,3,4,5]
2. **Root Formation**: Completes by around 18-20 years.[2,3,4,5]
3. **Eruption**: Typically occurs between the ages of 17 and 25 years, although it can vary widely. Some people may not experience an eruption at all.[2,3,4,5]

Radiographic examination, particularly using lateral oblique X-rays of the mandible, can help determine the developmental stage of the third molars and assess the timing of eruption. Age estimation based on third molar development is often used in the forensic field to estimate an individual's age, especially in adolescents and young adults.

This study was conducted at a tertiary health care centre for a period of six months. In the dental examination, the developmental characteristics of eruption and mineralisation of the third molars are of relevance for age estimation.

Research gap: The Total duration was si months.

Need for the study: Reliable age estimation is essential in medico-legal practice, particularly in cases involving late adolescents and young adults. Skeletal indicators become unreliable after 18 years due to epiphyseal fusion, necessitating alternative biological markers.

The third molar, being the last tooth to develop, provides valuable information for age assessment during this period through radiographic evaluation. However, variations in dental maturation across populations limit the accuracy of universally applied standards.

Establishing a correlation between third molar development and chronological age in medico-legal cases from a tertiary healthcare center is therefore required to generate population-specific data and enhance the forensic validity of age estimation.

Aims & Objectives: To correlate third molar tooth eruption with age in medicolegal cases.

Materials and Methods: This study was conducted ata tertiary health care facility, Mumbai, India. The patients brought for medicolegal examination were subjected to X-ray examination with necessary precautions after general physical examination and dental examination with prior consent. A special emphasis on the third molar teeth in correlation to age estimation was ensured.This is a cross-sectional study involving the evaluation of 161 cases.

Inclusion Criteria

1) Children and adults brought as medicolegal cases between the ages of 11 to 25 years, as the third molar tooth development and eruption are more prominent in this age group.
2) The Children and adults brought for examination possessed valid documents stating their ages between 11 to 25 years.

Exclusion Criteria

1) Children below the age of 11 years and adults above the age of 25 years.
2) Those with a history of dental extraction of the third molar tooth.
3) Previous history of surgery in the posterior jaws
4) Previous history of any pathology or developmental anomalies like cleft palate and syndromes.
5) Congenitally missing third molars were not included.

Methodology

The third molar developmental state was examined by direct visualisation using a cheek retractor, mouth mirror, and clinical palpation.

Clinical Evaluation of The Eruption Status of Third Molars

- Third molars that had erupted to the level of the occlusal plane and were completely visible
- Partially erupted third molars and partially visible clinically
- Clinically invisible third molars that had not yet erupted into the oral cavity.

Only clinically missing third molars were examined with X-rays to assess the state of the third molar tooth.

Results

Developmental status of the third molar with correlation to age from 11 to 16 years. Clinical eruption was not observed.

- From 11 to 16 years of estimated age, crown formation was radiologically evident in 74.6%. (Average Mean).

Table No. 1. indicates the percentage of clinical eruption of the third molars in the observed age groups.

Age Groups	Total no of cases in the Age groups	Cases with Eruption of 3rd Molar	% of eruption observed clinically
16 – 17 Years	17	2 (Partially)	11.70 (Partially)
17 – 18 Years	17	6	35.29
18 – 19 Years	10	4	40
19 – 20 Years	10	6	60
20 – 21 Years	14	12	85.71
21 – 22 Years	12	11	91.66
22 – 23 Years	14	14	100
23 – 24 Years	15	13	86.66
24 – 25 Years	14	14	100
	N = 161		

- In the present study, eruption of the third molar was noted between 16 and 22 years. Crown formation was reported from 11 years onwards. In almost all cases, above 22 years of age, third molar development in the form of physical eruption and crown formation was observed. Variability in the different stages of development of the third molar at different ages was noted.

Table No. 2. Crown formation and eruption correlation observed in the age groups 11 to 16 years.

Age groups (Y)	Crown formation (n= 38)	Percentage (%)	Clinically erupted
11 to 12	5/7	71.42 %	0
12 to 13	2/4	50 %	0
13 to 14	4/5	80 %	0
14 to 15	8/10	80 %	0
15 to 16	11/12	91.66 %	0
Average Mean		74.6 %	

- In about 14.29% of the cases, an impacted tooth was observed in age groups between 20 to 21 years of age.
- In conclusion, the eruption, development, and potential complications of third molars are closely tied to age.
- Individuals under 25 are more likely to experience complete eruption of their third molars, while older individuals may face delayed eruption or impaction.
- After the mid-20s, the likelihood of third molars erupting decreases significantly, and the chances of impaction rise as age increases.
- Radiological investigations play a key role in determining the third molar state of development.

Figures

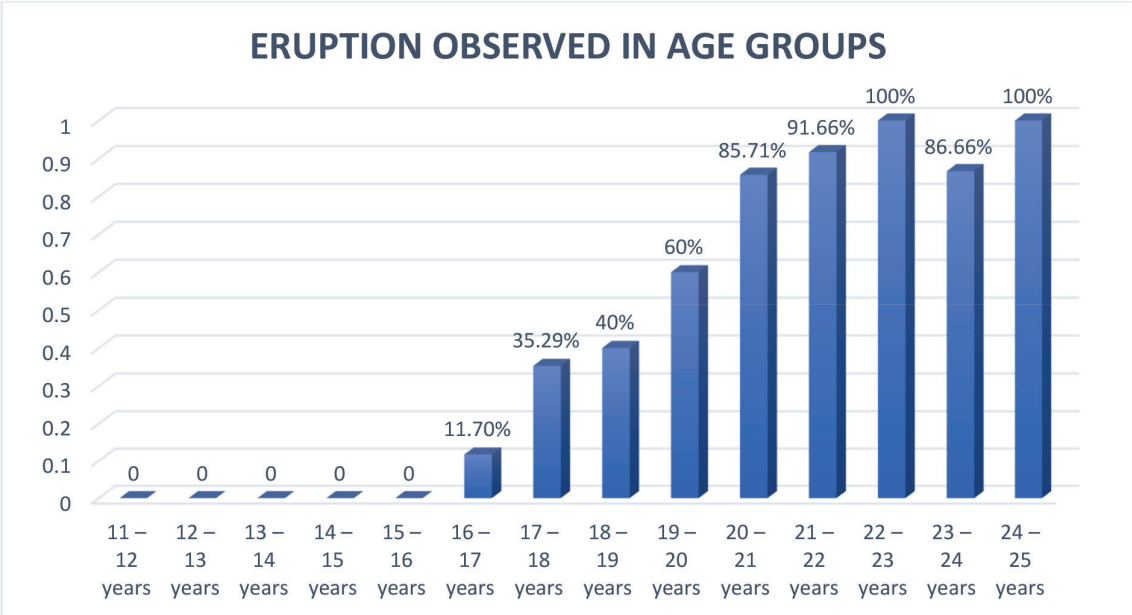


Figure No. 1: Indicates the eruption found evident in the observed age groups 11 to 25 years.

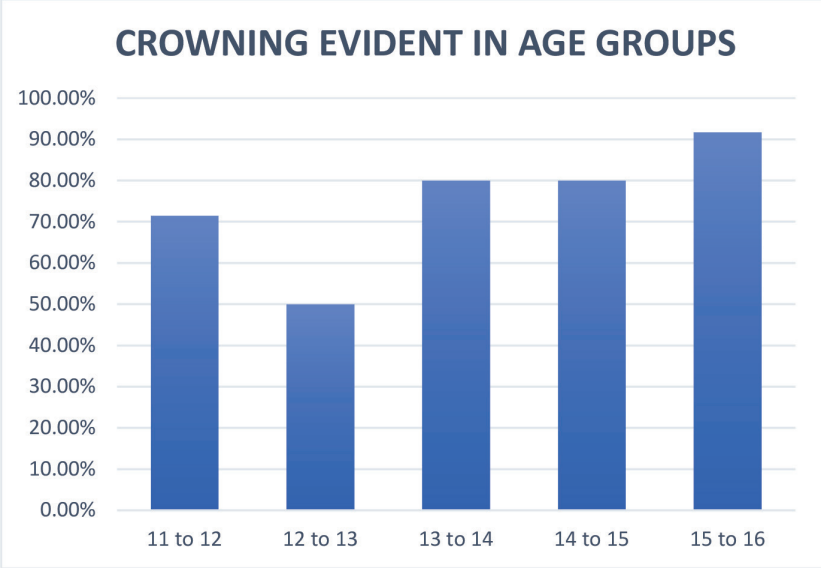


Figure No. 2: Indicates the crowning formation evident by radiological examination in the observed age groups 11 to16 years.

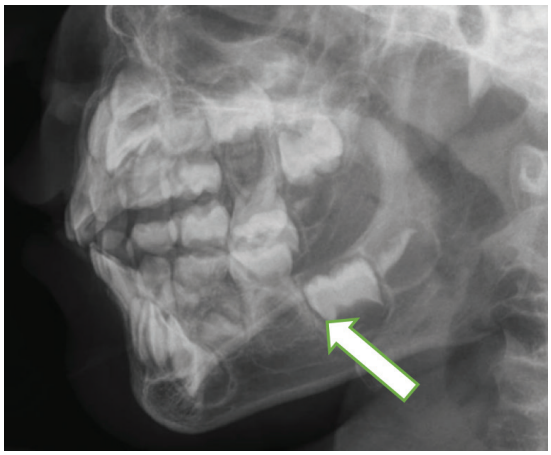


Figure No. 3: Radiographical image showing crowning of the third molar.

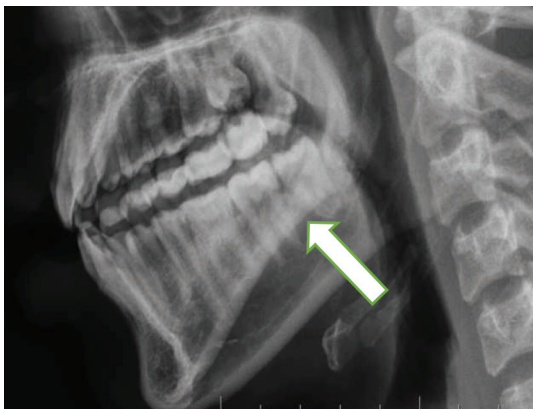


Figure No. 4: Radiographical image showing eruption of the third molar.

Discussion

In medico-legal practice, the estimation of age plays a crucial role, particularly in determining the legal status of an individual based on various age-related laws. These age thresholds hold significant legal and social importance, especially in the Indian context, where the following age groups have legal implications:

1. **12 years**: Individuals below this age are generally not considered capable of committing certain offences, as the legal system presumes they lack the mental maturity to understand the consequences of their actions.
2. **14 years**: This is the minimum age for employment under Indian labour laws. Children under 14 years cannot be employed in hazardous industries or work environments.
3. **18 years**: This is the age of majority in India, signifying adulthood, which gives an individual full legal rights and responsibilities. It also marks the legally permissible age for marriage for females in India.
4. **21 years**: This is the legal marriage age for males in India, impacting rights like voting and contract entry. Forensic odontology was used to

determine the accused's age, which was useful in cases, e.g., Baba Siddique's case[23], Carlos Alberto's case [24,]etc.

Dentition plays an essential role in age estimation due to its development and eruption patterns, which are relatively well-documented and provide valuable information at various stages of life.

The present study aimed to evaluate the correlation between third molar tooth development and chronological age, focusing on clinical eruption and crown formation stages. The eruption and development of third molars are frequently used in forensic medicine for age estimation, as their growth follows a relatively predictable pattern linked to chronological age. In this study, we explored the relationship between third molar development, crown formation, and eruption across a broad age range from 11 to 25 years. Our results revealed significant variation in eruption patterns, with third molar eruption starting between 16 and 17 years and reaching full eruption (100%) by 22-23 years. The average crown formation observed in the 11-16-year age group was 74.6%, while clinical eruption did not occur until the later teenage years.

- **Early Crown Formation and Delayed Clinical Eruption:** Our study found that crown formation in third molars was evident in 74.6% of cases in the 11-16-year age range, but clinical eruption was absent during this period. This finding is consistent with Reddy et al. (2010)[19]and Verma et al. (2016)[22], who also noted that crown formation precedes clinical eruption by several years. This emphasises that while tooth development may begin early, eruption into the oral cavity typically occurs after the age of 16 years.
- **Age at Eruption:** In our study, third molar eruption occurred gradually, with a notable increase in eruption rates after 16 years. Eruption was observed in 35.29% at 17-18 years, 60% at 19-20 years, and 85.71% at 20-21 years. The peak eruption rate of 100% was observed in the 22-23 years and 24-25 years age groups. This gradual increase in eruption rates is consistent with findings from Kumar et al. (2015)[20] and Patil et al. (2013)[21], although some variations in exact eruption timing and percentages were observed.
- **Impacted Third Molars:** In our study, 14.29% of individuals in the 20-21-year age group exhibited impacted third molars. This finding is consistent with studies by Reddy et al. (2010)[19] and Kumar et al. (2015)[20], where impaction rates were higher in the 20-25-year age range. This suggests that while eruption is common in the early 20s, there is still a significant risk of impaction, especially in individuals with smaller jaw sizes or other dental anomalies.
- **Age Estimation:** Our findings support existing literature that third molar development, particularly crown formation and eruption stages, can be used as a reliable marker for estimating age, especially for individuals between 16 and 25 years. Radiographic evaluation of third molar development remains an essential tool in forensic age determination, with implications in both legal and clinical settings.

Conclusion

The eruption of third molars, commonly known as wisdom teeth, is a key developmental milestone in dental anatomy. Typically, third molars begin to erupt between the ages of 17 to 25 years, although the exact timing can vary depending on factors such as genetics, gender, and overall health.

- Early eruption (16-18 years): In some individuals, third molars may erupt earlier, but this is less common.
- Typical eruption (18-25 years): Most people experience third molar eruption during their late teens to mid-twenties.
- Delayed eruption (26-30 years or later): Some people may have a delayed eruption, where the wisdom teeth may not fully emerge until their late twenties or even early thirties.

- Impacted molars: In many cases, third molars do not erupt at all due to space constraints in the jaw, leading to impaction, which may require surgical intervention.

The timing of eruption varies among individuals and is influenced by factors such as genetics, ethnicity, and dental development patterns. In some cases, third molars may never fully emerge, or they may become impacted, causing discomfort or other dental complications. Therefore, regular dental check-ups are essential to monitor the development and position of these teeth.

The third molar tooth eruption is one of the key factors involved in the estimation of age that correlates with the other parameters.

Limitations

- **Sample collection:** The sample collected is not of wide distribution and will require more extensive study based on geographic distribution.
- **Individual Variation**: Factors like genetics, nutrition, and health cause differences in dental development.
- **Population-Specific Data**: Methods may not apply accurately to different ethnic or geographic populations.
- **Wear and Tear**: Tooth wear over time can obscure age-related features, especially in older individuals.
- **Dental Treatment**: Fillings and other dental work can alter tooth appearance and interfere with age estimates.
- **Environmental Factors**: Diet and environmental conditions affect dental development and wear patterns.
- **Tooth Development Stages**: Not all teeth develop at the same rate, complicating estimates in younger individuals.
- **Age Range Limitations**: Less accurate for older individuals, especially beyond 50–60 years.
- **Radiographic Interpretation**: X-rays can be unclear, and interpretations may vary between examiners.

Future Research Recommendations

Research in dental age estimation should focus on:

- Creating diverse, population-specific databases for accuracy across different groups.
- Using advanced imaging techniques like 3-D scanning for better analysis.
- Conducting longitudinal studies to refine models for older individuals.
- Including genetic factors to account for individual variations.
- Studying the impact of dental wear, pathologies, and treatments on accuracy.
- Combining dental and skeletal analyses for reliable results.
- Utilising Artificial Intelligence and machine learning to automate and standardise the process.

These improvements would enhance precision and applicability in age estimation.

Source of Funding: Self.

Ethical Clearance: Ethical clearance was obtained from the institutional ethics committee vide letter no. IEC/Pharm/RP/336/25, dated 24/11/25. We confirm that the research was conducted as per the ethical guidelines, including adherence to the legal requirements of the study country.

Conflict of Interest: None

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Study of the Pattern of Unnatural Deaths at Kempegowda International Airport, Bengaluru, Subjected to Autopsy at Akash Institute of Medical Sciences and Research Centre

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Abstract

Kempegowda International Airport, Bengaluru, is one of the busiest airports in India. A one-year prospective study was conducted in the Department of Forensic Medicine and Toxicology at Akash Institute of Medical Sciences and Research Centre, Devanahalli, to analyze the pattern of unnatural deaths subjected to autopsy under the airport's jurisdiction. The study evaluated incidence, age and sex distribution, location of death (on board or off board), medical tourism status, seasonal variation, nationality, and manner of death.

During the study period, a total of 156 unnatural deaths were subjected to autopsy, of which 45 cases were referred from the Airport Police Station. A marked male predominance was observed (n = 35; 77.8%). The majority of deaths occurred off board within airport premises or after disembarkation. Indian nationals constituted the majority of cases. A substantial proportion had documented pre-existing medical illness, with coronary artery disease being the most common comorbidity. One-third of the deceased had travelled to India for medical treatment. A seasonal peak was observed in January. External causes such as assault accounted for a small proportion of cases.

The findings highlight the significant contribution of advanced age, male gender, chronic disease, and medical tourism to airport-related unnatural deaths, emphasizing the need for improved pre-flight assessment and strengthened airport emergency preparedness systemse, and medical tourism to airport-related unnatural deaths, emphasizing the need for improved pre-flight assessment and strengthened airport emergency preparedness systems[1.]

Key Words: Airport, Unnatural deaths, Autopsy

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Introduction

The Modern era has enabled rapid and widespread air travel across the globe, resulting in an unprecedented rise in air passenger traffic, currently estimated at nearly five billion trips annually. The increasing volume of airline passengers has led to a corresponding rise in the demand for in-flight medical assistance. In addition, a growing number of elderly individuals and passengers with pre-existing diseases or disabilities are undertaking air travel. There has been an estimated 30% increase in patients travelling by commercial airlines for medical treatment, a phenomenon commonly referred to as medical tourism.

Need for the Study

The rapid growth of air travel, coupled with an increasing number of elderly passengers and medical tourists, has led to a rise in medical emergencies and medico-legal deaths within airport settings. Despite India's position as a major aviation and medical tourism hub, systematic forensic data on unnatural deaths occurring under airport jurisdiction are limited. This study aims to address this gap by analyzing the demographic profile, medical background, and circumstances of such deaths at airport premises, thereby providing evidence to strengthen pre-flight assessment, airport emergency preparedness and other medico-legal protocols.

Research Gap

Present literature mainly focuses on in flight medical emergencies, with limited studies on unnatural deaths occurring within airport jurisdictions, especially in India. Data on deaths after disembarkation, the role of medical tourism, pre-existing illnesses, and seasonal variation remain scarce. This gap highlights the need for airport-based medical research for the prevention and improve emergency preparedness and its medico-legal implications sequently led to a significant increase in the incidence of in-flight medical emergencies as well off board, though different manner of deaths are reported in the premises of airport.

Materials and Methods

A total of 156 cases were subjected to post-mortem examination between 1September 2023 and August 2024. Among these, 45 cases were referred from the jurisdiction of the Kempegowda International Airport Police Station. These cases involved airline passengers who collapsed during boarding, disembarkation, or while waiting in the airport lounge and any unnatural deaths around airport.

Inclusion Criteria

- All unnatural deaths referred by the Airport Police Station to the Department of Forensic Medicine and Toxicology.
- Deaths occurring on board aircraft, within airport premises, or during transfer to the airport medical emergency room.
- Cases involving domestic and international passengers, irrespective of their nationality.
- Deaths occurring in both medical tourists and non-medical travelers.

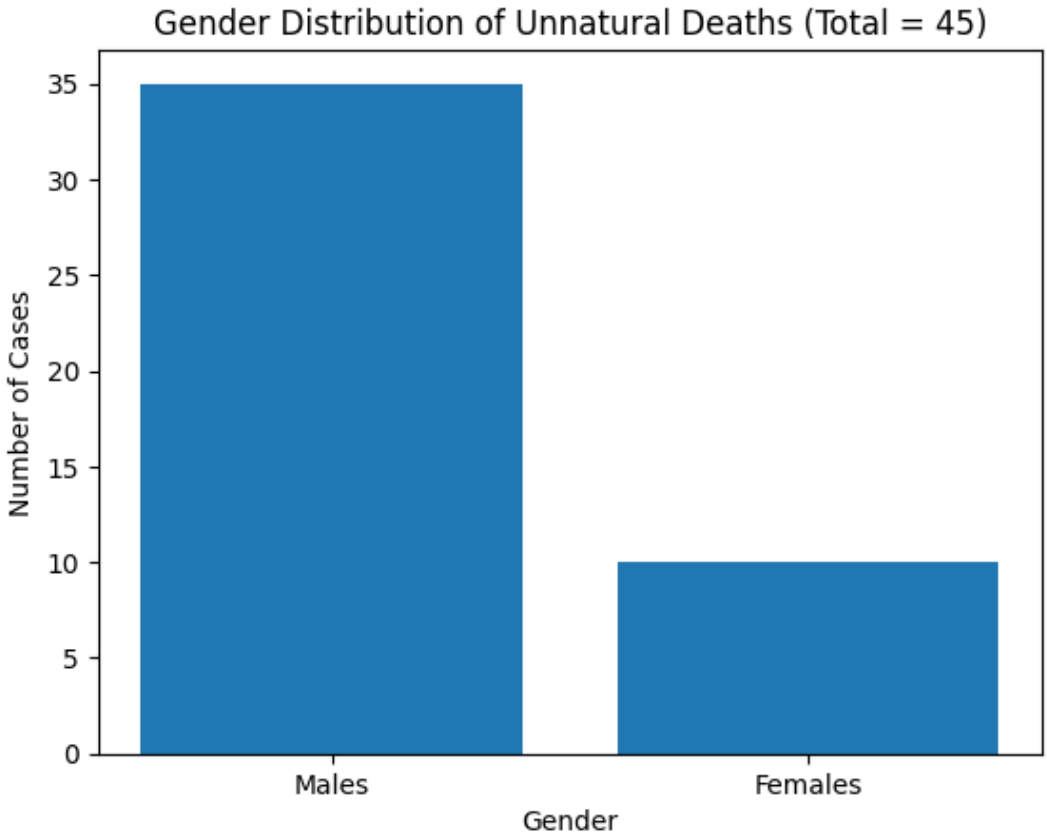
Exclusion Criteria

- Deaths occurring outside the jurisdiction of the Airport Police Station.
- Cases brought dead to hospital with no travel or airport association
- Unidentified cases where circumstantial details were unavailable

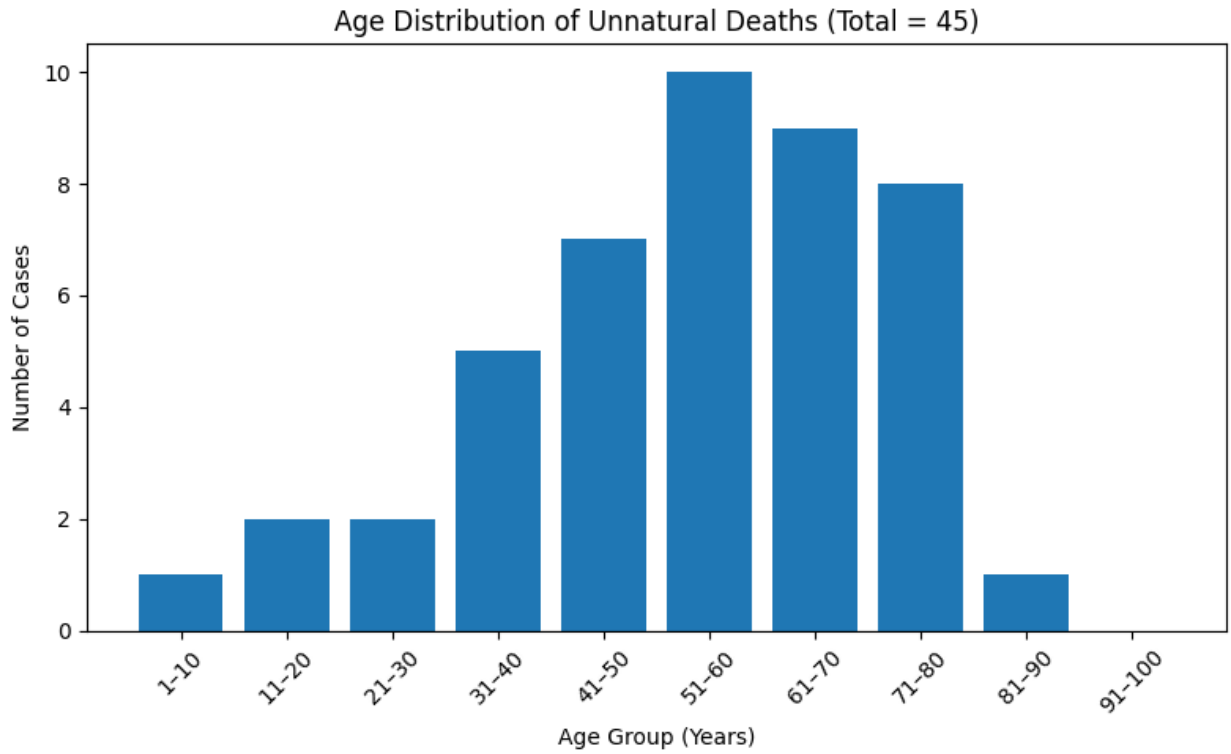
Results and Discussion

1. The **Bar chart** showing Gender distribution

In the present study of the 45 cases studied, **35 were males and 10 were females**, yielding a **male-to-female ratio of 3.5:1**. Males constituted **77.8%** of the total cases, while females accounted for **22.2%**. This marked male predominance indicates a substantially higher occurrence of unnatural deaths among male passengers in the present study population.



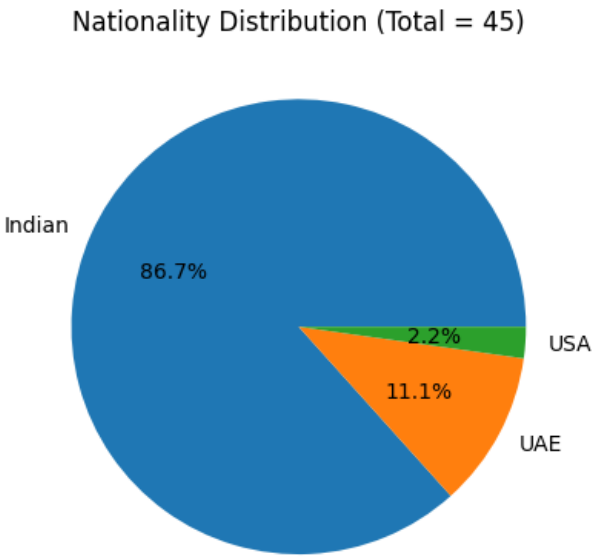
2. The Bar chart illustrating age distribution



In the present study of 45 cases maximum cases were recorded in the age group 51 to 60 years (22.2 %) followed by 61 to 70 years (20 %) cases in the extreme age groups the proportion was lowest.

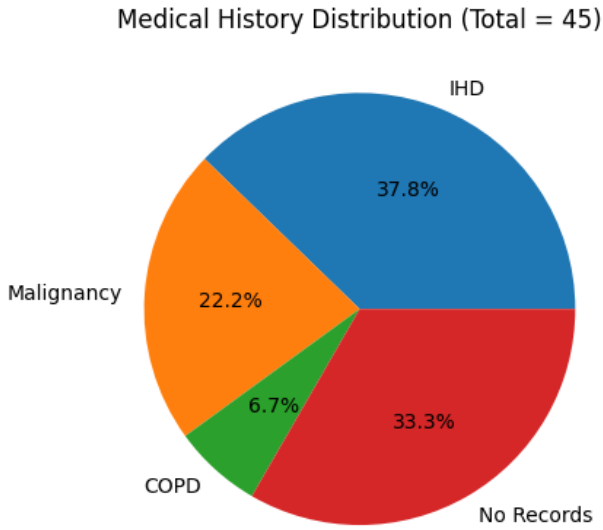
Umesh and Shukaili (2022) documented a clear male predominance and a higher incidence of medical emergencies among older passengers, findings that closely align with the male predominance (77.8%) and concentration of cases in the 51–80year age group observed in the current study. Both studies emphasize the vulnerability of elderly travelers with chronic diseases[3]

3. The **pie chart**illustrating nationality of the study population



In the present study Indian nationals constituted the vast majority of cases (86.7%), reflecting the dominant proportion of domestic travelers using Kempegowda International Airport. Foreign nationals accounted for 13.3% of the cases, with travelers from the United Arab Emirates forming the largest subgroup (11.1%). This pattern is likely related to the high volume of air traffic between India and Gulf countries, including a significant number of medical tourists and migrant workers. The low proportion of Western nationals (2.2%) is consistent with comparatively lower travel volume and shorter transit exposure within the airport jurisdiction.

4. The **pie chart** illustrating the patients with valid medical history

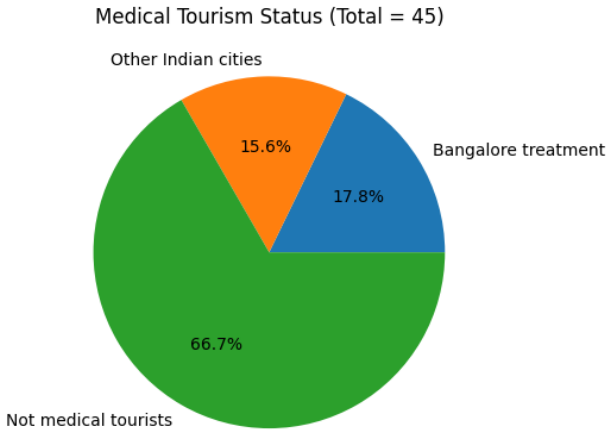


In the present study, substantial proportion of the deceased (66.7%) had documented pre-existing medical conditions, highlighting the significant burden of chronic diseases. Ischemic heart disease was the most prevalent condition, accounting for over one-third of all cases. This finding underscores the vulnerability of individuals with cardiovascular disease to adverse events during air travel, where factors such as hypoxia, stress, and prolonged immobility may act as precipitating triggers. Malignancy was the second most common comorbidity, reflecting the role of medical tourism and long-distance travel for cancer care. COPD constituted a smaller but clinically relevant proportion, given the respiratory challenges posed by cabin pressure and reduced oxygen levels. Notably, one-third of the cases lacked medical documentation, which may reflect emergency travel, inadequate record carriage, or unidentified underlying disease. The reporting of medical emergencies on board commercial airliners is voluntary and thereby somehow limited, although calls for a centralized registry have existed for more than a decade.[1,]

The findings of the present study are broadly consistent with earlier studies on in-flight medical emergencies and un natural deaths specific to airport jurisdictions.

Cummins *et al.* (1988) reported that in-flight deaths are relatively rare events, with most medical emergencies occurring in passengers with pre-existing illnesses, particularly cardiovascular disease. This observation parallels the present study, where ischemic heart disease was the most common underlying condition, reinforcing the role of cardiovascular morbidity as a major risk factor during air travel.[4]

5. Pie chart illustrating the medical tourism among the study population

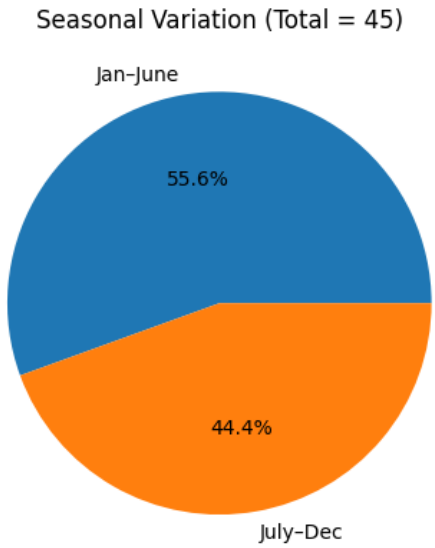


In the present study One-third of the cases in the present series were individuals who had travelled to India for medical treatment, underscoring the significant contribution of medical tourism to airport-associated deaths. Among medical tourists, a slightly higher proportion had planned treatment in Bengaluru (17.8%) compared with other major medical hubs such as Chennai, Cochin, and Delhi (15.6%). This distribution reflects Bengaluru's status as a major center for tertiary and quaternary care. The substantial presence of medical tourists highlights the vulnerability of seriously ill patients undertaking long-distance air travel, particularly in the context of chronic disease, malignancy, and cardiovascular conditions, which may predispose to medical emergencies and death during transit or shortly after arrival

Medical tourism has been a rising service industry across the world for the last two decades. The clustering of medical facilities in particular cities in India can lend itself to the development of health cities, which could have smart infrastructure geared towards the provision of world-standard medical care. The health cities could allow all stakeholders of the industry to come together and serve as generators of revenues that can be ploughed back into public healthcare provision.[2].

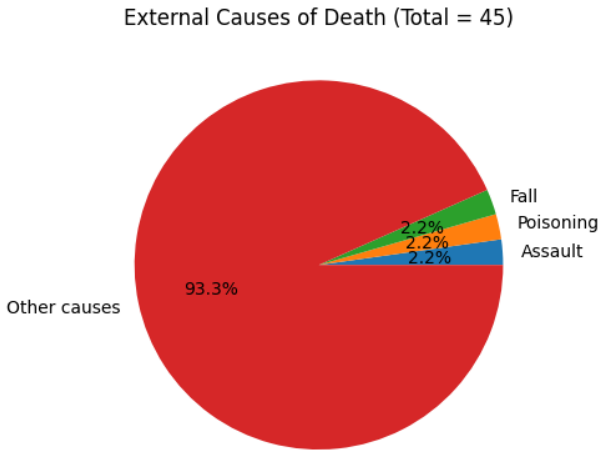
Barnwal (2024) highlighted the increasing movement of patients to India for specialized medical care. The current study corroborates this trend, with one-third of cases involving medical tourists, many of whom had malignancy or advanced chronic disease. This reinforces concerns regarding the risks associated with long-distance air travel in severely ill patients.[2]

6. Pie chart showing the seasonal variation



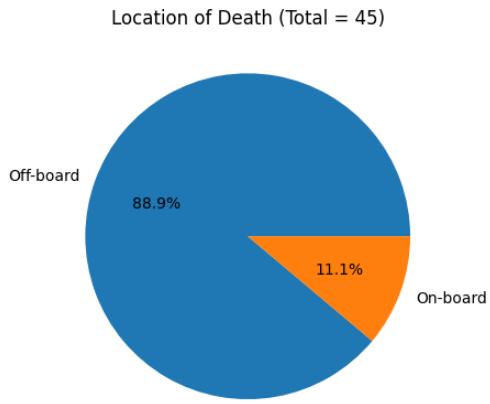
A modest seasonal variation was observed, with a higher proportion of cases occurring during the **January–June** period (55.6%) compared with **July–December** (44.4%). This finding aligns with the previously noted peak in January and suggests a greater burden of deaths in the early part of the year. Increased international travel after the winter holiday season, a higher influx of medical tourists, and the seasonal worsening of cardiovascular and respiratory conditions during colder months may contribute to this pattern. These observations highlight the importance of enhanced medical preparedness and surveillance at airports during the first half of the year.

7. Pie chart illustrating the external causes of death



In the present study, a small proportion of deaths in the present study were attributable to direct external causes, with assault, poisoning, and fall each contributing **2.2**% of cases. The predominance of other causes (93.3%) indicates that most deaths were not the result of overt trauma or violence but were more likely related to underlying medical conditions or natural disease processes occurring in a travel setting. The low frequency of violent or accidental deaths suggests that the airport environment is relatively safe; however, the presence of such cases underscores the importance of maintaining robust medico-legal surveillance and emergency response mechanisms within international airport premises.

8. Pie chart illustrating the location of death



In the present study, a striking majority of deaths (88.9%) occurred off board, within the airport premises or after disembarkation, whereas only 11.1% occurred on board the aircraft. This finding suggests that many critically ill passengers survived the flight but deteriorated during transit through the terminal or while awaiting or accessing medical care. Physical exertion after long-haul travel, delayed presentation of symptoms, and limited early medical intervention may contribute to this pattern. The predominance of off-board deaths highlights the critical role of airport-based emergency medical services, rapid triage, and immediate access to advanced life support in preventing potentially avoidable fatalities[3]

Discussion

The present study provides valuable insights into the pattern of unnatural deaths occurring under the jurisdiction of Kempegowda International Airport, Bengaluru, highlighting the significant role of air travel, medical tourism, and underlying disease in determining mortality patterns. A total of 45 airport-related cases were analyzed, representing a unique medico-legal population characterized by international travel, advanced age, and high prevalence of chronic illness.

A marked **male predominance** (77.8%) was observed, which is consistent with previous studies on air travel–related deaths and reflects the greater travel frequency among males for occupational, business, and medical purposes. The **male-to-female ratio of 3.5:1** suggests that men may be at higher risk of adverse events during air travel, possibly due to greater exposure to travel stressors and higher prevalence of cardiovascular risk factors.

The **age distribution** revealed that nearly **60% of deaths occurred in individuals aged 51–80 years**, with the highest concentration in the 51–60 year age group (22.2%). This finding highlights the vulnerability of older passengers, particularly those with pre-existing medical conditions, to physiological stress during long-distance flights. Reduced cabin oxygen pressure, dehydration, immobility, and psychological stress may precipitate fatal events in this age group.

The **nationality pattern** showed that **Indian nationals constituted 86.7%** of the cases, followed by passengers from the Middle East (11.1%). This reflects the dominant share of domestic and Gulf-bound travel through Bengaluru airport, as well as the high influx of medical tourists and migrant workers from these regions.

The presence of **documented medical illness in 66.7% of cases** is a critical observation. **Ischemic heart disease**, which accounted for 37.8% of all cases, was the most common comorbidity, emphasizing the central role of cardiovascular disease in air-travel–related mortality.. Sudden unexpected cardiac death was the cause of death in 63% (253/399) of the apparently healthy people and seems to be the major cause of death during air travel. These observations support the initiation of programs to train cabin personnel in the skills of basic cardiopulmonary resuscitation and in the use of automatic external defibrillators[4]In-flight cardiac arrest is a rare event that occurs at a rate of approximately 1 event in 3.8 to 4.7 million commercial airline passengers and at a rate of approximately 1 event in 1,500 to 3,000 patients transported by fixed wing international air medical transport. Only 13% to 19% of victims of in-flight cardiac arrest can be successfully resuscitated. The arrival of an aircraft with a deceased patient/ passenger on board triggers a country-specific procedure that focuses on public health and medico legal considerations.[1]

Malignancy (22.2%) was the second most common condition, supporting the influence of **medical tourism**, where critically ill patients undertake international travel for specialized treatment. COPD, though less frequent, remains clinically important due to the effects of hypoxia and reduced cabin pressure on respiratory compromise.

Medical tourism was identified in **33.3% of cases**, with Bengaluru being the planned destination in more than half of these. This underscores the city's position as a major healthcare hub in India and highlights the risks associated with long-distance travel among severely ill patients.

A **seasonal variation** was noted, with **55.6% of deaths occurring between January and June**, and a peak in January. This may be related to increased travel during the winter holiday season, as well as seasonal worsening of cardiovascular and respiratory conditions during colder months.

Only a small fraction of deaths were due to **external causes** such as assault, poisoning, and falls (each 2.2%), indicating that the majority of fatalities were not due to violence or accidents but were more likely triggered by medical conditions during or shortly after air travel.

Overall, the findings emphasize that airport-related deaths are predominantly influenced by **advanced age, chronic disease, and medical tourism**, rather than traumatic or violent events. These results highlight the need for improved **pre-flight medical screening, in-flight medical preparedness, and airport-based emergency care facilities**, particularly for high-risk passengers.

Despite the expansion of commercial air travel over recent decades, there are currently no guidelines for managing ill passengers during commercial flights from the standpoint of volunteer medical professionals. The incidence of these cases is hard to estimate given the paucity of available data. While commercial airlines often collect information on medical events during flight, they do not do so in a standardized format, so it is difficult to compare data across regions.[5]

Forensic literature, including case reports in journals such as the *Indian Journal of Forensic Medicine & Toxicology*, has largely been limited to isolated aviation-related deaths, such as stowaway fatalities or unusual traumatic cases. The present study adds to this body of knowledge by providing a systematic forensic analysis of airport-related unnatural deaths, integrating demographic, medical, seasonal, and circumstantial factors.

Conclusion

The present study demonstrates that unnatural deaths occurring under the jurisdiction of

Kempegowda International Airport are predominantly associated with advanced age, male gender, and pre-existing medical illnesses, particularly ischemic heart disease and malignancy.

A substantial proportion of the deceased were medical tourists, highlighting the risks associated with long-distance air travel among severely ill individuals. The clustering of deaths in the elderly age group and the seasonal peak during the first half of the year further emphasize the influence of physiological stress and seasonal disease exacerbation on mortality during air travel. Only a small proportion of cases were due to external causes such as assault, poisoning, or falls, indicating that most fatalities were medically precipitated rather than traumatic.

These findings underscore the need for enhanced pre-flight medical evaluation, improved in-flight medical support, and well-equipped emergency response systems at international airports, especially in major medical tourism hubs like Bengaluru.

Limitations of the Study

- Single-center, jurisdiction-based study limited to cases from Kempegowda International Airport, limiting generalizability.
- Small sample size (45 cases).
- Lack of a centralized registry for airport-related deaths, limiting broader trend analysis.

Scope for Further Study

Future studies should involve metacentric data from multiple international airports to better understand national and global trends in air travel–related deaths. Prospective studies incorporating detailed flight data, cabin environment, emergency response time, and in-flight medical interventions would provide deeper insights into the mechanisms of in-flight and airport-related mortality.[5]

Research focusing on high-risk groups, such as elderly travelers, cardiac patients, and medical tourists, could help develop evidence-based guidelines for pre-flight screening and travel fitness certification. Additionally, evaluation of airport emergency medical services and airline medical preparedness would assist in improving passenger safety and reducing preventable deaths.

Ethical Clearance: the ethical approval has been taken with the following reference number REF NO; IEC NO;AIMSRC/IEC/03/205-26,

Conflict of Interest: NIL

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Pattern and Nature of Skull Fractures in Blunt Head Truma

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Abstract

Background: Mechanical forces sustained to the head results in various types of skull fractures along the line of transmission of forces which is influenced by the thickness of skull, elasticity, impact velocity, impact surface characteristics, and contact period of blunt force impact. Force being a vector also influences the nature and course of skull fractures due to the variations of direction of application of force. The fractures noted during the study were fissured fractures, depressed fractures comminuted fractures, ring fractures, and suture diastasis or diastatic fractures.

Methods: This is a cross sectional descriptive study that involved 130 cases of blunt trauma head autopsied in department of Forensic Medicine, Government Medical college, Kozhikode, Kerala from 2020 to 2022. The skull fractures were photographed and digitally magnified to study the course through the vault and base of skull and the course pattern and nature of fracture and fracture line evaluated.

Conclusion: The fracture of skull was influenced by the direction of application of force, bony ridges, grooves and pits and the course of fracture line influenced by the thickness of the bone.

Keywords: Skull fracture – Mechanics- Blunt injury – Traumatic brain injury

Introduction

The cranial bones include frontal bone, two parietal bones, two temporal bones, one occipital, sphenoid and ethmoid of bone each. They are bound together by strong fibrous elastic bands of tissues in the form of coronal sutures, sagittal suture, squamous suture, lambdoid suture and the pterion. The line of transmission of force varied from case to case of traumatic brain injuries, however the fracture

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lines were seen to course along the areas of least resistance / through the thinnest part of bone, foraminal and the fracture passes only from the thicker to the thinner portions of the skull[1]. The base of the skull has numerous foramina that allow the entry of blood vessels and nerves and those openings functionally becomes weaker areas of the base of skull. The facial bones include the nasal bone, zygomatic bone, maxillae and mandible which also transmits the force indirectly to the brain during traumatic brain injury. There are three cranial fossa, the anterior cranial fossa forms from the frontal bone, sphenoid bone and ethmoid bone, the middle cranial fossa forms from the sphenoid bone and two temporal bones and posterior cranial fossa form from the occipital bone and two temporal bone. The anterior cranial fossa which accommodates the frontal lobe of the brain is weakened over the cribriform plate, the middle cranial fossa which accommodates the temporal lobe of the brain is weakened by the presence of optic canal, superior orbital fissure, foramen spinosum, foramen rotundum and foramen ovale, the posterior cranial fossa which accommodates the cerebellum and brain stem is weakened by the internal auditory meatus, jugular foramen, foramen magnum and hypoglossal canal. The frontal, parietal, occipital and squamous temporal bone (vault) and facial bones undergo intramembranous ossification. The skull base including sphenoid and ethmoid bones forms by endochrondral ossification possibly due to awaiting the completion of neurovsaculature formation allowing the development of foramina. The sutures of the skull allow for movement of cranial bones. Force transmitted over a smaller area results in localised skull injury rather than transmitted injuries along the vault and base of skull[2,3].

Materials and Methods

The skull fractures seen during medicolegal autopsy were photographed and digitally magnified to study the course through the vault and base of skull and the course pattern and nature of fracture and fracture line evaluated.

Study design: Cross sectional descriptive study

Study setting: Department of Forensic Medicine, Govt. Medical College, Kozhikode

Study period: 2020-2022

Sample size: According to the study "The correlation between skull fractures and intracranial lesions due to traffic accidents by M. Sunay yavuz. Mahmut Asirdizer, Gurse /cetin, Yasemin Gu nay Balci and Muzaffer Altinkok, of the 500 cases, 152 (30.4%) had only linear fractures; taking precision as 10%. The sample size is calculated as follows:

$n = HPq/d^2$ P=30, q = 100-30 = 70; d = 10

n = (4 x 30 x 70)/ (10 x 10) = 84

Inclusion criteria: All cases of blunt trauma to the head of known manner with fractures of skull.

Exclusion criteria: Traumatic brain injury due to multiple blunt force injuries.

There is no financial backing from any organization or agency. It is taken case by the Principal investigation. The details of the case and confidentiality are maintained through out the study.

Observations

A total number of 130 cases were analysed out of which 86 cases were that of a moving head hitting a stationary object without any protective head gears and 40 were moving objects hitting a stationary head which could move after the impact where as 4 cases were blunt injuries sustained on a fixed head.

Thickness of skull bone (Table 1)

	Frontal	Occipital	Parietal	Temporal
68	++++	+++	++	+
24	+++	++++	++	+
19	++++	++	+++	+
11	++++	++++	++	+
08	+++	++++	+++	+

Fractures of vault of skull (Table 2)

	69	7	21	2	6	2
Fissured	+++++					
Depressed		+++				
Comminuted			++++			
Ring fracture				+		
Suture diastasis					++	
Diastatic fracture						+

Fractures of base of skull (Table 3)

Anterior cranial fossa	9 cases
Middle cranial fossa	6 cases
Posterior cranial fossa	8 cases

Fracture of vault extending to base (Table 4)

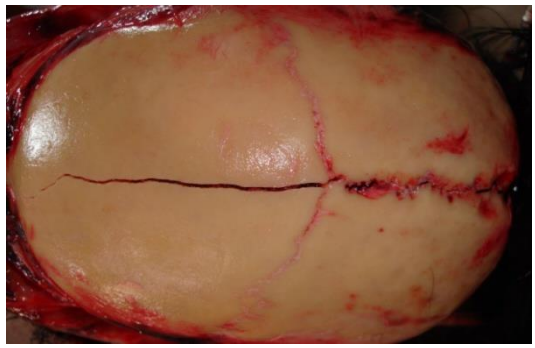
Primary impact	Total
Frontal	24
Temporal	16
Parietal	11
Occipital	13

Fissured 48 Comminuted fracture 14 Ring fracture 2

(All the depressed fractures and sutural fractures were restricted to the vault)

Fractures of base coursing through thinner bones/ canal/ fissure/ foramina (Table 5)

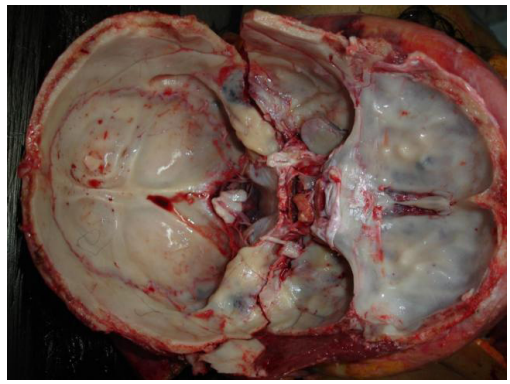
	Extending from vault	Solitary fracture
Anterior cranial fossa	18	9
Middle cranial fossa	16	6
Posterior cranial fossa	5	4



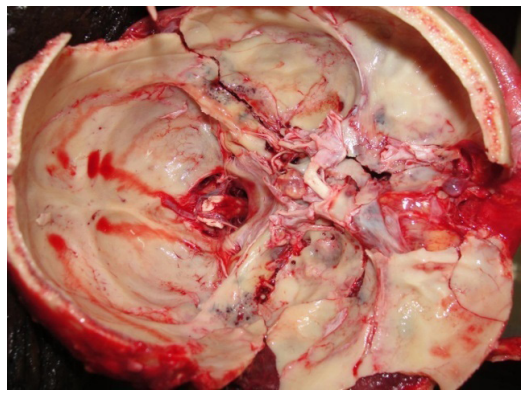
Fissured fracture suture separation (fig 1)



Comminuted depressed fracture (fig 2)



Fracture middle cranial fossa (fig 3)



Fracture of petrous bone and anterior cranial fossa (fig 4)

Discussion

The thickest skull identified was the frontal bone followed by occipital bone, parietal bone and temporal bone. Force transmitted over a smaller area results in localised skull injury and diffuse blunt trauma resulted in transmitted injuries along the vault and base of skull[2,3].

- Fissured fractures were the commonest fracture seen on the skull base, the greater the contusion (force), the fracture crossed the suture line and extended to the base of skull. All the fissured fractures were seen involving inner and outer table of skull.
- Depressed and comminuted fractures were seen involving the vault of skull[4]. Fissured fractures were seen extending from the margins extending to the base of skull but fissured fractures were not seen extending from depressed fracture of vault of skull without comminution. Comminuted fractured was seen involving the anterior cranial fossa in frontal impact and involving the squamous portion of posterior cranial fossa in forceful impacts of occiput and was more commonly seen over thinner portions of skull bones only[5].
- Isolated fractures of the base of skull were seen more in situations where scalp contusions were less than in fractures of vault of skull possibly due to glancing forces due to angular blunt force impacts rather than perpendicular forces on the skull as mechanical force is a vector[6].
- Fissured fractures extending onto skull sutures were seen as sutural diastatic before fusion of sutures and diastatic fracture after closure of suture. Fissured fractures were also seen extending across sutures after complete closure of inner and outer tables.
- Fractures were seen commonly extending from thicker portions of skull towards the thinner portions and the fractures which were fissured were seen more widely separated underlying dense areas of scalp contusions and they were seen tapering towards distal aspect[7].
- Paramedial fissured fractures of frontal bone were soon involving the outer table of frontal sinus only where as most of the fractures extending to thin table of anterior cranial fossa extending to the foramina cribrosa were from the sides of frontal bone extending through the thinner roof of orbit, which also was seen extending to the sphenoid bone[8].
- Fractures of the middle cranial fossa were seen anteriorly along the posterior margin of greater wing of sphenoid involving and extending uptosella turcica or hypophyseal fossa and crossing over depending upon the force of impact and fractures the petrous temporal bone was seen along the weaker areas of hiatus canalis and extended along foramen spinosinus, foramen lacerum or foramen ovale through the fossa hypophysiatis and to the opposite side along carotid groove. These fractures were commonly called hinge fractures[9].

Fractures involving the posterior cranial fossa were seen either involving the crista occipitalis interna invariably reaching upto posterior lip of foramen magnum or through the thinner fossa cerebellaris reaching upto the petrous temporal bone terminating at sulcus of sigmoid sinus or extending upto side margin of foramen magnum along sulcus for petrous sinus[10].

Fractures involving single bone of the skull were classified as low force blunt skull fracture and fractures crossing the suture lines between the bones were considered to be more forceful blunt impact injuries as the force required to cross suture lines were relatively more.

Skull bone Thickness

- Frontal and Occipital: In this study, the frontal bone was identified as the thickest (68 cases), followed closely by the occipital bone (24 cases). This aligns with studies which note these areas are reinforced to protect against direct impacts.

- Temporal Bone: Across all 130 cases, the temporal bone consistently showed the lowest thickness (+).

  The temporal bone being the thinnest and the frontal and occipital bone being the thickest are consistent with the work of Rupani et al. (2013)[3] and McElhaney et al. (1970)[2].

- Parietal: The parietal bone thickness showed variability, ranking primarily as the second or third thickest bone in 106 cases.

Comparison of Fracture Patterns

- Linear (Fissured) Fractures: This study noted fissured fractures as a primary finding, consistent with a study in Raichur where fissure fractures were the most common at 51.35% and also strongly corroborated by Vittala H. et al. (2023)[11] where linear fractures were the most common type, accounting for 66% of cases. Similarly, research by Rupani et al. (2013)[3] and Manish K et al.[12] also identified linear fractures as the most frequent pattern, occurring in 50% and 38.8% of cases respectively[12].
- Comminuted and Depressed Fractures: While this study highlights these patterns, other research shows varying hierarchies. For example, a study in Imphal found comminuted fractures to be the most prevalent at 31.5%. In contrast, the Raichur study reported comminuted fractures at 39.18% and depressed fractures at a lower frequency. A study in Lucknow found depressed fractures (30%) to be more common than comminuted fractures (20%).

Basilar Skull Fractures

While this study explores base of skull involvement, a study by Mirjalili et al. (2021)[13]focused specifically on basilar skull fractures, finding that the anterior cranial fossa was the most common site (54%), followed by the middle (32%) and posterior (14%) fossae.

Site of Impact and Extension into base of Skull

The frontal bone was the most frequent site of primary impact (24 cases), followed by the temporal (16 cases), occipital (13 cases), and parietal (11 cases) bones. The predominance of frontal impacts (24 cases) leading to basilar extension is consistent with the findings of Vittala H. et al. (2023)[11], where the frontal region was the most involved site (38.3%). Impact on the temporal bone (16 cases) frequently results in fractures extending along the petrous temporal bone and across the sella turcica, forming "hinge fractures". This is supported by McElhaney et al. (1995)[2], who emphasize that the middle cranial fossa's numerous foramina act as stress concentrators for these extensions.

In this study, the Anterior Cranial Fossa was the most common site for both solitary fractures (9 cases) and extensions from the vault (18 cases).This finding is highly consistent with Mirjalili et al. (2021)[13] where the ACF was identified as the most frequent site of basilar injury (54%).

This study found a higher number of solitary fractures in the Posterior Cranial Fossa (8 cases) compared to the Middle Cranial Fossa (6 cases). Many clinical studies, such as those cited by Wani et al. (2013)[6], often report the MCF as a more frequent site of injury due to the vulnerability of the petrous temporal bone. The higher PCF involvement in this study is corroborated by Vittala H. et al. (2023)[11].

Conclusion

The fractures of the skull was influenced by the direction of application of force and distinct bony ridges, grooves and pits on the inner table of the calvaria. The fracture of the base of skull and those extending to the base was influenced by the thickness of the skull as the fracture line had a tendency to course along the thinner areas of base of skull, however along the thicker areas of base of skull. However along the thicker areas of the base of skull the fracture have coursed along the canals, foramina and fissures which were weakened areas which offered least resistance for causing of the fracture

lines. Fractures of anterior and middle cranial fossa had a tendency to move towards the ethmoid and sphenoid sinuses due to the thinness of the bones forming the sinus and its weakness due to air filled cavities.

Limitations of the study: The thickness of the skull along the fracture lines were not evaluated and the force repaired could not be quantified.

Future recommendations: Further studies of biomechanics of skull fractures using postmortem human surrogates by using quantified force for determining the threshold for injury and to evaluate the mechanics of skull fractures after obtaining ethical protocols of dead body donor programmes and ethical guidelines.

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Retrospective Analysis of Death due to Burns at Atertiary Care Hospital, Solapur

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Abstract

Introduction: Burn injuries represent a significant cause of mortality and morbidity within the Indian population, with epidemiological patterns varying greatly across regions. Burn injuries, which are predominantly accidental, contribute significantly to traumatic injuries and have devastating mental, physical and functional consequences, along with a high mortality risk. Understanding the prognosis and risk factors of burn injuries is essential for improving treatment and reducing complications.

Material and Methods: This retrospective study was carried out on death due to burn cases brought to the tertiary care hospital for medico-legal autopsy examination. Data was collected from the autopsy record register from 1st January 2023 to 31st December 2024. Data was analysed retrospectively in respect of the incidence of burn deaths, age, sex, cause of death, place of death, and other relevant data.

Observation and Result: During the study period, 95(1.99%) burn death cases were recorded out of 4767 medico-legal autopsies conducted. Upon analysing the given data, it was observed that the most common age group was 21 to 30 years of age, accounting for 32.63%, with a predominance of female mortality accounting for 53.68% of cases. Accidental burns were the most common manner of death, accounting for 77.89% and married people accounted for 78.94% of cases. The major cause of death was septicaemia(58.94%).

Keywords: Burn injuries, Accidental, Medicolegal autopsy, Septicaemia, Mortality.

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Introduction

Burn injuries are a major global health concern, causing an estimated 180,000 deaths annually, with over two-thirds occurring in low- and middle-income countries, especially in the African and South-East Asia regions[1]. According to the National Crime Records Bureau (NCRB), accidental death and suicides in India (ADSI) reports, 7,435 accidental burn deaths were reported across India in 2022, compared with 8,348 deaths in 2021 and 9,110 deaths in 2020. In Maharashtra, 778 accidental burn deaths were documented in 2022, with survivors often facing long-term disability, disfigurement and economic hardship[2].

Most victims are young adults, predominantly females and flame burn from domestic cooking are the leading cause[3]. Rural areas bear a higher burden due to unsafe cooking practices, delayed treatment and limited burn care facilities[4].While accidental burns predominate, suicidal and dowry-related homicidal burns remain significant medico-legal issues in some regions[5].

Survival is closely linked to total body surface area (TBSA) burned, with mortality rising sharply beyond 40–60% TBSA in resource-limited settings[1]. Early deaths often result from inhalational injury and burn shock, whereas septicaemia is the leading cause of late mortality[6]. Burn injuries remain a major health issue in India due to poor facilities, high costs, unsafe domestic practices and a lack of awareness. Despite medical advances, extensive burns still carry high mortality and severe psychosocial and economic impact, highlighting the need for prevention, timely care, and expansion of specialized burn units[7].

This study identifies vulnerable groups and emerging trends in burn mortality, providing data to inform targeted prevention, more effective resource allocation and enhanced strategies to reduce burn-related deaths. A focused regional assessment is crucial for identifying vulnerable groups, patterns of mortality, and gaps in burn care services. Understanding the demographic and medico-legal profile of burn deaths in Solapur will provide evidence needed for targeted prevention, better resource planning, and improved clinical outcomes, thereby filling the existing knowledge gap.

Material and Method

This retrospective study was carried out on cases of death due to burns brought to the mortuary of the Department of Forensic Medicine and Toxicology, Dr. V.M.GMC, Solapur (Maharashtra) for medico-legal autopsies. The data in relation to age, sex, place of death, cause of death and manner of death due to burn was collected from the autopsy record register from 1st January 2023 to 31st December 2024. In our study, we included all the deaths due to flame burn injuries that were brought for autopsy at the tertiary care hospital, while cases of death due to burns other than flame burns were excluded from the study. Data was collected from the inquest report, postmortem report, and the investigating police officer. The data was analysed statistically.

Observation

During the study period, total of 95(1.99%) cases of death due to burns were recorded out of 4767 medico-legal autopsies. It was observed that the most common age group was 21 to 30 years (32.63%), followed by 31-40 years (22.10%) of age group. The extremes of the age group were least involved as compared to the adult age group. The gender wise distribution of the cases of death due to burn showed majority of cases were related to female(53.68%) as compared to male(46.31%)(Table no.1). Married people accounted for 78.94% of the death due to burns, followed by unmarried people (11.57%) (Table no.2). Regarding the cause of death, most of the victims died of septicaemia (58.94%), followed by primary shock (41.05%). (Chart no.1 and Table no.3). Accidental burns (77.89%) were the most common manner of death, followed by suicide (22.10%). (Table no.4). The majority of hospitalized patients (30.52%) survived for 5-7 days, followed by 3-5 days (27.36%) and 1-3 days (20%), indicating that most deaths occurred within the first week of admission, which was 74 (77.89%). Only a small proportion (3.15%) survived beyond one month, suggesting a generally poor prognosis and highlighting the severity of

illness at presentation (Chart no.2). Among 95 burn cases, the majority (43.15%) had 50–59% TBSA burns, followed by 70–79% (24.21%) and 60–69% (11.57%). Burns involving <40% and 40–49% TBSA were less frequent (5.26% and 9.47%), while >80% burns occurred in 6.31%. Severe burns (>50% TBSA) were mainly seen in young adults (21–40 years), indicating this group's higher vulnerability to extensive burn injuries(Table no.5).

Table No. 1. Age and gender wise distribution of cases of death due to burns

Age in years	Male	Female	Total (%)
0-10	03	02	05 (5.26%)
11 to 20	02	03	05(5.26%)
21-30	15	16	31 (32.63%)
31-40	09	12	21 (22.10%)
41-50	05	09	14 (14.73%)
51-60	04	04	08 (8.42%)
61-70	04	04	08 (8.42%)
71- above	02	01	03(3.15%)
Total	44 (46.31%)	51 (53.68%)	95 (100%)

Table No. 2. Marital status of burn death cases

Marital status of burn death cases			
Marital status	**Male**	**Female**	**Total**
Married	34	41	75 (78.94%)
Unmarried	05	06	11 (11.57%)
Widow/Widower	05	04	09 (9.47%)
Total	44 (46.31%)	51 (53.68%)	95 (100%)

Table No. 3. Cause of death of burn death cases

Cause of death of burn death cases in the year (2023)			
Cause of death	**male**	**Female**	**total (%)**
Primary shock	20	19	39 (41.05%)
Septicaemic shock	24	32	56 (58.94%)
Total	44 (46.31%)	51 (53.68%)	95 (100%)

Chart No. 1: Cause of death of burn death cases

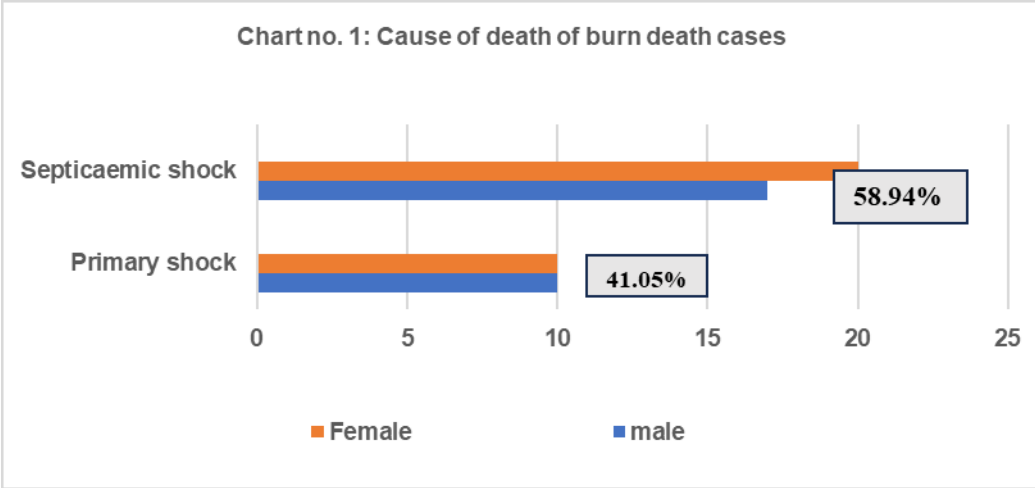


Table No. 4. Manner of burns

Manner of Burns			
Type of burns	**Male (%)**	**Female (%)**	**Total**
Accidental burns	35(36.84%)	39 (41.05%)	74 (77.89%)
Suicidal burns	09 (9.47%)	12 (12.63%)	21 (22.10%)
Homicidal burns	00	00	00 (00 %)
Total	44 (46.31%)	51 (53.68%)	95(100%)

Chart No. 2. Survival period in hospitalized cases

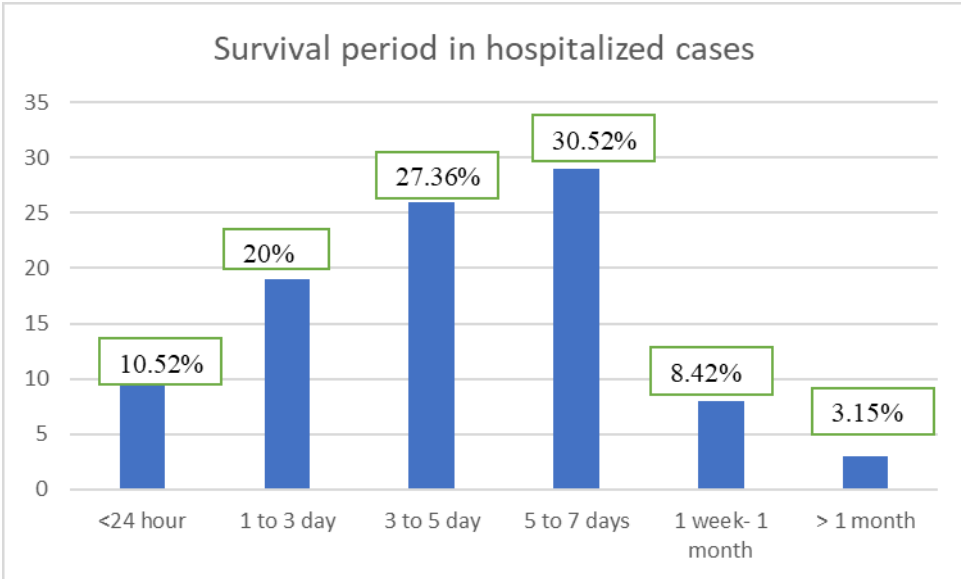


Table No. 5. Age-wise involvement of total body surface area burnt leading to death

Age group	% of burns						
	<40%	**40-49%**	**50-59%**	**60-69%**	**70-79%**	**>80%**	**Total**
0-10	00	00	03	00	01	01	**05**
11 to 20	01	00	02	00	02	00	**05**
21-30	02	02	13	02	09	03	**31**
31-40	01	03	07	06	04	00	**21**
41-50	01	02	05	03	02	01	**14**
51-60	00	01	04	00	02	01	**08**
61-70	00	01	04	00	03	00	**08**
>=71	00	00	03	00	00	00	**03**
Total	**05(5.26%)**	**09(9.47%)**	**41(43.15%)**	**11(11.57%)**	**23(24.21%)**	**06(6.31%)**	95 (100%)

Discussion

In the present study, the 21–30year age group was most commonly affected, accounting for 32.63% of cases. These findings are consistent with a study conducted by Khan RN et al (47.1%)[4] and Chaudhari KR et al (41.12%)[8]. However, a study conducted by Junaidi KA et al[9]observed more cases of death due to burns (52.9%) in the 21-30 years of age group. This highlights the vulnerability of young adults, particularly women, who are at increased risk of exposure to domestic fire hazards due to marriage and household responsibilities.

In the present study, burn-related mortality was higher among females (53.68%) than among males (46.31%). Similar findings were observed by NayakMetal[10], who observed a higher proportion of female deaths (64.25%) compared to male (35.75%). Other study also observed female preponderance in death due to burns like study by Bhansali C et al[11] which showed 72.36% of female died due to burns compared to male (27.63%), while study by Chaudhari KR et al[8]which observed78.33% of female died due to burns compared to male(21.67%). Similarly, study conducted by Zanjad N.P and Godbole H.V[12] which observed 75.3% of female died due to burns compared to male (24.7%), but the percentage of female death due to burns varies in percentage. The predominance of female victims highlights the continued vulnerability of women, particularly in domestic settings where open-flame cooking remains common.

In our present study, married individuals accounted for 78.94% of burn-related deaths, followed by unmarried individuals, 11.57%. The study conducted by Chaudhari KR et al[8] and NayakM et al[10] observed similar findings, which showed rates of 76.11% and 64%, respectively, among married individuals.Married women are primarily involved in cooking and household activities, increasing their exposure to open flames. Sociocultural issues such as dowry-related harassment may further elevate risk.

Regarding the cause of death, our study findings observed that most of the victims died of septicaemia (58.94%), followed by primary shock (41.05%).This is consistent with the findings of the study of Goudar BV et al[13] which observed that 58.11% of all deaths were due to septicemic shock, whereas 41.89% were due to hypovolemic shock. The findings in the study by Devasahayam G[14]are in contrast with the present study, which showed in majority of cases, the cause of death was burns shock (83.15%) and septicaemia (16.85%).Mortality variation reflects care quality—timely resuscitation

reduces early shock deaths but increases late sepsis, while poor care leads to early shock mortality before sepsis develops.

In this study, accidental burns (77.89%) were the most common manner of death, followed by Suicidal (22.10%) which shows consistent trends with other studies conducted by Zanjad N.P and Godbole H.V[12]also observed accidental burn (75.9%) followed by suicidal burn (20.2%) and our findings are also similar to the study of Varghese A and Joshi R[15] in which majority of the cases had accidental burns (89.4%), followed by suicidal (10.6%).The reasons for predominance of accidental burns may be due to unsafe cooking practices, open flames and poor fire safety awareness, especially in rural, low-income homes while suicidal burns relate to psychosocial stress, marital discord and dowry issues among young women.

The majority of deaths (77.89%) due to burns occurred within a week of the incident. During this period, the maximum number of deaths occurred within 5-7 days (30.52%) followed by 3-5 days (27.36%) which is consistent with study of Goudar BV et al[13]which showed67.57% of the deaths occurred in the first 7 days of admission and Bhansali Cet al[11] where 75% of the patients died within 5 days and 90% of the patients died within 8 dayswhereas in the study of Chaudhari KRet al[8],maximum number of victims, 64 cases (35.56%), survived for 3-7 days after getting burns. Most deaths occurred within the first week due to severe burn shock and inhalation injury, while later deaths in survivors were mainly from sepsis.

In the present study, most burn victims sustained extensive injuries, with 43.15% had50–59% TBSA burns and another 42.09% showed involvement above 50% TBSA which is consistent with study of Singh D.et al[3] who observed that over 88% of fatal burns involved more than 50% TBSA, while Zanjad N.P and Godbole H.V[12] observed that 75.1% of victims had burns over 60% TBSA, underscoring the lethality of high-percentage burns highlighting the continuing high mortality associated with extensive burns in India, emphasizing the need for early intervention, improved burn care facilities and targeted preventive strategies to reduce burn incidence and fatalities.

Conclusion

Most burn injuries were accidental in nature, with married individuals were found to be more vulnerable. A significant proportion of deaths occurred within the first week of the incident, with septicemia was the leading cause of mortality. To address this, an effective burn prevention program must be developed and implemented, focusing on high-risk groups and populations.

Raising awareness about the severity and potential lethality of burn injuries, educating people on safe cooking practices and personal preventive measures and encouraging early reporting of burn cases to advanced healthcare centers for timely and effective treatment.

Though this study had certain limitations, as the retrospective data from autopsy and hospital records lacked clinical and socioeconomic details. Only fatal medico-legal cases were included; nonfatal burn outcomes were not assessed—single-centre study, limiting broader applicability.

Fora comprehensive understanding of burn outcomes, we should conduct prospective, multi-centre studies incorporating clinical, social, and psychological variables and also by examining socioeconomic and environmental factors contributing to burn injuries, especially among high-risk groups like women and young adults. Evaluate the impact of public health interventions, fire-safety programs, and improvements in burn-care facilities.

Ethical Approval: As this is a retrospective study, ethical approval was not obtained. The data was kept confidential, and no harm was done to any individual.

Conflict of Interest: None.

Source of Funding: None.

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Socio-Demographic Profile, Manner and cause of Death in Medico-legal Autopsy Casesat a Tertiary Care Teaching Hospital in South Bengaluru: A Retrospective Analytical Study

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Abstract

Background: Medico-legal autopsies provide important epidemiological insights into patterns of unnatural and sudden deaths. South Bengaluru, characterized by rapid urbanization, industrial expansion, and heavy highway traffic, and a large migrant workforce, represents a dynamic setting where mortality profiling is essential for forensic, legal, and preventive strategies.

Objectives: To analyse the socio-demographic profile, manner and cause of death, seasonal distribution, and gender-based associations among medico-legal autopsy cases conducted at a tertiary care teaching hospital in South Bengaluru.

Materials and Methods: A retrospective analytical study was conducted on 769 medico-legal autopsies performed between January 2024 and December 2025 using universal sampling. Data were extracted from post-mortem reports, hospital records, and investigative records. Descriptive statistics were calculated. Associations between gender and suicidal death and road traffic accident (RTA) death were assessed using Chi-square test. Odds Ratios (OR) with 95% confidence intervals (CI) were computed. Multivariate logistic regression adjusted for age group.

Results: Males constituted 83.7% of cases (male-to-female ratio 5.2:1). The most affected age group was 21–30 years (26.5%). Accidental deaths (32.8%) and natural deaths (32.0%) were nearly equal in proportion, followed by suicides (25.5%). Road

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traffic accidents accounted for 23.7% of all deaths. Hanging constituted 83.1% of suicides. Females demonstrated higher proportional odds of suicidal death (OR 3.90; 95% CI 2.62–5.80; p<0.001), while males had higher odds of RTA death (OR 2.19; 95% CI 1.29–3.70; p=0.003). Associations remained significant after age adjustment.

Conclusion: Young adult males form the largest share of medico-legal mortality. Significant gender-based differences were observed in suicide and RTA deaths. The findings underscore the need for targeted preventive and road safety interventions in rapidly urbanizing regions.

Keywords: Autopsy, Medico-legal, Road Traffic Accidents, Suicide, Hanging, Seasonal Variation, Odds Ratio, South Bengaluru.

Introduction

Medico-legal autopsy is a fundamental component of forensic investigation, enabling determination of cause and manner of death while contributing to regional mortality surveillance. Beyond its legal function, autopsy-based data provide insight into demographic vulnerabilities and evolving public health challenges.

Globally, non-communicable diseases account for nearly three-quarters of deaths, while injuries contribute substantially to premature mortality.[1] In India, road traffic accidents remain a major public health concern, with over 1.7 lakh fatalities reported in 2023.[2] The Ministry of Road Transport and Highways identifies increasing vehicular density and over-speeding as key contributors.[3] Sudden natural deaths, particularly cardiovascular causes, also form a significant portion of medico-legal autopsy workloads.[4] The India State-Level Disease Burden Initiative has documented a rising burden of non-communicable diseases in Karnataka.[5]

South Bengaluru is characterized by rapid industrialization, expanding highway corridors, and a large migrant workforce. Despite this dynamic socio-economic landscape, limited recent analytical autopsy data are available from this region. The present study was undertaken to analyse the socio-demographic profile, manner and cause of death, seasonal distribution, and gender-based associations among medico-legal autopsies conducted at a tertiary care teaching hospital in South Bengaluru.

Materials and Methods

Study Design and Setting

Retrospective record-based analytical study conducted in the Department of Forensic Medicine at a tertiary care teaching hospital in South Bengaluru.

Study Period: 1st January 2024 to 31st December 2025.

Ethical Approval

Approved by the Institutional Ethics Committee. Individual consent was waived due to anonymized retrospective data.

Sampling: Universal sampling was adopted. All eligible medico-legal autopsies with complete documentation during the study period were included.

Inclusion Criteria: Autopsies with complete records of age, sex, and manner of death.

Exclusion Criteria: Cases with incomplete key documentation.

Data Collection: Data were extracted from post-mortem reports and investigative records using a structured proforma. Variables included age, sex, month and season, jurisdiction, manner of death, and cause of death.

Classification: Manner of death was categorized as natural, accidental, suicidal, homicidal, or undetermined based on autopsy findings and available investigative information.

Statistical Analysis: Data were analysed using SPSS version 30.

- Descriptive statistics were expressed as frequencies and percentages.

- Associations between gender and suicidal death and RTA death were tested using Chi-square test.
- Odds Ratios (OR) with 95% Confidence Intervals (CI) were calculated.
- Exact p-values were reported.
- Multivariate logistic regression models adjusted for age group.
- $p<0.05$ was considered statistically significant.

Results

A total of 769 medico-legal autopsies were performed.

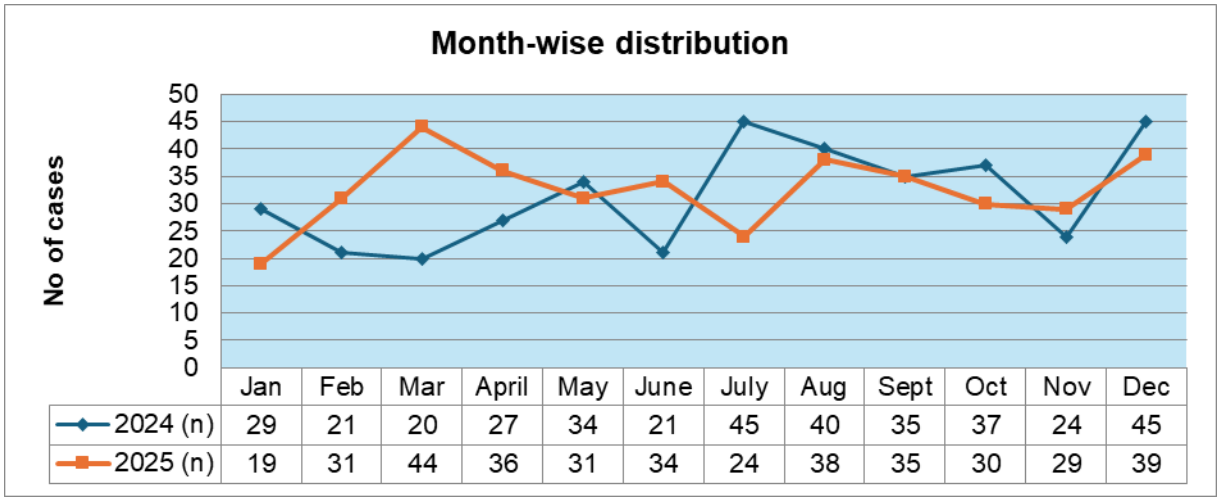
Socio-Demographic Profile

Males constituted 644 cases (83.74%) and females 125 cases (16.26%), yielding a male-to-female ratio of approximately 5.2:1.

The 21–30 year age group was most affected (26.53%), followed by 31–40 years (24.84%). Individuals aged 21–50 years constituted 74.25% of cases.

Seasonal Distribution

Monsoon months accounted for 35.4% of cases, followed by post-monsoon (26.5%), summer (25.0%), and winter (13.0%). These represent observational distribution patterns within the study period.



	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2024 (n)	29	21	20	27	34	21	45	40	35	37	24	45
2025 (n)	19	31	44	36	31	34	24	38	35	30	29	39

Figure 1: Month-wise distribution of autopsy cases (2024-2025)

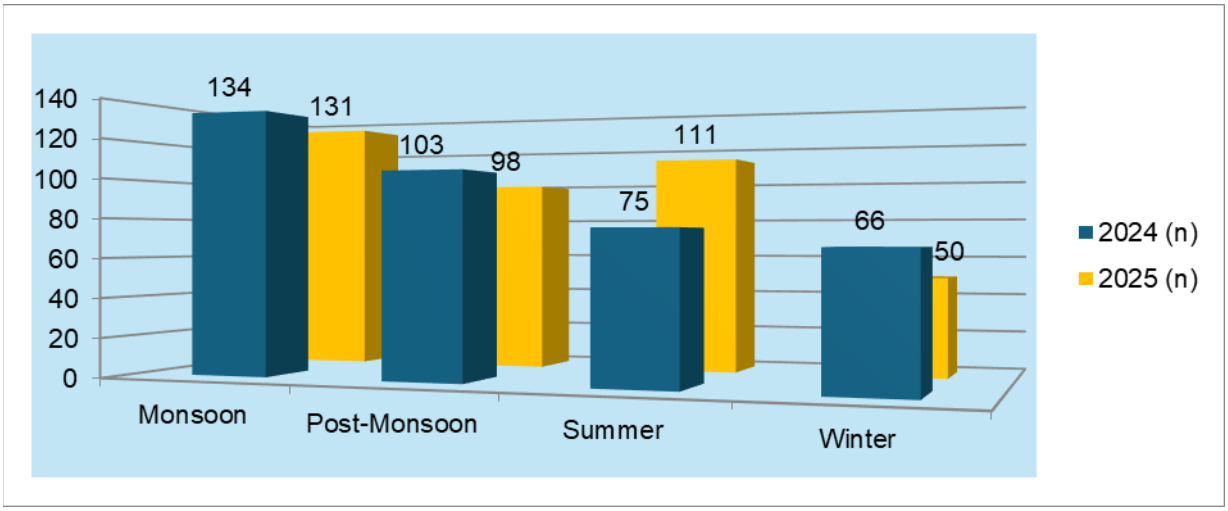


Figure 2: Season-wise distribution of autopsy cases (N=769)

Manner of Death

Table No. 1. Manner of Death

Manner	Number	Percentage
Accidental	252	32.8%
Natural	246	32.0%
Suicidal	196	25.5%
Homicidal	38	4.9%
Undetermined	37	4.8%

Cause of Death

Accidental Deaths (32.8%)

- Road Traffic Accidents : 182 (23.7%)
- Fall from height : 32 (4.2%)
- Drowning : 28 (3.6%)
- Electrocution : 8 (1.0%)

Suicidal Deaths (25.5%)

- Hanging : 163 (83.1% of suicides)
- Self-poisoning : 33 (16.9%)

Natural deaths were predominantly cardio-vascular in origin.

Gender Associations

Gender and Suicidal Death

Table 2. Association Between Gender and Suicidal Death (N = 769)

Gender	Suicidal n (%)	Non-Suicidal n (%)	Total (n)
Male	133 (20.7%)	511 (79.3%)	644
Female	63 (50.4%)	62 (49.6%)	125
Total	**196 (25.5%)**	**573 (74.5%)**	**769**

OR = 3.90 ; 95% CI: 2.62–5.80 ; $p < 0.001$

Females demonstrated significantly higher proportional odds of suicidal death within the medico-legal autopsy dataset. After age adjustment, the association remained statistically significant.

Although males accounted for a higher absolute number of suicide deaths, suicide constituted a larger proportion of medico-legal deaths among females in this hospital-based population.

Gender and RTA Death

Table 2. Association Between Gender and Road Traffic Accident (RTA) Death (N = 769)

Gender	RTA n (%)	Non-RTA n (%)	Total (n)
Male	165 (25.6%)	479 (74.4%)	644
Female	17 (13.6%)	108 (86.4%)	125
Total	**182 (23.7%)**	**587 (76.3%)**	**769**

OR = 2.19 ; 95% CI: 1.29–3.70 ; $p = 0.003$

Males had significantly higher odds of RTA death compared to females. The association persisted after age adjustment.

Discussion

This study demonstrates a marked male predominance in medico-legal autopsies, consistent with previous Indian tertiary centre reports.[6–13] The majority of deaths occurred in economically productive age groups, reflecting substantial societal impact.

Accidental deaths formed the largest category, with road traffic accidents predominating. This aligns with national data from the National Crime Records Bureau and the Ministry of Road Transport and Highways. Male gender showed independent association with RTA mortality.

Suicides accounted for one-fourth of cases, with hanging as the leading method. While males formed the majority in absolute terms, females showed higher proportional odds of suicide within autopsy cases. These findings highlight gender-specific patterns within medico-legal mortality.

The higher proportional representation of suicide among females in the autopsy dataset may be attributed to gender-specific vulnerabilities rather than absolute incidence alone. Recent Indian

evidence indicates that young women experience a substantial burden of suicide, often linked to sociocultural stressors such as domestic conflict, marital issues, and economic dependency. In contrast, males are more frequently represented in other medico-legal deaths such as road traffic injuries, which reduces the relative proportion of suicide among them.[14,15]

Natural deaths constituted nearly one-third of cases, predominantly cardiovascular in origin, reflecting the growing burden of non-communicable diseases documented in national health reports.[4,5]

Homicidal deaths (4.9%) and undetermined cases (4.8%) formed smaller but consistent components of the autopsy workload. Jurisdictional analysis revealed a concentration of cases from industrial and highway corridors, particularly Attibele and Sarjapura, highlighting the medico-legal burden in rapidly urbanizing zones. The presence of unidentified individuals among the caseload underscores the socio-economic and migratory dynamics of the region.

Seasonal variation represented distributional patterning during the study period; causal inference cannot be established due to the retrospective design.

Limitations

- Single-centre, hospital-based design limits generalizability.
- Autopsy data do not represent population mortality rates.
- Retrospective methodology may introduce documentation bias.
- Possible misclassification of manner of death.
- Absence of detailed toxicological and psychosocial correlation

Conclusion

Medico-legal mortality in South Bengaluru is predominantly observed among young adult males. Accidental and natural deaths contributed nearly equal proportions, with road traffic accidents and hanging forming the leading causes of unnatural death. Significant gender-based differences were observed in suicide and RTA mortality. These findings highlight the need for strengthened road safety enforcement and targeted preventive strategies in rapidly urbanizing regions.

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- Declaration of conflicts of interest: None

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