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Contents

Case Study

Crime Scene Reconstruction from Analysis of Injuries in a Case of Self-Inflicted Fatal Gunshot Injury: A Case Report

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Abstract

Firearm suicides, though less common than poisoning and hanging in India, have been increasing due to rising gun availability and insufficient mental health evaluations in firearm licensing. This case report examines the wound ballistics of a 45-year-old security officer who died from a self-inflicted gunshot wound to the forehead at one of the Sessions Court, Kolkata. Autopsy findings revealed a hard-contact gunshot wound with a stellate entry laceration, muzzle imprint, soot deposition, and characteristic skull fractures, including inward beveling at the entry site and outward beveling at the exit. The bullet passed through the brain, causing severe trauma, including deep bruising and bleeding, which led to a fatal buildup of pressure inside the skull. The presence of cadaveric spasm and the CCTV footage supported the conclusion of suicide. This case highlights the forensic significance of wound ballistics in reconstructing firearm-related deaths, distinguishing between contact, close-range, and distant gunshot wounds, and establishing the manner of death through ballistic analysis and forensic medicine, and pathology.

Keywords: Firearm suicide, wound ballistics, contact gunshot wound, forensic pathology, case report.

Introduction

Suicide is a complex issue influenced by biological, psychological, social, and environmental factors, affecting individuals of all ages and leaving a lasting impact on those left behind[1]. Contributing factors include stress, depression, academic struggles, relationship issues, substance abuse, financial problems, and chronic pain[2]. Globally, suicide rates have returned to their peak since 2022, with over 49000 reported cases of suicide and 1 death every 11 minutes[3]. According to National Crime Records Bureau (NCRB) data, the national suicide rate stood at 12.4 per lakh, while it has been reduced to 9.87 per lakh in 2024[4]. It is particularly concerning among young adults aged 15-49, making up 4.8% of female deaths and 5.7% of male deaths[5]. Most suicides (84%) occur in low- and middle-income countries (LMICs), with India and China alone accounting for 49% of cases[6]. In India, suicide is most common among people aged 20-29, with females having higher rates under the age of thirty, but the trend reverses after the age of thirty[4].

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While poisoning and hanging remain the most common suicide methods in India, deaths due to suicidal firearm injuries are rising, with gunshot fatalities making up 5% of intentional firearm injuries, mostly in the 21-40 age group[7]. Increased gun availability, the lack of mental health checks in licensing, financial stressors, and the shift to nuclear families contribute to this trend[8]. In most cases, victims target vital areas, with 71.43% of gunshot suicides affecting the head and neck and 28.57% the trunk[9].

Case Report

On one fine morning of February 2025, at approximately 07:00 hrs., police personnel received information about an incident at one of the Sessions Court premises in Kolkata. Upon arrival, officers discovered a 45-year-old male seated on a chair in a pool of blood. He was immediately referred to the emergency department of Medical College and Hospital, Kolkata, where he was declared dead by the on-duty medical officer. Arrangements were made for a post-mortem examination to reconstruct the sequence of events and determine the cause of death.

Examination Findings:

On external examination:

1. An average-built and nourished male subject wearing apparel stained by dried blood and dust in places. There were no ammunition holes present on the wearing apparel. Thick, blackish clotted blood coming out from the wound to the right side of the forehead to the upper helix, clotted blood dribbling right cheek to the right side of the neck. Blood clots were also present around the nostrils, coming down to the right side of the lower lip, up to the chin.
2. Postmortem staining was distributed over the lower portion of the upper limbs and the lower portion of the lower limbs. Both hands were in a state of cadaveric spasm.
3. One cruciate entry wound at middle of forehead measuring 2″ x 2″ with a bony gap of 0.5″ at the frontal bone of the skull, lower border 1.2″ above the fronto-nasal junction and upper end 1″ above an imaginary line connecting to frontal eminence, with brain matter noted at the entry wound, blackish abrasion collar with blacking of skin noted with a circular hole measuring 0.5″ x 0.5″, 1.5″ above glabella.
4. Cruciate-shaped exit wound at the middle of the occipital bone, 7″ below the external occipital protuberance.

On internal examination:

There is an extraduralhemorrhage just below the frontal bone with a global subdural hemorrhage. The tract of the bullet wound diverges through the structure of the brain between two cerebral hemispheres towards the exit wound, and on the right cerebral hemisphere, on the back, is associated with cerebral contusion.

Fracture of both tables of skull bone with separation of coronal sutures, with separation of the anterior one-third of the sagittal suture. One of the most notable features is the presence of soot deposition and a muzzle imprint on the skin's surface caused by the high-pressure gases expelled from the firearm upon discharge. These gases often cause stellate lacerations around the wound, particularly in areas with tight skin, such as the forehead or scalp. The interaction of the bullet with the skull results in specific fracture patterns.

At the point of entry, the skull commonly displays inward beveling, where the outer table remains relatively intact while the inner table exhibits coning due to the forceful penetration of the projectile. If the projectile has a high velocity, the bone may fragment significantly, creating secondary missiles that can cause further damage to brain tissue. The extent of soft tissue damage in contact gunshot wounds is also significant. The passage of the bullet through the brain creates both a temporary and a permanent cavity, with the temporary cavity expanding rapidly due to the energy transfer from the projectile.

However, since the brain is enclosed within the rigid skull, its expansion is limited, resulting in increased intracranial pressure and secondary brain injuries. The negative pressure effect of cavitation can also draw in external elements such as skin, hair, or fabric into the wound. Another key forensic phenomenon in close-range shootings is "back spatter," where blood and tissue are expelled backward against the direction of fire, sometimes depositing on the shooter or firearm.

Additionally, the extreme intracranial pressure caused by the bullet's force can severely impact the brainstem, often leading to immediate fatality. In contact gunshot injuries, there is disruption of underlying tissues, as discussed, due to expansile gases, and intact underlying structures are rarely found, however, the case discussed below exhibited an unusual finding of intact internal tissue structure despite it being a contact gunshot wound. The forensic characteristics of the gunshot wound were notable. The presence of soot deposition and a distinct muzzle imprint on the forehead indicated a hard-contact firearm discharge. Stellate lacerations formed due to high-pressure gases expelled into the tight skin of the forehead. The skull exhibited inward beveling at the entry site and outward beveling at the occipital exit, consistent with the expected bullet trajectory. Interestingly, despite being a contact wound, internal brain structures were relatively preserved, which is uncommon in such cases. Additionally, evidence of "back spatter" was noted, with blood and tissue deposited in the reverse direction of fire, a feature often seen in close-range shootings.

All relevant evidence, including biological samples, was collected and forwarded for forensic examination.

Discussion

An analysis of the peer-reviewed literature reveals a lack of recent articles examining the survival time and physical activity following gunshot wounds, even though a careful determination of these can be crucial in reconstructing a crime[10]. It is necessary to interpret the injuries of the deceased to determine the probable sequence of events, particularly in cases with conflicting evidence and testimony[11]. Following a complete autopsy, the cause of death, as determined by the forensic pathologist, was attributed to the injury sustained due to a gunshot wound to his forehead. As stated by the investigating officer, a pistol was found under the chair in front of him, along with one discharged and disfigured bullet nearby. However, a closer observation as to the general description of the dead body and the pattern of injuries was made as follows: The gunshot to the head entered through the mid-frontal region of the scalp and exited through the occipital region, almost in the midline but with a propensity more towards the left side. The entrance wound, as depicted, was a stellate-shaped laceration with a prominent muzzle impression and without any abrasion collar, grease collar, contusion collar, or tattooing- indicative of a hard contact shot.

i. The exit wound, at the back of the head, was a roughly oval defect with beveling on the outer table of the skull.

ii. Evidence of back spatter and the blowback phenomenon.

iii. Typical distribution of hypostasis only over the upper and the lower limbs.

iv. Evidence of cadaveric spasm noted in both hands.

If an analysis from the above observations is made, the victim has allegedly held the firearm in both the hands and pulled the trigger using both the thumbs (observation no. iii and observation no. v), while being seated on a chair, pressing the muzzle end of the firearm quite hard to the skin surface (observation no. i). As to observation no. iv) The victim has dropped down the firearm, following discharge, with both hands hanging by the sides of the chair.

Research on firearm types used in suicides shows no major difference between rifles, shotguns, and handguns in terms of range[12]. However, 96% of firearm suicides involve contact wounds, meaning the gun is pressed directly against the skin[13]. Injuries to the head are more common with handguns and rifles than with shotguns[12].

Fig 1: Place where the body was discovered

Fig 2: Blood of the deceased due to the firearm injury along with the firearm and cartridge

Fig 3: Entry wound over the forehead as per the autopsy report

Fig 4: Exit wound over the occipital region as per the autopsy report

Fig 5: Back spatter over the dorsal aspect of the right hand

Fig 6: Deceased at the crime scene

Unique Findings:

This case presented several unusual yet significant forensic findings that merit emphasis. While contact gunshot wounds to the head typically result in extensive disruption of both soft and hard tissues, this case revealed a surprising preservation of internal brain structures, despite the hard-contact nature of the shot. Such conservation is rare and underscores the variability in wound dynamics even within standard ballistic scenarios. The presence of back spatter and the pattern of blood distribution further align with forensic expectations in a contact-range gunshot wound, reinforcing the reconstruction's reliability.

Moreover, the availability of CCTV footage documenting the incident provided a rare opportunity to correlate forensic findings with real-time actions, enhancing the evidentiary strength of the conclusions drawn. These combined elements make this case a valuable reference for forensic pathologists and crime scene investigators in distinguishing between suicidal and homicidal gunshot wounds. A subsequent inquiry revealed that the deceased had been on night duty, and his body was discovered in the morning when another officer arrived to clear the area. Reviewing CCTV footage provided crucial insights into the incident. The footage showed the officer sitting down, removing his glasses and mobile phone, placing them beside him, then drawing his firearm, positioning it against his forehead, and pulling the trigger. The bullet passed through his forehead and struck the wall behind him, where it was later recovered. Blood was present at the scene, and the total ammunition found included 12 bullets in his belt and seven in the pistol's magazine, in addition to the discharged bullet.

Forensic pathologists who perform autopsies in gunshot cases may be asked to determine the bullet trajectories in the body to elucidate the circumstances of an unnatural death following a gunshot injury and answer questions about the range of fire, the order of shots fired, and the relative position of the victim at the crime scene. Thus, it is necessary for the forensic pathologist to objectively analyze the pattern of injury to testify whether the witnesses' testimonies are consistent with the scene, evidence, and autopsy findings.

Conclusion

This case underscores the critical role of comprehensive forensic analysis in confirming the manner of death in firearm-related fatalities. The autopsy findings, supported by scene examination and cadaveric evidence, were consistent with a self-inflicted contact gunshot wound. Unique forensic markers such as the presence of rigor mortis, external gunshot residue, and intact internal structures

despite a contact wound offered rare insights into the wound dynamics.

The case further emphasizes the need for psychological evaluation in firearm licensing and highlights the value of integrating forensic pathology with crime scene reconstruction. The findings advocate for continued education on wound ballistics among forensic professionals and point toward the necessity for standardized protocols when distinguishing between homicidal and suicidal gunshot injuries. Future studies may focus on expanding the database of wound characteristics correlated with CCTV-supported suicides to refine diagnostic accuracy.

Conflict of Interest: The authors have no conflict of interest in this case report.

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Consent: Written informed consent for publication of clinical details, post-mortem findings, and images was obtained from the autopsy surgeon, investigating police personnel, and the patient's relative.

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References

1. World Health Organization. Preventing suicide: a global imperative. Geneva: WHO; 2014.
2. Beautrais AL. Risk factors for suicide and attempted suicide among young people. Aust N Z J Psychiatry. 2000;34(3):420–36.
3. World Health Organization. Suicide worldwide in 2019: global health estimates. Geneva: WHO; 2021.
4. National Crime Records Bureau. Accidental Deaths & Suicides in India 2024. New Delhi: Ministry of Home Affairs; 2025.
5. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019. Seattle, WA: Institute for Health Metrics and Evaluation (IHME); 2020.
6. Patel V, Ramasundarahettige C, Vijayakumar L, et al. Suicide mortality in India: a nationally representative survey. Lancet. 2012;379(9834):2343–51.
7. Sharma BR, Harish D, Sharma A, et al. Suicidal firearm fatalities in Northern India. J Forensic Sci. 2008;53(5):1105–8.
8. Karp A. Small Arms Survey 2007: Guns and the City. Cambridge: Cambridge University Press; 2007.
9. Saukko P, Knight B. Knight's Forensic Pathology. 4th ed. CRC Press; 2015.
10. DiMaio VJM. Gunshot wounds: practical aspects of firearms, ballistics, and forensic techniques. 3rd ed. CRC Press; 2016.
11. Spitz WU, Spitz DJ. Spitz and Fisher's Medicolegal Investigation of Death. 5th ed. Charles C Thomas Publisher; 2006.
12. Rao D. Essentials of Forensic Medicine and Toxicology. 35th ed. Jaypee Brothers Medical Publishers; 2017.
13. Shkrum MJ, Ramsay DA. Forensic Pathology of Trauma: Common Problems for the Pathologist. Totowa, NJ: Humana Press; 2007.

Case Study

Unraveling the Consequences; Methotrexate Induced Abnormal Uterine Bleeding: A New Case Report

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Abstract

A 49-year-old female patient was admitted in a tertiary care hospital with complaints of heavy menstrual bleeding and breathlessness on exertion and fatigue. The personal history was 15-20 pads/day fully soaked/ clots+ 5-6 days. She had past medical history of Rheumatoid Arthritis for 2 years and was taking Disease- Modifying Antirheumatic Drugs (DMARDs). Ultra sound abdomen showed bulky uterus. Due to improper dosing and monitoring of DMARDs ,it led to alteration in progesterone/ estrogen levels, resulting in abdominal uterine bleeding. Plan of care was primarily to withhold DMARDs, and perform Hysteroscopy guided with Polypectomy, D and C (dilation and curettage). At the time of discharge the patient was stable and wanted to consult rheumatologist outside.

Keywords: DMARDs, Abdominal Uterine Bleeding, Hysteroscopy, Polypectomy, Rheumatoid Arthritis.

Introduction

Abnormal Uterine Bleeding (AUB) is a broad term that defines irregularities in menstrual cycle including frequency, regularity, duration and volume of flow outside of pregnancy. A normal menstrual cycle lasts 2 to 7 days with 5 to 80 millimeters of blood loss of frequency about 24 to 38 days. differences in any of these parameters constitute Abnormal uterine bleeding.

In 2011 the Federation International de Gynecologie et d'Obstetrique (FIGO) described etiology of AUB with the help of acronym PALMCOEIN. PALM represents structural causes: Polyp, Adenomyosis, Leiomyoma, Malignancy. COIEN represents non- structural causes: Coagulopathy, Ovulatory disorders, Endometrial, Iatrogenic and Not otherwise classified. Any structural derangement in uterus, or to the clotting pathways or disruption of the hypothalamic-pituitary- ovarian axis can affect menstruation which lead to AUB.[1,2,3]

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Disease- Modifying Antirheumatic Drugs (DMARDs) are class of drugs used for the treatment of especially inflammatory arthritis including Rheumatoid Arthritis, Psoriatic arthritis, Ankylosing Spondylitis and also for connective tissue diseases like Systemic Sclerosis, Systemic Lupus Erythematosus, Sjogren Syndrome. Mostly used conventional DMARDs include Methotrexate, Leflunomide, Hydroxychloroquine and Sulfasalazine. Biological agents include Infliximab, Adalimumab, Etanercept, Rituximab, Abatacept, Tocilizumab, Tofacitinib.[4]

Here we are reporting a case of wrong dosage form and monitoring of DMARDs induced Abdominal Uterine Bleeding with endometrial polyp followed by severe anemia.

Case Report

A49 year old female patient was admitted to Obstetrics and Gynaecology department with the complaints of fatigue, heavy menstrual bleeding and breathlessness on exertion. She had an OBG history of three full term normal vaginal delivery and last child birth was 30 years back. Her menstruation history for the last 2 to 3 months was 15- 20 pads per day fully soaked with clots about 5 to 6 days. The patient had past medical history of Rheumatoid Arthritis for 2 years, and managed with T. METHOTREXATE 10mg P/O 1-0-1, T. HYDROXYCHLOROQUINE 400mg P/O 1-0-0, T. CEFEXIME 200mg P/O 1-0-0, T. CALCIUM + VITAMIN D 500mg P/O 1-0-0, T. METHYL PREDNISOLONE 4mg P/O 1-0-0, T. LEFLUNOMIDE 20mg P/O 0-0-1, T. PANTOPRAZOLE 40mg P/O 1-0-0.

The patient was conscious, oriented with pallor, heart sounds were heard, chest was clear, was able to move all limbs and GI was non-tender. During admission, she had a Pulse Rate of 72 beats/min, Respiratory Rate of 20 breaths/min, Blood Pressure of 120/80mmHg. Her laboratory investigation showed an elevation in RBC distribution width (21.4%), MCHC (25.6%), RBS (154mg/dL), Triglycerides (219mg/dL) and decline in Hemoglobin (6.5, 8.1g/dL), PCV (17.6%), RBS (2.07 million/cmm), Urea (10mg/dL), Serum Iron (10µg/dL), Transferrin Saturation (2.70%),. The liver parameters were Total Protein (5.9g/dL), T. Bilirubin (0.37mg/dL), D. Bilirubin (0.13mg/dL), I. Bilirubin (0.24mg/dL), AST (20U/L), ALT (24U/L), ALP (55.0U/L), Serum Albumin (3.4g/dL), Serum Globulin (2.4g/dL) Ultra sound abdomen and pelvis suggested bulky uterus with a focal solid cystic lesion in fundus of uterus close to endometrial cavity, diffuse mild fatty change in liver and diffuse thickening of wall of urinary bladder.

At first the patient's initial medication regimen was withheld. INJ. CEFOTAXIME SODIUM 1g IV 1-0-1 was given for prevention of infection, INJ. PANTOPRAZOLE 40mg IV 1-0-1 for prevention of gastric irritation, INJ. TRANEXAMIC ACID 500mg IV 1-0-1 for prevention of bleeding and T. MEFENAMIC ACID + DICYCLOMINE HYDROCHLORIDE 250mg/10mg P/O 1-0-1 for pain. On day 3, patient had undergone Hysreroscopy guided Polypectomy with D and C. For that INJ. METOCLOPRAMIDE HYDROCHLORIDE 10 mg IV was given for prevention of nausea, vomiting and INJ. MISOPROSTOL 400mg IV was given to soften the cervix. On day 2, 20 PRBC were given, on day 3, 30 PRBC were given, on day 4, 20 PRBC were given to treat severe anemic condition. Finally the patient was stable with no active bleeding but had C/O cough and was discharged with SYP. BROMHEXINE HYDROCHLORIDE + TERBUTALINE SULPHATE + GUAIPHENESIN + MENTHOL 5ml P/O 1-1-1, T. CEFIXIME 200mg P/O 1-0-1, T. PANTOPRAZOLE 40mg P/O 1-0-1 for 5 days, T. FERROUS ASCORBATE + FOLIC ACID P/O 1-0-0 for 30 days and C. B- COMPLEX FORTE + VITAMIN C P/O 0-1-0 for 7 days. Patient wanted to continue treatment of Rheumatoid Arthritis from outside and denied consultation from current hospital.

Discussion

Methotrexate is an FDA approved folic acid antagonist indicated for treatment of Rheumatoid Arthritis. Methotrexate toxicity occurs when the drug, commonly used in the treatment of various cancers, autoimmune diseases, and inflammatory disorders, reaches harmful levels in the body. This can result in a range of adverse effects due to its mechanism of inhibiting folic acid metabolism, which is essential for DNA synthesis and cellular division. Acute toxicity may manifest as gastrointestinal symptoms, such as nausea, vomiting, and diarrhea, while chronic toxicity can lead to more serious complications, including bone marrow suppression, liver damage, pulmonary

toxicity, and renal dysfunction. High doses or prolonged use of methotrexate can exacerbate these risks, making close monitoring of serum levels and organ function essential, especially in patients with pre-existing conditions or those taking other medications that affect renal or hepatic function. The onset of toxicity can be subtle and may require aggressive management, including drug cessation, folinic acid rescue therapy, or other supportive treatments. Preventive measures, such as proper patient education, routine monitoring, and dose adjustments, are crucial in minimizing the risk of methotrexate toxicity. Usual oral dose is as weekly as single dose or three divided doses over 8 hourly in 24 hours in a week. Folate supplementation with 1mg per day 5 to 7mg once weekly should be taken to prevent bone marrow suppression. The peak serum levels are achievable within 1 to 2 hours and oral absorption depends on dose taken. Methotrexate will affect in corpus luteum and results in less support in the production of progesterone leading to menstruation complication. The usual dosing is weekly once but here it was administered twice daily.[5,6]

Other drugs in DMARDs suppresses immune system and thereby results in abnormality for endocrine system.[7,8] T. CEFEXIME was unnecessary for Rheumatoid Arthritis[9]. The standard treatment for Rheumatoid Arthritis are shown in table 1.1[10,11]

Table 1: Treatment of Rheumatoid Arthritis

DRUGS	DOSE	MECHANISM	SIDE EFFECT	CONTRAINDICATION
DMARDS METHOTREXATE	Oral or IM 7.5-15mg/week	Inhibit cytokine production and purine biosynthesis and stimulate adenosine release all of which leads to inflammatory property.	Stomatitis Indigestion Nausea Vomiting	Pregnency, chronic liver diseases, leukopenia
LEFLUNOMIDE	Oral 100mg daily for 3 days then 10 – 20mg daily without loading dose	It inhibit pyramidine synthesis which reduces lymphocyte proliferation and modulation of inflammation.	Diarrhoea, Headache, Nausea, Leukopenia, Thrombocytopenia	Liver diseases,Pregnency
HYDROXY CHLOROQUINE	Oral 200-300 mg twice daily after 1-2 month may decrease to 200mg once or twice daily	Regulate the activity of immune system which may be over active in some condition it can modify the underline disease process rather than simply treaing symptoms	Rashes, Graying of hair, myopathy, neuropathy	Anaemia, low blood sugar, low amount of potassium, and magnesium
SULFASALASINE	Oral: 500mg twice daily, then the 1g twice daily	Work by the reducing swelling, this keep in reduce the symptoms of inflammatory condition like rheumatoid arthritis	Neutropenia, thrombocytopenia	Asthma, liver problem, G6PD Defiency
MINOCYCLINE	Oral:100-200mg daily	It inhibit metaloproteases active in damaging articular cartilage it may be an alternative for patient with mild diseases and without feature of poor prognosis	Photosensitivity Dizziness Vomiting Itching Diarrhoea	Pregnency, Lactation, decrease kidney function, liver diseases

TOFACTINIB	Oral: twice daily Oral XR: 11mg once daily	It is a JAK B and JAK 1 kinase inhibitor, interface with JAK-STAT signaling pathway and DNA transcription production of inflammatory mediators and release of cytokine is inhibited	Headache, insomnia, diarrhea, hypertension	Anemia, cancer
NSAIDS ASPIRIN	Adult 2.6-5.2g Children 60-100mg	It inhibit the activity of of the enzyme called cyclo oxygenase which leads to the formation of prostaglandin that causes swelling, pain, fever, inflammation	Heartburn, nausea, stomach, bleeding	Active bleeding, hemorrhagic disorder
INDOMETHACIN	50-200mg – adult 2-4 mg children	It produce potent anti-inflammatory effect with antipyretic action	Vomiting, Nausea, Bleeding, edema	Asthma, allergic reaction
DICLOFENAC	Adult- 150-200mg	Inhibition of prostaglandin by inhibiting COX1 and COX2	Loss of appetite Vomiting Stomach ulcer Heart burn Nausea	Edema, Hepatotoxicity, Gastrointestinal Bleeding, Anaphylaxis
CORTICOSTE-ROID PREDNISOLONE	7.5mg per day	It modulates the gene expression by blocking the glucocorticoid receptor they promote the upregulation of anti-inflammatory gene	High BP Stomach upset Fluid retension	Osteoporosis Glaucoma Systemic fungal infection
TRIAMCINO-LONE	10mg /ml or 40 mg/ml injection			

Here it is the first case representing the condition. The prescription error in DMARDs is the significant cause of reaction. The regimen was not according to standard therapeutic guidelines. The improper monitoring and irregular follow ups paved the condition. Methotrexate can disrupt hormonal balance, affecting follicular development and ovulation, leading to irregular bleeding. It may also cause bone marrow suppression, reducing red blood cells and platelets, which can contribute to bleeding or clotting disorders. Additionally, methotrexate may directly affect the endometrial lining, causing abnormal bleeding. Other DMARDs, by suppressing the immune system, can disrupt endocrine function, particularly estrogen and progesterone, further contributing to uterine bleeding.The Naranjo adverse drug reaction probability scale was 5 that represents probable. According to WHO classification of adverse drug reaction, the condition belongs to Type C (Continuous) that is usually dose related and due to long term use of drug. According to Hartwig severity assessment scale, classified as Severe Level 5 (The adverse reaction cause permanent damage to the patient).

Conclusion

A new case of methotrexate-induced abnormal uterine bleeding has been reported. The condition was confirmed through both subjective and objective evidence and resolved upon withholding the drug and implementing appropriate management. However, it was not further confirmed through methods like serum drug concentration testing or therapeutic drug monitoring. Depending on its severity, this reaction can be classified as a severe adverse drug reaction, potentially life-threatening,

with the possibility of causing permanent damage and requiring intensive medical treatment. The lack of patient education and failure in management contributed to the adverse reaction. For preventing the condition, standard algorithm of Rheumatoid Arthritis should be obtained from consultant with regular follow ups and monitoring.

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Ethical Consideration: The informed consent was taken from the patient and physician for publication.

References

1. Pharmacotherapy 5th edition by Joseph T Dipiro, et al 2002: 1463- 1480, 1623-1638
2. Janet R Albers, et al. Abnoraml Uterine Bleeding. *American Family Physician*. 2004; 69(8): 1915-26
3. Emily Davis, et al. Abnormal Uterine Bleeding. *National Library of Medicine*. 2023
4. Onecia Benjamin, et al. Disease- Modifying Anti-rheumatic Drugs (DMARD). *National Library of Medicine*. 2023
5. Maryam Hanoodi, et al. Methotrexate. *National Library of Medicine*. 2023
6. Mitchell D. Creinin, et al. Methotrexate Effects on Trophoblast and the Corpus Luteum in Early Pregnancy. *American Journal of Obstetrics and Gynaecology*. 1998; 179(3): 604-609
7. Maria P Yavropoulou, et al. Immune System Effect on Endocrine System. *National Library of Medicine*. 2023
8. Dala N Daraghmeh, et al. Female Reproductive Status and Exogenous Sex Hormone use in Rheumatoid Arthritis Patients treated with Tocilizumab and csDMARDs. *Rheumatology (Oxford) Journal*. 2023; 62(2): 583-95
9. Mesut Ogrendik. Antibiotics for the treatment of Rheumatoid Arthritis. *International Journal of Medicine*. 2013; 7: 43-47
10. Jacqueline Bullock, et al. Rheumatoid Arthritis: A Brief Overview of the treatment. *Medical Principles and Practice*. 2018; 27: 501-07
11. Reesha Gupta, et al. Advancement in the management of Rheumatoid Arthritis. *RPS Pharmacy and Pharmacology Reports*. 2023; 2(1): 1-7.

Case Study

Postmortem Findings in Etoricoxib Poisoning: Reporting of a Rare Case

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Abstract

This case report details the postmortem findings of a case of Etoricoxib poisoning. Etoricoxib, a selective cyclooxygenase-2 (COX-2) inhibitor, is commonly used for pain management in musculoskeletal disorders. It usually has significantly low gastrointestinal symptoms. It is reported to be associated with rare but serious adverse effects when ingested in excessive amounts. In the present case, there is a history of an accidental overdose of Etoricoxib, and the victim expired during treatment and was sent for autopsy, wherein a grossly icteric body, all organs congested with muddy-looking liver, and an enlarged heart with biventricular dilation were seen.

Keywords: Etoricoxib poisoning, postmortem, toxicology, forensic, COX-2 inhibitor overdose

Introduction

Etoricoxib, a non-steroidal anti-inflammatory drug (NSAID) that selectively inhibits COX-2, is commonly used for the management of chronic pain and inflammation, usually in osteoarthritis, rheumatoid arthritis, and dental pain[1]. Despite its selective action, overdose and poisoning can lead to significant toxicity and cardiovascular complications, though it remains relatively rare. We have elaborated on the pharmacological profile of Etoricoxib as a selective COX-2 inhibitor, highlighting its common use in osteoarthritis, rheumatoid arthritis, ankylosing spondylitis, and acute pain. Further, we have incorporated data on recommended dosages and outlined potential adverse effects, particularly focusing on gastrointestinal, hepatic, renal, and cardiovascular risks. Relevant national and global case reports and toxicological studies have been cited to reflect the drug's toxicity profile. Notably, we included references documenting adverse outcomes and toxicity even at therapeutic dosages in susceptible individuals. In addition, we have reviewed the literature to assess the incidence of Etoricoxib toxicity in patients adhering to recommended dosages. These have been cited appropriately, with special emphasis on the need for vigilance in high-risk populations.The present report discusses the postmortem findings in a fatal Etoricoxib poisoning case, contributing to the understanding of the drug's postmortem profile.

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Case Presentation

Patient Information

A 60-year-old lady was admitted to Medical College Kolkata with an alleged history of mistakenly taking all 10 tablets of pain medication, later identified to be Etoricoxib (90 mg), which was recently prescribed to her for osteoarthritis of the knee. She was under treatment, gastric lavage was not performed because the patient was admitted more than six hours after ingestion, which falls outside the recommended timeframe for effective gastric decontamination. According to standard toxicological guidelines, gastric lavage is most effective when initiated within one hour of ingestion. Beyond this period, the risks may outweigh the benefits, especially in patients who are already showing signs of systemic toxicity or gastrointestinal distress. Additionally, considering the patient had already developed symptoms such as severe abdominal pain and vomiting, further invasive procedures like lavage could have exacerbated the condition. He expired after a week later and the body was sent for post-mortem examination, in a background of unnatural death. No significant history of suicidal behaviour or other substance misuse was reported.

Clinical History:

The patient was admitted with a history of overdose of etoricoxib 90 mg tablets, which were supposed to be taken 1 tablet twice daily. On admission, she had complaints of nausea, vomiting, severe abdominal pain, etc. conservative management started with ulcer protective drugs, maintaining fluid balance, and others. Despite the patient developing progressive oliguria, rising serum creatinine levels, and electrolyte imbalances, including hyperkalaemia, during her hospital stay. These findings are consistent with acute kidney injury (AKI), and conservative renal management was attempted. The patient gradually worsened with mismatched fluid balance and electrolyte imbalance, and the patient showed episodes of hypotension requiring vasopressor support. ECG findings revealed nonspecific ST-T changes, and echocardiography indicated reduced ejection fraction with signs of biventricular dysfunction. These symptoms were consistent with cardiotoxicity. The patient was shifted to the ICU with mechanical ventilation initiation. The patient expired 1 week from admission and was sent for autopsy as a case of unnatural death due to poisoning.

Autopsy Findings:

Upon autopsy, the body showed no significant external injuries. Was grossly icteric. Internal examination revealed that most of the organs were congested. Notable findings included: - congested liver with a muddy look weighing 1571 gm, oesophagus and stomach congested and diffuse erosion seen in the mucosa, patchy submucosal haemorrhage in the stomach with some amount of chocolate-coloured fluid. Lungs were heavy, oedematous, and congested with evidence of patchy areas of consolidation involving all regions of both lungs, weighing Rt- 745 gm and Lt- 641 gm. Both kidneys were congested and showed subcapsular petechial haemorrhages. The heart weighed 435 gm, enlarged due to biventricular dilation. Coronary vessels sclerosed with evidence of Grade-II atheroma at the root of the aorta. Routine viscera i.e. Whole of the stomach with its contents, Proximal 30 cm of small intestine along with its contents, 500 gm of the liver with gall bladder, half of each kidney, all duly preserved in containers containing Saturated Solution off common salt with control amount of saturated solution of common salt and 30 mL of blood without preservatives were sent to FSL, FSL reports mentioned no traces of any poison detected.

Histopathological Findings:

Sections of the kidney, heart, and liver were sent for a histopathological examination in 10% of Formol Saline. The kidneys show areas of haemorrhage, oedema, and necrosis. [Fig.4] The liver shows cystic spaces with areas of haemorrhage, hemosiderin-laden macrophages, and chronic inflammatory cells. [Fig 5]. The microscopy of the Heart was, however, unremarkable.

Comparison with Recent Studies:

The toxicological effects observed in our case are consistent with findings from other recent studies on Etoricoxib overdose. For instance, Kumar et al. (2022) reported similar gastrointestinal sparing effects but highlighted significant cardiovascular risks associated with long-term COX-2 inhibition, which aligns with our observation of myocardial changes.

Likewise, a study by Sharma et al. (2021) documented hepatic enzyme depletion and jaundice in acute Etoricoxib toxicity, comparable to the liver inflammation seen in our case. Renal histopathological findings such as hemorrhage and oedema have also been reported in overdose scenarios (Patel et al., 2023), supporting our interpretation of the renal damage observed. These findings collectively underscore the systemic toxicity potential of Etoricoxib when consumed in excessive amounts and reinforce the conclusions drawn from our case.

Figure 1: Body of the deceased.

Figure 2: Midline incision showing the gross icteric state.

Figure 3. Grossly congested and icteric organs as seen clockwise from top left: stomach cut open, liver (sectioned), lung, kidney (cut open), heart, brain

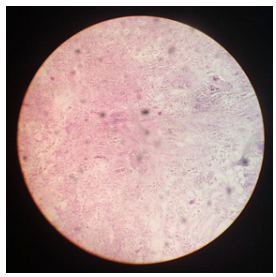

Figure 4. Kidney showing haemorrhage, edema, and necrosis in HPE

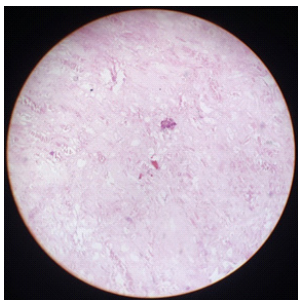

Figure 5. Liver showing cystic spaces with areas of haemorrhage, hemosiderin-laden macrophages, and chronic inflammatory cells in HPE.

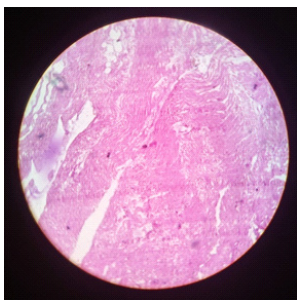

Figure 6. The heartwas unremarkable in HPE.

Discussion

Etoricoxib was introduced in India and approved by the Drugs Controller General of India in 2004[2]. Etoricoxib selectively inhibits the COX-2 enzyme, reducing the production of prostaglandins involved in pain, inflammation, and fever. Unlike non-selective NSAIDs, it spares COX-1, which is essential for GI mucosal protection and platelet function. Hence, its effect on GI Mucosa is less compared to non-specific COX inhibitors like Diclofenac Sodium, Ibuprofen, etc. It has low incidences of gastrointestinal toxicity and hence also suitable for prescribing without accompanying Proton Pump Inhibitors or H2 Receptor blockers[3]. The long half-life (~22 hrs) of Etoricoxib allows for once daily dosages without significant loss in efficacy[4]. Hence, there is a very low chance of overdose unless voluntarily/accidentally taken. However, there is an increased chance of cardiovascular events as it has been hypothesized that selective COX-2 inhibition will lead to decreased levels of endothelial prostacyclin (PGI2), a prostaglandin with vasodilatory and antithrombotic properties, and increased levels of thromboxane (TXA2), a platelet-derived prothrombotic vasoconstrictor. This shift in the myocardial prostaglandin milieu is thought to lead to increased coronary thrombosis and MI. Similar to Non-selective COX inhibitors in case of acute overdose, the significant load of metabolization of the drug causes acute depletion of the liver enzymes and causes jaundice due to inflammation of the liver seen in this case. Also, as seen in any poisoning, there is acute kidney injury seen consistent with the subcapsular petechial haemorrhages observed in this case[5]. Also, histopathology suggested haemorrhage, oedema, and necrosis in the kidneys, which further supports this finding. Here we can see that the heart is enlarged and the ventricles are dilated. But this dilation of the heart may be due to pre-existing heart conditions, details of which are not accurately available. We consider the finding of Grade II atheroma seen at the root of the aorta, and its contribution to causing the death of the individual cannot be neglected. Since treatment was done, and patient survived for some duration before expiring. We can say that death was due to the sequelae of toxicity due to etoricoxib overdose.

Conclusion

Despite its selective COX-2 inhibition and lower gastrointestinal risk compared to non-selective NSAIDs, there has always been a need to highlight the potential toxicity and fatal sequelae associated with Etoricoxib overdose. While accidental overdose of Etoricoxib is uncommon, its long half-life and metabolic burden on the liver can lead to severe systemic complications, including hepatic dysfunction, acute kidney injury, and cardiovascular effects. The postmortem findings, including hepatic congestion, renal haemorrhages, and ventricular dilation, suggest multi-organ involvement in the pathophysiology of toxicity. Although the presence of pre-existing cardiovascular conditions cannot be ruled out as a contributing factor in this case, the findings emphasize the need for cautious prescription practices, patient education on dosage adherence, and early recognition of overdose symptoms to prevent fatal outcomes. Grade II classification indicates minimal luminal narrowing and is unlikely to have caused significant ischemia or directly led to cardiac dysfunction. Instead, the observed biventricular dilation is more plausibly attributed to the toxic effects of Etoricoxib on myocardial tissue or fluid overload secondary to renal dysfunction. This distinction helps to avoid over-attributing the cardiac findings to pre-existing vascular pathology.

Acknowledgement:

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Consent: Written informed consent for publication of clinical details, post-mortem findings, and histopathological images was obtained from the autopsy surgeon, investigating police personnel, and the relative of the deceased.

Ethical Clearance: Date:17/06/2025 Referenceno.:MC/KOL/IEC/2790/06/2025 Name: Institutional Ethics Committee, Medical College, Kolkata

Conflict of interest: The authors have no conflict of interest in this case report.

Source of funding: None

References

1. Takemoto JK, Reynolds JK, Remsberg CM, Vega-Villa KR, Davies NM. Clinical pharmacokinetic and pharmacodynamic profile of etoricoxib. Clinical pharmacokinetics. 2008 Nov; 47:703-20.
2. Shetty U, Neema P, Muthu S, Bhojwani D, Muchhala S, Shetty UK, Neema PP, Muthu S, Bhojwani DG. Nationwide Etoricoxib Injection Clinical Experience (NICE): Real-World Evidence in Indian Patients. Cureus. 2024 Feb 11;16(2).
3. Patrignani P, Capone ML, Tacconelli S. Clinical pharmacology of etoricoxib: a novel selective COX2 inhibitor. Expert Opinion on Pharmacotherapy. 2003 Feb 1;4(2):265-84.
4. Agrawal NG, Porras AG, Matthews CZ, Rose MJ, Woolf EJ, Musser BJ, Dynder AL, Mazina KE, Lasseter KC, Hunt TL, Schwartz JI. Single- and multiple-dose pharmacokinetics of etoricoxib, a selective inhibitor of cyclooxygenase-2, in man. The Journal of Clinical Pharmacology. 2003 Mar;43(3):268-76.
5. Reddy KSN, Murty OP. The essentials of forensic medicine & toxicology. 35th ed. New Delhi, India: Jaypee Brothers Medical; 2022. 24, General Considerations, p.388.
6. Rodrigues AD, Halpin RA, Geer LA, Cui D, Woolf EJ, Matthews CZ, Gottesdiener KM, Larson PJ, Lasseter KC, Agrawal NG. Absorption, metabolism, and excretion of etoricoxib, a potent and selective cyclooxygenase-2 inhibitor, in healthy male volunteers. Drug metabolism and disposition. 2003 Feb 1;31(2):224-32.
7. Schumacher Jr HR, Boice JA, Daikh DI, Mukhopadhyay S, Malmstrom K, Ng J, Tate GA, Molina J. Randomised double blind trial of etoricoxib and indometacin in treatment of acute gouty arthritis. Bmj. 2002 Jun 22;324(7352):1488-92.
8. Tripathy S, Dash SC. Etoricoxib-induced life-threatening hyperkalemia and acute kidney dysfunction against the background of telmisartan and a low-sodium diet. International journal of emergency medicine. 2010 Dec; 3:443-6.
9. Tripathy S, Dash SC. Etoricoxib-induced life-threatening hyperkalemia and acute kidney dysfunction against the background of telmisartan and a low-sodium diet. International journal of emergency medicine. 2010 Dec; 3:443-6.
10. Smirnov G, Terävä M, Tuomilehto H, Hujala K, Seppänen M, Kokki H. Etoricoxib for pain management during thyroid surgery–a prospective, placebo-controlled study. Otolaryngology—Head and Neck Surgery. 2008 Jan;138(1):92-7.
11. Modern Medical Toxicology;5th Edition 2023 by V V Pillay.

Case Study

Management of Lifethreatening Multiorgan Dysfunction Due to Glufosinateammonium Poisoning: A Rare Case Report

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Abstract

Glufosinate ammonium is an herbicide that is considered one of the most hazardous substances and is prohibited in 29 countries worldwide. The mechanism involves inhibition of the enzyme glutamine synthase, leading to an increase in blood ammonia levels and subsequent damage to various organs, particularly the nervous system. Hyperammonaemia is considered one of the main mechanisms of glufosinate ammonia toxicity in humans. Commercial preparations also contain surfactants ranging from 30% to 70%, which can contribute to cardiovascular depression. The most striking feature is late-onset amnesia; this is due to the toxin-induced damage to the hippocampus.

This case of a 31-year-old female who consumed 500 ml of a glufosinate ammonium-based herbicide highlights the entire clinical management. She presented to us after 48 hours with a GCS of 8. She was intubated and ventilated for 4 days, during which she developed seizures, arrhythmias, myocarditis, and pulmonary oedema. She was started on vasopressors and antiarrhythmic, and we used colchicine for myocarditis, as it inhibits the activity of NLRP3 (NOD-, LRR-, and pyrin domain-containing protein 3), mediating its anti-inflammatory properties. We have also used Intralipid emulsion therapy, as lipid emulsions can isolate the lipophilic toxins, reducing their bioavailability and toxicity.

The timely use of amiodarone infusion, colchicine and the intralipid emulsion therapyreflected in the clinical outcome of the patient. She was extubated after 4 days and discharged in a stable hemodynamic state after two more days of general ward observation.

Keywords: Glufosinate ammonium, myocarditis, neurotoxicity, colchicine, lipid sink theory.

Introduction

Glufosinate-ammonium, a broad-spectrum herbicide, is highly hazardous according to the Pesticide Action Network (PAN) India. It is banned in 29 countries, but it is used to control weeds in India. The bulletin published by the Indian Council of Agricultural Research (ICAR) reports

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several unauthorised uses, including in food crops. This organophosphate/phosphonoglycine herbicide is classified as Class II by WHO, which means that it is moderately hazardous, and it falls under the Herbicide Resistance Classification (WSSA) 10[1]. As there is no antidote for this, the supportive therapy is the base of the treatment. The literature on this poisoning is limited, including reports of fatalities.

The primary mechanism of glufosinate ammonia is inhibition of theenzyme glutamine synthase, leading to an increase in blood ammonia levels and subsequent damage to various organs, particularly the nervous system, and tissue necrosis. The proposed mechanism of hyperammonemia secondary to glufosinate exposure is inhibition of glutamine synthetase in human cells[6]. Commercial formulations often contain surfactants that contribute to cardiovascular depression and vasodilation.

This case of 31-year-old glufosinate ammonium poisoning illustrates the urgency and complexity of treatment. Despite the severity and major organ involvement, timely medical intervention resulted in remarkable recovery of our patient.

Case report

A 31-year-old female with no prior comorbid illness presented to our hospital after 48 hours of consuming 500 ml of glufosinate-ammonium herbicide. The empty bottle of poison was brought by the attenders. According to them, she had intentionally consumed the poison due to its easy availability.

Initially, she was admitted to a nearby hospital withmild symptoms of nausea and abdominal pain. First aid measures to remove the poison were given, but details are not clearly provided by the attendants. She was later discharged.

Fig 1: Chest X-ray in ICU

Fig 2: Chest X- ray on Day 3

Fig 3: Chest X- ray on discharge

Upon admission to our emergency department, she appeared drowsy (E3V1M5), with 3 mm reactive pupils and no focal neurological deficits. Her Glasgow Coma Scale(GCS) dropped to 8, accompanied by bronchospasm and hypoventilation. She was intubated in emergency and started onmechanical ventilation. A respiratory examination revealed bilateral diffuse crepitations, and a chest x-ray was suggestive of pulmonary oedema. Blood gas showed metabolic acidosis with a high anionic gap. Later she was moved to ICU for further management.

In the ICU all the necessary examinations and evaluations were done. Her ammonia level was 181, and she started to have facial twitching. Hyperammonemia is considered one of the potential risk factors for neurotoxicity[7]. An EEG was done which showed seizure-like activity. Other laboratory parameters showed elevated Trop I and severe LV dysfunction with bilateral pulmonary oedema. She was in severe cardiogenic shock and in need of high vasopressors and inotropes. Her arrhythmias were addressed with amiodarone infusion.

We have also given colchicine (0.5 mg twice daily) for myocarditis, as the studies suggest that it works by reducing NLRP3 activity and has been shown to improve several cardiac conditions, including acute coronary syndrome and pericarditis. Hepatoprotective agents were added for ischaemic transaminitis. Intralipid emulsion therapy was given for 2 days (20% bolus of 1.5 ml/kg followed by 0.25–0.5 ml/kg/min) as the studies showed that the use of lipid sink theory is promising in reducing the risk of cardiotoxicity. Using it in the initial period was a crucial role. On monitoring for 4 days in ICU, her parameters improved and shock was resolved.

She was successfully extubated, switched to nasal oxygenation and finally discharged in a stable haemodynamic state after two more days of general ward observation.

Monitoring for late-onset amnesia, a known feature of this poisoning, showed a favourable outcome, where she initially experienced the symptoms which started after a month of discharge, but later, upon following up, she completely recovered with no such episodes.

Table 1: Trend of vitals and other lab parameters

Parameters	Day 1	Day 2	Day 3	Day 4	Discharge
Vitals					
BP (mmHg)	130/90	87/63	112/68	92/74	110/80
HR	90 bpm	140 bpm	100	98 bpm	80bpm
RR	22	18 bpm	22	24bpm	20 bpm
ABG					
pH	7.15				
PaCO2	31	-	-	-	-
PaO2	58				
HCO3	14				
Lactate	5.3				
Ammonia	-	54	181	60.5	-
Cardiac marker					
Trop I	-	3286	10430	-	-
Liver function test					
ALP	54	46	54		60
AST	63	486	344	202	85
ALT	17	298	305	265	135
GRBS	259	164	-	-	-
CBC					
Hb	15.1	12.2	12.4	12.6	12.6
RBC	5.52	4.42	4.40	4.52	4.52
Platelet	202	198	183	176	176
Renal parameter & electrolytes					
Creatinine	1.16	0.66	0.79	0.6	0.59
Sodium	136	150	146	144	138
Potassium	3.8	3.69	4.5	3	3.9
Chloride	111	98	97	100	100
Calcium	7.5	7.7	8	7.3	8.3
CUE		-	-	-	-
Color	Pale yellow				
pH	5.5				
Appearance	Hazy				
Proteins	1+				
Glucose	Absent				
Blood	3+				
Pus cells	Plenty				

Discussion

Glufosinate is an analogue of glutamate, which is an excitatory amino acid in the human central nervous system (CNS). It inhibits the enzyme glutamine synthetase, leading to intracellular accumulation of ammonia, where hyperammonaemia is considered to be one of the main mechanisms of glufosinate ammonia toxicity in humans[1]. Based on the mechanism of glufosinate poisoning, serum ammonia level could increase when glufosinate activity is irreversibly inhibited in acutely poisoned patients.

Initial symptoms will be nausea, vomiting, abdominal upset, pain and dizziness. Moderate symptoms will be dyspnoea, confusion and agitation. Severe symptoms will be respiratory failure, coma, seizure and shock[2].

Due to toxin exposure and its metabolites, which lead to an imbalance between glutamate, ammonia and glutamine, there is neurological toxicity. Among the various neurotoxicological effects, late-onset amnesia is the most noticeable feature due to toxin-induced damage to the hippocampus[6].

Haemodynamic effects are observed after the intoxication, such as changes in vascular resistance or cardiac output. Cardiovascular manifestations were also observed, like tachycardia and hypotension. These cardio-suppressive effects were likely due to the surfactant [2], which is anionic in nature, sodium polyoxyethylene alkyl ether sulfate, and also its concentration varies from 30 % to 70 % [6].

Studies have shown that colchicine prevents the progression of the disease in viral myocarditis. This anti-inflammatory drug works in part by reducing NLRP3 activity and has been shown to improve several cardiac conditions, including acute coronary syndrome and pericarditis [4].

There have been documented fatalities resulting from the ingestion of glufosinate-containing herbicide. Pathological autopsy revealed that the cause of death was acute cardiorespiratory failure due to glufosinate intoxication characterised by multi-organ congestion without specific pathological findings [5].

The lipid sink theory is a therapeutic approach in which intravenous lipid emulsion (ILE) is used as a potential antidote for certain intoxications. This theory states that the administration of a lipid emulsion can scavenge lipophilic toxins [3]. Surfactant in the glufosinate ammonium herbicide is lipophilic in nature, so intravenous lipid emulsion is found to be promising therapy [6].

Conclusion

Careful evaluation, examination and to look for complications like myocarditis, pulmonary aspiration and neurotoxicological effects along with quantification of intoxication is important inguiding the treatment. Use of colchicine to improve cardiac conditions and lipid sink theory is used in our study, which showed promising result in the treatment. Patients should be hospitalised until fully recovered, and follow-up is also required for late manifestations.

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Declaration of conflicts of interest statement if applicable: Not applicable

References

1. Donti NR, Dileep AD, et al. Glufosinate ammonium: An overview. Pesticide Action Network India. 2022 Dec.
2. Mao YC, Hung DZ, Wu ML, Tsai WJ, Wang LM, Ger J, et al. Acute human glufosinate-containing herbicide poisoning. Clin Toxicol (Phila). 2012;50(5):396-402. Doi: 10.3109/15563650.2012.676646.
3. Jaffal K, Chevillard L, Mégarbane B. Lipid emulsion to treat acute poisonings: Mechanisms of action, indications, and controversies. Pharmaceutics. 2023 May 3;15(5):1396. Doi: 10.3390/pharmaceutics15051396. PMID: 37242638; PMCID: PMC10224337.
4. Pappritz K, Lin J, El-Shafeey M, Fechner H, Kühl U, Alogna A, et al. Colchicine prevents disease progression in viral myocarditis via modulating the NLRP3 inflammasome in the cardiosplenic axis. ESC Heart Fail. 2022 Apr;9(2):925-41. Doi: 10.1002/ehf2.13845. PMID: 35178861; PMCID: PMC8934990.
5. Zhao S, Li X, Jiang Z, Lin Y, et al. Forensic toxicological studies of acute glufosinate poisoning: A case series. J Forensic Leg Med. 2024 Aug; 106:102732. Doi: 10.1016/j.jflm.2024.102732.
6. Shankar D, Murali T, Gopinathan T, Varun S. A rare case of glufosinate ammonium poisoning. Journal of evidence-based medicine and health care2022; 9(08):1-6
7. Yan-chiao M, Jiaan-Der W, Dong-Zong H, et al. Hyperammonemia following glufosinate-containing herbicide poisoning: A potential marker of severe neurotoxicity. Clin Toxicol. 2011;49:48-52.

Review Article

A Review of Ricochet Occurrence: As a Function of Critical Angle and Different Material Targets

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Abstract

Bullet ricochets are a frequent occurrence in shooting situations and can yield a lot of information that helps in the reconstruction of the shooting incident. This review is the cumulation of various bullet ricochet examinations done worldwide based on critical angle, target material, and type of bullet. The article overviews ricochet angles observed on common surfaces like wood, concrete, metal sheets, glass, ceramic, water etc. The review also explores additional factors impacting ricochet events such as bullet wipe marks, splintering effect, ramping effect, plugging effect, ramping, and tunnelling effects. The combined knowledge of these discoveries advances our comprehension of both the complex dynamics of bullet ricochets and forensic ballistics.

Keywords: Bullet, ricochet, critical angle, target surface.

Introduction

Forensic Ballistics is a subfield of forensics that focuses on the examination of weapons, and ammunition, and the study of projectile motion and their impact[1]. When a bullet (projectile) comes in contact with any surface and gets unexpectedly diverted from its trajectory, forensic experts frequently look into such shooting occurrences[2,3,5]. This phenomenon is known as a ricochet[6,4].

Because the surface absorbs some energy and reflects the remaining, a bullet that strikes below the critical angle ricochets and deflects rather than entering. The angle of incidence influences ricochet behaviour; larger angles result in greater deflection, whereas shallow angles increase skimming[7-11]. Another important factor is surface composition; tougher surfaces, such as steel, cause greater deflections[12-13], whereas softer materials absorb more energy, limiting ricochet. The form and substance of bullets are also very important. Round-nosed bullets are more prone to ricochet than hollow-point or flat-nosed bullets[11-6,] and the danger of ricocheting is greater for tougher materials like copper and steel[11] than for softer lead. While bullets with flat or hollow ends may shatter or do less harm, sharp-nosed bullets tend to penetrate and baton rounds mostly used in crowd control, bounce[14-15]. Ricochet angle

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and velocity are affected by several factors, including impact velocity, obliquity angle, yaw, projectile mass, and target attributes[16,17]. Ricocheted bullets can keep their deadly energy even after distortion[7]. To find important incident facts, forensic specialists examine their trajectory, shape, and surface properties[18-20].

Reconstruction of events require the use of critical angles and bullet markings[2,21,23]. At a specific velocity, 50% of bullets will bounce off or cease ricocheting at the critical ricochet angle[10-11]. High-speed bullets affect the transfer of material between the bullet and the target, following Locard's concept of exchange[6]. The carbonaceous substance, lubricant, and sealant that makeup bullet wipe marks offer important forensic information[14-26].

During the literature survey, authors noticed that different review articles have been published about ricochet gunshot wounds, wherein mainly focussing on various facets of bullet behaviour on living beings[27-32]. However, during any shooting incident whether indoor or outdoor, a bullet can hit various target surfaces at some non-ideal level of uncertainty[33].

Using a variety of bullets and weapons, this article investigates ricochet behaviour on a range of surfaces at various critical angles. It emphasises the significance of target surfaces and crucial angles in comprehending projectile rebound, providing information useful for disaster studies, forensic investigations, projectile velocity analysis, shooting range design, the creation of protective gear, and safety precautions.

Methodology

A systematic literature review was performed using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. The review was conducted without date or language restrictions in major databases (Science Direct, Scopus, Elsevier, Wiley, MDPI, ProQuest, etc.) that centred on the keywords "ricochet of the bullet on different surfaces like woods, concrete, glass, metal sheet or water". This search returned 2520 English language articles published from 1990 to 2024. After eliminating results; a large number of additional irrelevant articles (e.g., Recovery of fired ammunition, sound design for three short films also wounds created by ricochets of bullets), 65 publications remained for review. The PRISMA flowchart is shown in (Fig. 1).

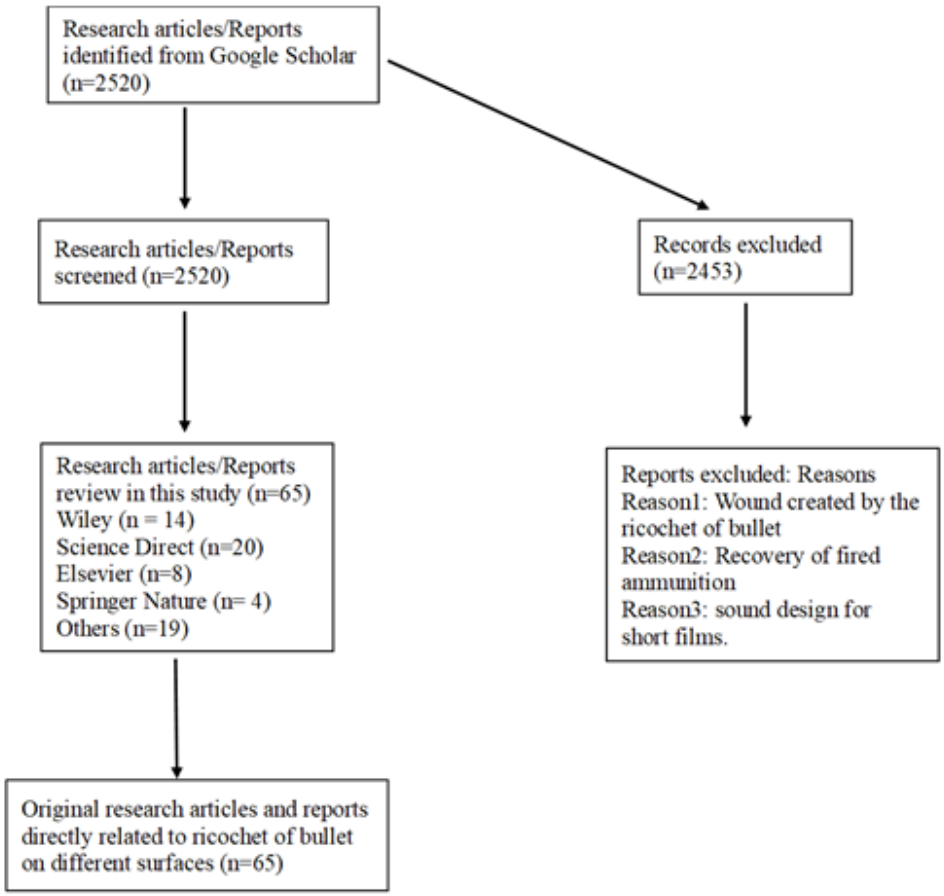

Fig. 1: PRISMA flow Chart

Discussion:

The discussion includes review on investigation involving ricochet cases, using variety of guns and calibres on different surfaces, followed by important components that provided information on bullet trajectories, impact behaviours, and forensic examinations.

Wood:

Following Table 1, highlights the ricochet phenomenon observed by authors – (a) Bandula et. Al.[26], showed Nine of the ten projectiles a tunnelling effect in pine wood at a ricochet angle of 13°. In study (b) Kerkhoff, et al.[10] show critical angle for ricochet of .32 Auto bullets are wider than that of 9 mm Luger rounds. In study (c) Abdul et al.[34] Jelutong wood showed deep penetration and sapele partial penetration. As a result, harder woods resulted in a higher critical ricochet angle and lower incident angle. Erwin et al. (d) uses SEM/EDX to analyse critical ricochet angle influenced by material properties and bullet type. In study [36] (e) Bullet weight and ricochet angle correlated, Resak has a higher modulus of elasticity than Seraya and Balau, bullet weight loss attributed to target material composition.

Table 1: Ricochet observed on various wood surfaces.

Study	Firearms	Caliber in (mm)	Average Speed (m/s)	Material & Critical Ricochet Angle
a	AK rifle (Type 56 MK II)	7.62*39	722 ±10	Teak:13.0°, Jackwood: 9.9° Mahogany:12.7°, Pine:13.3°
b	Skorpion, Steyr TMP submachine guns	.32 Auto, 9mm Luger	293 344	32 auto, 9mm Abachi:- 10.4° 10.3° Pine:- 23.2° 20.6° Beech:- 33.6° 28° Ipe:- 45° 33.4°
c	Bolt-action rifle	.22	150	Pine: 15° Jelutong:15°, Sapele: 40°
d	Smith & Wesson Model 586-3	9mmLuger.38 Special	349± 2, 227± 1	MDF Green Board: 10° Gypsum: 10°, Steel Plate: 5°
e	CZ 75SP-01 handgun	9mm	Not given	Balau, Resak, seraya: 10°-65°

Concrete:

Table 2 shows the ricochet review on Concrete – (a) Bandula et al.[24] studied rough concrete had more consistent ricochet angles than intermediate concrete. (b) Bryan Burnet's [37] report remarks about the laminae on the bullet's trailing edge, indicating the bullet strike direction. The creation of the laminal structure shows the complex dynamics at the bullet-concrete contact. (c) Miguel et al.[38].45 calibre performed best at low angles; the 2D ellipse and lead-in technique was accurate and repeatable. (c) Neculai et. al.[39] uses high-speed camera, showed caliber specific ricochet behavior; 7.62×39 mm exhibited constant ricochet angles on all slopes, highlighting angle selection importance.

Table 2: Ricochet observed on various concrete surfaces.

Study	Firearms	Caliber in (mm)	Average Speed (m/s)	Material & Critical Ricochet Angle
a	Type 56 MK II/ Chinese (AK Rifle)	7.62	716±7.5	Cement: 10.8° Rough Concrete: 11.1° Intermediate Concrete: - 13.2°
b	Not given	.22	Not given	Concrete: 30°
c	Glock 17, Revolver 0623, Glock 22, Glock 21	9mm, .22, .40, .45	339-478 (varied per calibre)	Drywall
d	AKM rifle	7.62×39	Not given	Varied Inclined Targets: - 60°

Metal sheet:

Table 3, reviews - (a) Bandula et al.[40] reported that the angle of incidence has an inverse relationship with the bullet hole length. (b) Same authors[41] investigated that the sheet's sharp edges resulted in triangular jacket pieces and double-headed impact imprints. (c) YILMAZ et al.[42] - the critical ricochet angle is material-specific and impact velocity. (d) Eugene et al.[18] reported that Winchester Ranger did not bounce after piercing the plate because of its high velocity. (e) Farouk et al.[43]simulations reveal complex interaction modes based on velocity and angle the accuracy of high-velocity impact predictions is impacted by modelling restrictions related to axial deceleration and material characteristics. (f) Yingxiang et al. [44] reported damage patterns vary with velocity and angle, helpful in protective structure design. (g) Tore et al.[45] highlight the transition from perforation to ricochet at higher angles and give insights for armour and protection design.

Table 3: Ricochet observed on various metal sheets.

Study	Firearms	Caliber in (mm)	Average Speed (m/s)	Material & Critical Ricochet Angle
a)	Type 56-MKII Assault Rifle	7.62	714.4±7.6	1mm Zinc- coated metal sheet: 15°
b)	Universal receiver	7.62 standard ball	760.62±1.89	1mm Metal Sheet: 3°
c)	LS-DYNA 971 simulation	AP 7.62	Not given	5mm Metal plates a) Ti6Al4V:55°, b) AlSl 4340: 25°, c) Inconel-718: 20° d) AlSi10Mg: 80° e)A16061-T6: 75°
d)	Glock, model 17 L	9mm Luger, Sintox, 9mm, Winchester ranger, 9mm, Hornady, 9mm luger Samson, 9mm Remington	Varied	.35mm steel plate: 14° and 20° for 9mm Luger, Hornady, 9mm luger, Samson, 9mm 14° for Sintox
e)	LS-DYNA simulations	Aluminium Projectiles	250-1500	Steel plate: at 25° and 40°
f)	Light gas gun	Ogive Shaped Projectile; 40	300-800	Steel Plate: 30°
g)	Mauser rifle	7.62 NATO ball, 7.62 APM2	830	20mm AA6082-T4 aluminium plate: below 60°

Glass surface:

Table 4 highlights - (a) Jan et al. [46] finds out that bullet deviation unpredictably increases with an angle up to 30°. (b) Erwin et al.[11] for each kind of bullet, the study determined critical ricochet angles; FMJ rounds had smaller ricochet angles than hollow-point or perforated bullets. (c) Shunsuke et al.[47] highlights no discernible variations in static fracture stress were found in indentation testing for different windshields, suggesting uniform material robustness. (d) Bahman et al.[48] studies Ceramic enhances performance at higher velocities**.** There was evidence of projectile erosion, which was more noticeable in vertical hits than oblique ones.

Table 4: Ricochet observed on various Glass surfaces.

Study	**Firearms**	**Caliber in (mm)**	**Average Speed (m/s)**	**Material & Critical Ricochet Angle**
a)	Pistol	.22 CCI-NR semi-wadcutter .38 Fedral gold wadcutter	210 (.22), 230 (.38)	6mm glass plate: 40°
b)	Skorpian submachine, Smith & Wesson-625-3 revolver, Steyr TMP	.32 auto, .45 auto, 9mm luger, 9mm luger action NP	293-427	5mm plain float commercial glass .32 auto: 21° .45 auto: 17.6°, 9mm luger:15.8°
c)	Revolver	.38	244.4	5mm thick glass windshield: beyond 60°
d)	Steel projectile LS-DYNA simulation	7.62	430	10mm ceramic/ aluminium: 67°

Water:

Table 5 explores - (a) Baillargeon etal.[49] Studied all the projectiles showed similar ricochet angles at shallow angles but exhibited variability and larger angles at higher incidence. (b) Ramzi Mirshak's [50] finds out Shallow angle preserved projectile speed, while steep angles caused significant velocity loss and unpredictable behaviour.

Table 5: Ricochet observed on various water surfaces.

Study	**Caliber in (mm)**	**Average Speed (m/s)**	**Material & Critical Ricochet Angle**
	5.56mm Ball C77,0.5 cal AP-T C44,K50 BMG, 0.5-cal Ball M2, 7.62-mm Ball C21	937, 749, 740, 893, 879	Water pool (3.6×0.6×0.3m mild steel with polycarbonate glass): 15°-30°
	.50 cal ball. 50 Cal AP-T, .56mm, 7.62mm, K50 BMG	Varied	Tank simulating flat water surface: Less than 10° and 5.56 mm: ~20°

Miscellaneous:

A comprehensive literature study identifies elements that disclose bullet trajectory and angle of impact in ricochet scenarios, such as splintering, ramping, plugging, and tunnelling.[26, 24, 41, 52, 62]

Bullet wipe mark:

Bullet wipe markings, a black ring of lubricant, debris, and traces surrounding a bullet hole, are used in wound ballistics to determine the type, calibre, and weapon connection of a bullet. Their patterns show the place and direction of impacts and aid in reconstructing gunshot incidents[35,57,58].

During the interaction, the exchange leftovers can change due to environmental conditions, which can provide the timing of events. And because ricocheting reduces the surface imperfections, ricocheted bullets usually leave less noticeable bullet wipes than direct shots.[60,61]These marks can function as long-lasting forensic identifiers, holding up even

after six months on wood, according to Nishshanka et al. [26] On concrete, Nishshanka et al. discovered noticeable wipe traces at a 7° impact angle but none at 5°, 9°, or 11° [24].

Splintering effect: Surface splintering happens when a bullet deforms and displaces material above its elastic limit, radiating parallel to the surface grain, particularly in soft woods like pine[26].

Ramping effect: The trajectory of the bullet may be impacted by detailed ricochet markings. According to research, smooth cement surfaces are more affected than rough concrete, which only leaves minor blemishes[24].

Plugging effect: The "plugging" phenomenon results in the formation of a plug when a bullet hits a target. Both glass [35] and metal sheets showed this, with the glass plug's diameter being more than the bullet's calibre [62-65]. Compared to jacketed bullets, which show plugging effects on metal sheets at 20 feet, lead bullets deform more and lose velocity quickly. Estimating the angle of incidence and initial contact is made easier by important ricochet parameters such as angle, departure ramp, deepest point, and pinch point [66-67].

Tunnelling effect: When a bullet travels through a substance and reappears in a different location, this phenomenon is known as the tunnelling effect. The effect was seen on pine wood due to its soft nature.[26] The impact angle, trajectory, orientation, and surfaces it touched are all visible in the ensuing imprints [26,61.]

Conclusion

A comprehensive understanding of the ricochet behaviour of bullets on diverse surfaces, necessitates considering the results of several research. Studies consistently demonstrate that ricochet angles, as greatly influenced by bullet velocity, surface roughness, incidence angle, and material composition. Materials like hard wood, concrete, metal sheet, demonstrate higher ricochet angle. Whereas glass, owing to its fragile nature, exhibits complicated behaviour, with bullet type and glass thickness having a significant impact on whether a bullet ricochets or passes through. On contrary when the bullet hits water surface, based on hydrodynamic forces and angle of entry, bullet either travels inside the fluid with varied velocity or ricochets. The review lists critical ricochet angles on different surfaces, also highlights how crucial bullet wipe markings and other effects like splintering and plugging effects are to forensic ricochet studies.

Ricochet studies could provide insightful information about any shooting incident, forensic investigations and crime scene reconstruction, also offer useful information for enhancing safety precautions in developing bulletproof materials and other amenities.

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References

1. Jain R, Pokhariyal P, Dubey D, Pandey A, Patel B, et al. National Human Rights Commission India, Ahuja P. Kumar S. Chapter 12. Forensic
Ballistic in Criminal Justice. First. Lal B, Nim DK, editors. Forensic Science and Human Rights. National Human Rights Commission; 2023.
2. Girard JE. Criminalistics: Forensic Science, Crime, and Terrorism. Jones & Bartlett Learning; 2021.
3. Nordin FA, Bominathan UR, Abdullah AFL, Chang KH. Forensic significance of gunshot impact marks on inanimate objects: the need for translational research. Journal of Forensic Sciences. 2019 Aug 2;65(1):11–25. doi.org/10.1111/1556-4029.14142
4. MAJID A, Birch, Jais, Zakaria. The behaviour of projectile ricochet off various wooden targets. Journal of Engineering Research & Education. Vol. 3, 2006 (70-75). 2006.

5. Mattijssen EJAT, Kerkhoff W, Hermsen R, Hes RAG. Interpol review of forensic firearm examination 2019–2022. Forensic Science International Synergy. 2022 Dec 14;6:100305. doi.org/10.1016/j.fsisyn.2022.100305
6. Chisum WJ, Turvey BE. Crime reconstruction. Academic Press; 2011.
7. Burke T, Rowe W. Bullet Ricochet: A comprehensive review. Journal of Forensic Sciences. 1992 Sep 1;37(5):1254–60. doi.org/10.1520/jfs13312j
8. Gold R, Schecter B. Ricochet dynamics for the Nine-Millimetre parabellum bullet. Journal of Forensic Sciences. 1992 Jan 1;37(1):90–8. doi.org/10.1520/jfs13215j
9. Hall LE. The laws of motion: An Anthology of Current Thought. The Rosen Publishing Group, Inc; 2008.
10. Kerkhoff W, Alberink I, Mattijssen EJAT. An empirical study on the relation between the critical angle for bullet ricochet and the properties of wood. Journal of Forensic Sciences. 2015 Feb 12;60(3):605–10. doi.org/10.1111/1556-4029.12738
11. Mattijssen EJ a. T, Pater KDH, Stoel RD. Ricochet behavior on Glass—Critical ricochet angles, ricochet angles, and deflection angles. Journal of Forensic Sciences. 2016 Sep 19;61(6):1456–60. doi.org/10.1111/1556-4029.13201
12. Nurazzi NM, Asyraf MRM, Khalina A, Abdullah N, Aisyah HA, Rafiqah SA, et al. A review on natural fiber reinforced polymer composite for bulletproof and ballistic applications. Polymers. 2021 Feb 22;13(4):646. doi.org/10.3390/polym13040646
13. Finney MA, Maynard TB, McAllister SS, Grob IJ. A study of ignition by rifle bullets. 2013 Jan. doi.org/10.2737/rmrs-rp-104
14. Heard BJ. Handbook of Firearms and Ballistics: Examining and Interpreting Forensic Evidence. John Wiley & Sons; 2011.
15. Tawell MG. Kinetic energy less lethal weapons and their associated blunt trauma injuries. 2010.
16. Segletes SB ARod Ricochet Model. 2004.
17. 17. Segletes SB. A model for rod ricochet. International Journal of Impact Engineering. 2006 Feb 15;32(9):1403–39.doi.org/10.1016/j.ijimpeng.2004.12.003
18. Liscio E, Imran R. Angle of impact determination from bullet holes in a metal surface. Forensic Science International. 2020 Sep 13;317:110504. doi.org/10.1016/j.forsciint.2020.110504.
19. Burke T, Rowe W. Bullet Ricochet: A comprehensive review. Journal of Forensic Sciences. 1992 Sep 1;37(5):1254–60. doi.org/10.1520/jfs13312j
20. Li QM, Chen XW. Penetration and Perforation into Metallic Targets by a Non-deformable Projectile. Engineering Plasticity and Impact Dynamics. 2001 Dec 1;173–92. doi.org/10.1142/9789812794536_0010
21. Colas J, Billard J, Ferriol S, Gascon J, Salagnac T. Development of data processing and analysis pipeline for the Ricochet experiment. Journal of Low-Temperature Physics. 2022 Nov 21;211(5–6):310–9. doi.org/10.1007/s10909-022-02907-5
22. Karger B, Hoekstra A, Schmidt PF. Trajectory reconstruction from trace evidence on spent bullets. International Journal of Legal Medicine. 2001 Aug 1;115(1):16–22. doi.org/10.1007/s00414000020
23. Hueske EE. Practical analysis and reconstruction of shooting incidents. CRC Press; 2005.
24. Nishshanka LCB, Shepherd C, Punyasena MA, Ariyarathna MR. Ricochet of AK bullets (7,62 × 39 mm) on concrete and cement surfaces; a forensic-based study. Science & Justice. 2021 Jun 8;61(5):467–76. doi.org/10.1016/j.scijus.2021.06.004
25. Moxnes JF, Frøyland Ø, Skriudalen S, Prytz AK, Teland JA, Friis E, et al. On the study of ricochet and penetration in sand, water and gelatin by spheres, 7.62 mm APM2, and 25 mm projectiles. Defence Technology. 2016 Jan 8;12(2):159–70. doi.org/10.1016/j.dt.2015.12.004
26. Nishshanka B, Shepherd C. AK bullet (7,62 × 39 mm) ricochet off flat, wooden targets; A forensic-based study. Forensic Science International. 2021 Jul 13;326:110903. doi.org/10.1016/j.forsciint.2021.110903
27. Vakil MT, Singh AK. A review of penetrating brain trauma: epidemiology, pathophysiology, imaging assessment, complications, and treatment. Emergency Radiology. 2017 Jan 14;24(3):301–9. doi.org/10.1007/s10140-016-1477-z
28. Farrugia A, Raul J, Géraut A, Ludes B. Ricochet of a Bullet in the Spinal Canal: A case report and review of the literature on bullet migration. Journal of Forensic Sciences. 2010 Apr 29;55(5):1371–4. doi.org/10.1111/j.1556-4029.2010.01439.x
29. Arunkumar P, Maiese A, Bolino G, Gitto L. Determined to die! Ability to act following multiple self-inflicted gunshot wounds to the head. The Cook County Office of Medical Examiner Experience (2005–2012) and review of literature. Journal of Forensic Sciences. 2015 Apr 4;60(5):1373–9. doi.org/10.1111/1556-4029.12780

30. Slobodan S, Slobodan N, Djordje A. Popliteal artery bullet embolism in a case of homicide: a case report and review of the tangible literature. Forensic Science International [Internet]. 2003 Nov 20;139(1):27–33. Available from: https://doi.org/10.1016/j.forsciint.2003.09.014

31. Tong D, Beirne R. Combat body armor and injuries to the head, face, and neck region: A Systematic review. Military Medicine. 2013 Apr 1;178(4):421–6. doi.org/10.7205/milmed-d-12-00522

32. Elkbuli A, Carlin M, Ngatuvai M, McKenney M, Boneva D. Survival following devastating penetrating gunshots polytrauma with grade 5 liver injuries requiring multiple massive transfusion protocols: A case report and review of the literature. International Journal of Surgery Case Reports. 2022 Sep 1;98:107608. doi.org/10.1016/j.ijscr.2022.107608

33. Børvik T, Hopperstad OS, Langseth M, Malo KA. Effect of target thickness in blunt projectile penetration of Weldox 460 E steel plates. International Journal of Impact Engineering. 2002 Dec 30;28(4):413–64. doi.org/10.1016/s0734-743x(02)00072-6

34. Majid MSA, Birch RS, Jais MI, Senin HB, Idris NH. The effects of varying target hardness on ricochet angle. AIP Conference Proceedings. 2007 May 9;85–9. doi.org/10.1063/1.2739830

35. Vermeij E, Rijnders M, Pieper P, Hermsen R. Interaction of bullets with intermediate targets: Material transfer and damage. Forensic Science International. 2012 Sep 19;223(1–3):125–35. doi.org/10.1016/j.forsciint.2012.08.016

36. Sam MN, Yee GTJ, Hamzah NH, Embi MZ, Rejab AZM, Gabriel GF, et al. Effects of shooting angles and ricochet angles on bullet weight upon impact on three types of woods (Balau, Resak, and Seraya). Pertanika Journal of Science & Technology. 2023 Mar 30;31(3):1475–91. doi.org/10.47836/pjst.31.3.19

37. Burnett, B. Nose or base Strike: Analysis of bullet orientation in a ricochet, Case Study. 2005

38. Walters M, Liscio E. The accuracy and repeatability of reconstructing single bullet impacts using the 2D Ellipse method. Journal of Forensic Sciences. 2020 Feb 24;65(4):1120–7. doi.org/10.1111/1556-4029.14309

39. Neculai-Daniel Zvîncu, Cristian-Emil Moldoveanu, Ioan Vedinaș, Material deflection and bullet ricochet determinations for different angles of firing on a concrete plate, Proceedings of International Scientific Conference, 2020.

40. Nishshanka B, Shepherd C, Ariyarathna R. AK bullet (7.62 × 39 mm) holes on 1-mm sheet metal: A forensic-related study in aid of bullet trajectory reconstruction. Journal of Forensic Sciences. 2021 Jul 1;66(4):1276–84. doi.org/10.1111/1556-4029.14717

41. Nishshanka B, Shepherd C, Paranirubasingam P. Forensic based empirical study on ricochet behaviour of Kalashnikov bullets (7.62 mm × 39 mm) on 1 mm sheet metal. Forensic Science International. 2020 May 10;312:110313. doi.org/10.1016/j.forsciint.2020.110313

42. Yilmaz Ü, Kaya O, Çakir M. Investigation of Ricochet Angles for 5 mm Various Metal Plates with AP 7.62 Bullets. Sakarya University Journal of Science. 2022 Jan 4;26(1):185–94. doi.org/10.16984/saufenbilder.942038

43. Farouk B, Segletes SB. Ricochet of High Speed Aluminium Projectiles From a Steel Plate. ASME. 2016 Nov 11; doi.org/10.1115/imece2016-65164

44. Wu Y, Tao X, Xue Y. Analytical investigation of ricochet range of OGIVE—Shaped nose projectile obliquely penetrating thick steel target. Applied Sciences. 2022 May 6;12(9):4692. doi.org/10.3390/app12094692

45. Børvik T, Olovsson L, Dey S, Langseth M. Normal and oblique impact of small arms bullets on AA6082-T4 aluminium protective plates. International Journal of Impact Engineering. 2011 Feb 10;38(7):577–89. doi.org/10.1016/j.ijimpeng.2011.02.001

46. De Kinder J, Lory S, Van Laere W, Demuynck E. The deviation of bullets passing through window panes. Forensic Science International. 2002 Jan 1;125(1):8–11. doi.org/10.1016/s0379-0738(01)00607-7

47. Hirakawa S, Saimoto A, Ishimatsu T. The Critical Angle for Perforation versus Ricochet of a .38 CAL. LRN Bullet on a Windshield. Journal of Forensic Sciences. 2016 Mar 25;61(4):1080–4. doi.org/10.1111/1556-4029.13060

48. Salimi B, Vahedi K, Petrudi AM, Rahmani M. Optimization and Numerical Analysis of the Ricochet of Conical Nose Projectile in the Collision with Ceramic-Aluminum Armor. Journal of Advanced Mechanical Engineering Applications. 2020 Aug 23;1(2). doi.org/10.30880/jamea.2020.01.02.006

49. Baillargeon Y, Bergeron G. Prediction of projectile ricochet behavior after water impact*. Journal of Forensic Sciences. 2012 Apr 26;57(6):1556–61. doi.org/10.1111/j.1556-4029.2012.02170.x

50. Mirshak R. Collateral damage risk: Quantifying the water surface bullet ricochet problem. IEEE Xplore. 2010 Nov 1;1–7. doi.org/10.1109/wssc.2010.5730264.

51. Yong YE. A systematic review on ricochet gunshot injuries. Legal Medicine. 2017 Mar 10;26:45–51. doi.org/10.1016/j.legalmed.2017.03.003
52. Jason A, Haag LC. Bullet Entry Holes in Fabric: Fibers, facts, and fallacies. Vol. 46, AFTE Journal. 2014 season-01 p. 134.
53. DiMaio VJM. Gunshot wounds: Practical Aspects of Firearms, Ballistics, and Forensic Techniques, Third Edition. CRC Press; 2015.
54. Nishshanka MB, Paranirubasingam P, Shepherd C. A forensic-based study on low-angled AK rifle bullet entry wounds using a porcine model. Journal of Forensic and Legal Medicine. 2020 Jul 18;74:102025. doi.org/10.1016/j.jflm.2020.102025
55. Bailey JA. Analysis of bullet wipe patterns on cloth targets - ProQuest.
56. Randich E, Duerfeldt W, McLendon W, Tobin W. A metallurgical review of the interpretation of bullet lead compositional analysis. Forensic Science International. 2002 Jul 1;127(3):174–91. doi.org/10.1016/s0379-0738(02)00118-4.
57. Almog J. Firearms: Identification of handling of Firearms/Trace metal detection. Wiley Encyclopedia of Forensic Science. 2009 Apr 17; doi.org/10.1002/9780470061589.fsa345
58. M.G. Haag, L.C. Haag, Shooting Incident Reconstruction, second ed., Academic Press, San Diego, 2011.
59. Haag LC. Wound production by ricocheted and destabilized bullets. American Journal of Forensic Medicine & Pathology. 2007 Feb 20;28(1):4– 12. doi.org/10.1097/01.paf.0000257398.35411.d6
60. Traces of Ricocheted Action Safety Bullets : The American Journal of Forensic Medicine and Pathology. LWW.
61. Gusentsov A. Effect of incident angle on the shape of entrance wounds in experimental targets resulting from a ricochet when fired from a 9mm Makarov pistol. AFTE J. 2014 Jan 1;46(1):72–5.
62. Mattijssen EJ a. T, Alberink I, Brouwer SD, Kerkhoff W. The influence of wood grain on the bullet's ricochet behavior. Journal of Forensic Sciences. 2016 Jan 4;61(3):765–72. doi.org/10.1111/1556-4029.13023
63. Backman ME, Goldsmith W. The mechanics of penetration of projectiles into targets. International Journal of Engineering Science. 1978 Jan 1;16(1):1–99.
64. Li QM, Chen XW. Penetration and Perforation into Metallic Targets by a Non-deformable Projectile. Engineering Plasticity and Impact Dynamics. 2001 Dec 1;173–92. doi.org/10.1142/9789812794536_0010
64. Rusinek A, Rodríguez-Martínez JA, Arias A, Klepaczko JR, López-Puente J. Influence of conical projectile diameter on perpendicular impact of thin steel plate. Engineering Fracture Mechanics. 2008 Feb 2;75(10):2946–67. doi.org/10.1016/j.engfracmech.2008.01.011
65. Haag LC. Bullet penetration and perforation of sheet metal. AFTE J, 1997.

Review Article

The Importance of Biological Traces in Investigative and Criminal Proceedings

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Abstract

Biological traces originating from a human, whether it is a victim or an attacker, or from other persons who happened to be there accidentally or intentionally – are of great importance. These are traces of blood in various quantities and forms, traces of semen, sweat, hair, feces, urine, vomit, meconium. The method of collecting, packaging and processing these traces falls within the scope of the work of the police forensic service, and the found material is processed in forensic laboratories. The aim of this paper is to examine and explain the importance of biological traces in investigative and criminal proceedings, i.e. their use to determine the identity of the person to whom they belong, the relationship between the victim and the attacker during the commission of the crime, the type of participation in a traffic accident, etc. Thanks to these traces, it is possible to find answers to the questions sought by investigative authorities related to a specific case.

Keywords: biological traces; blood;semen; sweat; hair; feces; urine; forensic medicine.

Introduction

Forensic autopsy, as an indisputable method of determining the cause of death and numerous facts related to it, is only one part of the investigative actions in the process of collecting data and evidence that will provide the investigative authorities with answers to the questions asked in connection with a specific case. Forensic technical research, in addition to photographing the place of death or related to it, and everything that preceded and followed it, includes collecting traces that were left on the corpse, its clothing and footwear, and the surroundings. Also, traces of struggle, contact between the attacker and the victim are collected, among other things, from the clothing and footwear of the possible attacker, from his body parts, the vehicle in which they were after the event, and from the room in which the event took place, or in which he stayed afterwards.[1,2,3]

Biological traces of human origin

The investigator is interested in clues that arose during and in connection with the event, therefore, those that are relevant to criminal law, and not others that are unrelated to the event.[2,4,5]

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To eliminate any doubt about the identity of the sample, each trace or trace-bearing object must bear a permanent identification mark from the moment it is fixed at the scene until the procedure is completed.[6]

A trace becomes material evidence if the elements that determine its origin, or the method of its creation, are identified and proven (identification).

An expert witness does not always have the objective ability to determine or rule out with absolute certainty, by applying scientific methods, the origin or manner of occurrence of a trace, and therefore to express his opinion in degrees of probability, where the assessment "possible" means about 50% of the absolute value, "low probability" about 60%, "high probability" about 80%, and "very high probability" about 90%. In such cases, the evidence is subject to the assessment of the court.

Material traces, can be of various origins. They can come from weapons and implements used to commit murder or inflict injury, or they can indicate the time of death based on changes in the environment or the place where the body was found. [1,2,7,8,9]

The results of laboratory research on biological traces of human origin are used to determine the identity of the person to whom they belong, the relationship between the victim and the attacker during the commission of the crime, the behavior of the victim and the perpetrator after the event. In addition to traditional research, the most commonly used method today is the determination of DNA profiles.[3,10,11,12]

Blood

Blood can be found at the scene of an incident and in its surroundings in many forms, depending on the size and type of injured blood vessel, the amount of blood that has leaked, the relationship between the injured body part and the surface, body movement, etc.[1,2,3]

Blood can also be found on objects used to commit a crime (e.g. a knife).[5,6,7]

If blood drips vertically onto a surface, depending on the height, circular spots with uneven edges in the form of short arms are formed around the spot. If blood drips at an angle to the objects on which it falls, the spots have a more or less elongated shape, depending on the sharpness of the angle. When an injured person moves, the blood trail has a specific shape that indicates the direction of movement of the body or the part of the body from which the injured person is bleeding. This trail is in the form of an elongated blood stain with several smaller elongated spots that are created in the direction of movement.[1, 2, 3, 13]

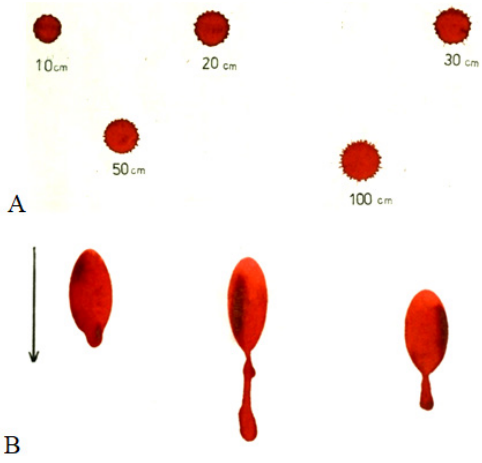

Fig. 1: A -Traces of vertical blood dripping from different heights; B -Traces and direction of blood dripping down a vertical side (Dobričanin, 2004.)[2]

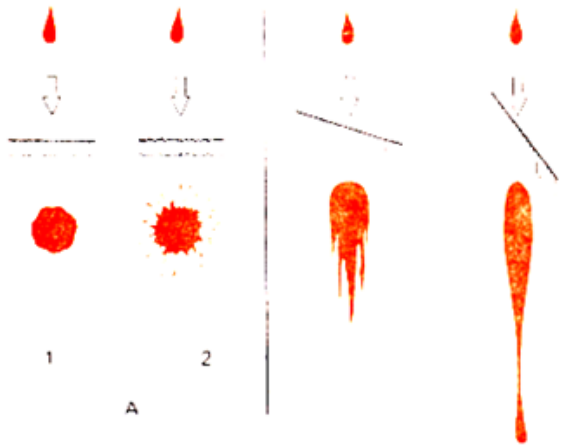

Fig. 2: Blood dripping onto a horizontal and inclined surface(Dobričanin, 2004.)[2]

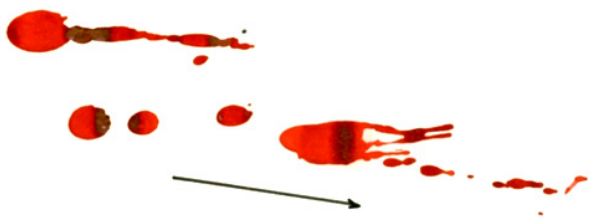

Fig. 3: Direction of movement of the person from whom the blood traces originate(Dobričanin, 2004.)[2]

Fig. 4: When you hit a bloody surface, blood sprays in various directions(Dobričanin, 2004.)[2]

Collection and transportation of blood samples

If blood is on fabric, it is collected with it, and if it is on shoes, glass or smooth surfaces, it is removed with filter paper with water or saline. Blood from walls and floors is removed by scraping, and if it is on wood or paper, it is collected with that material. In the case of traces under the nails, the nails are cut off. The collected traces are placed in plastic or paper containers, properly labeled and transported for further processing.[1,13]

Wet blood stains and clots are collected in a test tube with saline. [5,6,13]

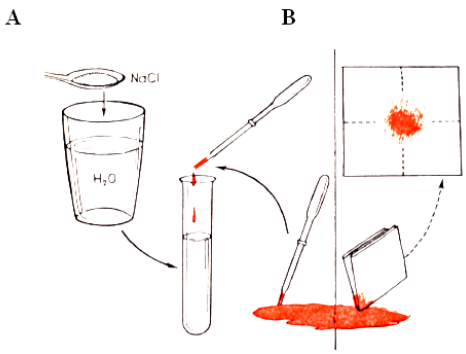

Fig. 5: Collection of liquid or clotted blood samples from a wet spot: A – into a test tube with saline solution and B – onto a clean cloth or filter paper(Dobričanin, 2004.)[2]

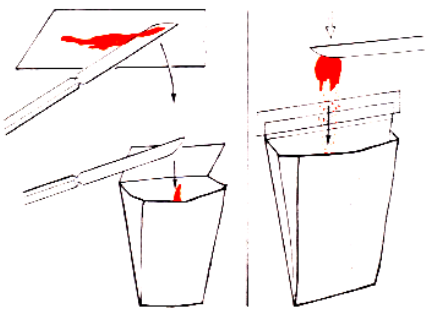

Fig. 6: Removing dried blood stains from horizontal and vertical surfaces (Dobričanin, 2004.)[2]

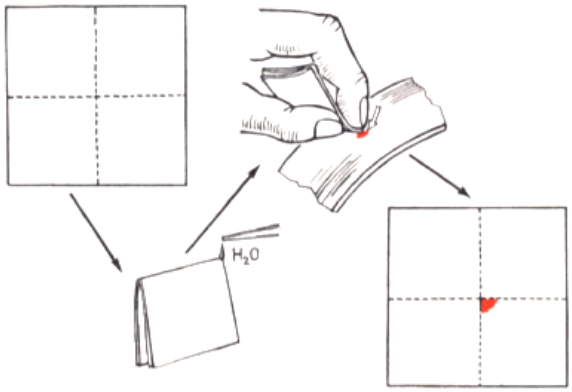

Fig. 7: Removing small blood stains from a non-absorbent slanted surface (Dobričanin, 2004.)[2]

Blood trace analysis

Various tests are used to confirm whether a stain is blood. Orientation tests react to the presence of catalase and peroxidase in the blood, while selective tests detect specific crystals in the presence of hemoglobin.

Basic tests include:

1. Benzidine test - Shows a blue color change in the presence of blood.
2. Leucomalachite green test - A green color appears if blood is present.
3. Luminol test - Uses chemiluminescence to detect blood.
4. Kastle-Meyer test - A pink color change indicates the presence of blood.

Selective methods include the formation of specific crystals that indicate hemoglobin, such as Tichmann crystals and reaction with acetone and hydrochloric acid.

Once the stain is determined to be blood, methods are used to determine the origin of the blood (human or animal), as well as whether it is male or female, or if it is menstrual or fetal.

Methods such as precipitin reaction and electrophoresis can help determine the origin of the blood, and specific detectors such as Barr bodies for females and fetal hemoglobin tests for newborns.

A recent study shows that attenuated total reflectance Fourier transform infrared (ATR FT-IR) spectroscopy combined with chemometrics can effectively estimate the time since deposition of blood

from a crime scene. In their study, the researchers analyzed 960 bloodstains on a variety of surfaces, both indoor and outdoor, over a period of 212 days to develop models for predicting the time since deposition (TSD). They focused on four different surfaces: white cotton woven fabric, plain cellulose paper, filter paper, and glass.[14]

The research team used ATR FT-IR spectroscopy because it provides a detailed molecular fingerprint, allowing them to track how the composition of the blood changes over time. PLSR models demonstrated strong predictive capabilities, with residual predictive deviation (RPD) values exceeding 3 and R^2 values greater than 0.90. Notably, the models performed better on non-rigid surfaces, such as cloth and paper, than on rigid surfaces such as glass. These models can reliably estimate how long a bloodstain has been present, whether it is on cloth in a dark indoor environment or on paper exposed to outdoor conditions. [14]

UV-vis spectroscopy has been extensively studied, but near-infrared (NIR) spectroscopy, despite its potential advantages, has received less attention. A recent study addresses this gap by comparing NIR and UV-vis spectroscopy for forensic dating of bloodstains.15 The study aimed to evaluate NIR spectroscopy for estimating the age of bloodstains. Classical preprocessing methods such as Savitsky-Golay derivatives and standard normal variance (SNV) transformation were used, along with targeted strategies such as cluster centering, which have been shown to be effective through principal component analysis (PCA). Partial least squares (PLS) regression models were then applied to assess the accuracy of the methods in estimating the time since deposition (TSD) of bloodstains. The results showed that both NIR and UV-vis spectroscopy were comparable in estimating TSD, with root mean square errors of prediction (RMSEP) of approximately 40 hours for UV-vis and 55 hours for NIR. These findings suggest that NIR could be a promising tool for dating bloodstains, with further improvements over previous studies. [15]

The authors conclude that NIR spectroscopy, with the right chemometric strategies, holds great promise for forensic dating of bloodstains, but further research is needed to refine these methods for practical use in real cases. [15]

Sperm

Traces of semen can be found in cases of rape, murderof women, in places such as the oral cavity, female genitalia, anus, and other parts of the body. Traces can also be found on clothing, underwear, and bedding.

Sperm is whitish-yellow in color and leaves characteristically shaped stains. They can be seen on the skin under ultraviolet light. If the presence of sperm is suspected, swabs or scrapings are taken from the skin, and the suspicious stain is cut from the clothing and bedding.

The origin of the stain is determined by semen analysis, as well as acid phosphatase tests. If sperm are absent, microcrystallographic tests such as the Florence and Barbieri tests, which are not specific for sperm, are used. [2,3,5,6,16]

Acid phosphatase is an enzyme secreted by prostate cells and is a regular component of seminal fluid. The amount of acid phosphatase is expressed in King-Armstrong units. There are about 2,500 King-Armstrong units of acid phosphatase in 1 ml3 of seminal fluid.

"Phosphatabs Acid" is reagent is produced in the form of two tablets: yellow and silver. The reaction itself is carried out as follows: the stain, which is assumed to contain traces of sperm, is placed together with the substrate in a porcelain laboratory cup and two milliliters of distilled water are poured over it. After standing for 30 minutes, the extract is separated and placed in an amount of 0.2 ml in a prepared test tube, and a silver-colored reagent tablet is placed on it and crushed with a glass rod. Depending on the temperature in the laboratory, this solution is left in the test tube for about 20 minutes. After that, a yellow reagent tablet is placed in the test tube, which is also crushed well. After 3 minutes, a brownish-purple color appears, which may vary in intensity. The color intensity is compared with a graph showing the determined values of acid phosphatase for individual degrees of color change. [5,6,16]

Next-generation sequencing (NGS) marks a major breakthrough in forensic genomics, enabling high-throughput in-depth genetic analysis and is particularly valuable in cases where sperm are present in low quantities or have undergone degradation.

Benefits of NGS in forensic sperm analysis: High sensitivity[17], Comprehensive profiling[18] and Resistance to degradation: NGS can effectively process degraded DNA samples, which is a common problem in forensic investigations where sperm may have been exposed to adverse environmental conditions.

Artificial Intelligence (AI) capabilities in forensic sperm analysis, such as image recognition, pattern identification, and predictive modeling, offer substantial advantages.

Benefits of AI in Forensic sperm analysis:

1. Automation: AI can simplify sperm identification and counting, reducing human errors and speeding up analysis.[19,20]
2. Increased accuracy.[17]
3. Predictive analytics.[21]

Flow cytometry (FC) is a powerful method that evaluates the physical and chemical properties of cells or particles as they pass through a light beam in a fluid stream. In forensic semen analysis, this technique allows for more precise identification and quantification of sperm cells.

Benefits of FC in forensic semen analysis:

1. High throughput: FC can process thousands of cells per second, making it ideal for analyzing large volumes of forensic samples.[18]
2. Multi-parameter analysis. [22]
3. Specificity.[20]

Microfluidic devices, or lab-on-a-chip systems, manipulate tiny fluid volumes through channels on a microscopic scale. These devices offer precise control over biological samples, making them ideal for forensic sperm analysis.[23]

These devices enable highly efficient sperm analysis, especially in cases where sample volume is limited.[17,18]

Secret from the nose

The forensic significance of this secretion comes down to determining the group in dried stains on pocket handkerchiefs from the scene of the incident in order to "identify" the owner.

In practice, however, these stains do more harm than good: when traces of blood or semen are found on the tissue, the nasal secretion stains significantly interfere with the analysis and make the interpretation of the results more difficult.[4,5,7]

Sweat

Sweat interferes with analysis. For example, if a blood type 0 stain on a cloth soaked in sweat from a type A person gives a result that corresponds to type A, the expert must take this influence into account.[1,2,3]

Urine

Urine stains are rarely taken for analysis. In practice, this is done when we want to check whether a person has been lying unconscious for a long time or has been forcibly confined or immobilized (tied) in one place and/or in cases where it is necessary to determine whether urine was maliciously poured on a helpless person.[2]

Excrement

Feces may be submitted for examination in cases of malicious coating of objects, or even a person, with feces, in cases where the perpetrator relieves himself at the scene of the crime, in cases where the perpetrator steps on feces found at the scene of the crime with his shoes, etc.[5,6,10,11]

The possibilities of identifying the person from whom the feces originated are minimal: if intestinal parasite eggs are found in a disputed stool sample and such eggs are not found in the feces of the suspect, the finding will provide grounds to exclude the suspect.

Hair

Hair is a common biological trace that serves to shed light on significant facts related to the commission of a crime.[24,25]

The morphology of hair is such that it cannot be replaced by fibers of any origin.[26] Hair grows an average of 0.5 mm per day. [2,3]

The difference between human and animal hair is based on the ratio of the cortex to the medulla. In humans, the medulla is narrow and the cortex is wide, while in animals the medulla is wide and the cortex is narrow. [2,3]

In the case of a relatively close-range gunshot wound, unburned gunpowder particles can also be found on the hair. In close-range gunshot wounds, the hair is tanned, partially burned. [27,28]

A specially modified absorption method can be used to determine the blood type of people who belong to the secretor group.

The identity of a person is established by determining the DNA profile of the hairs found, which must be at the root, which is compared with the DNA profile of the suspect.

Hair collection and packaging

They can be collected with a vacuum cleaner with a filter, tweezers, or clear adhesive tape, or the specific item can be completely packaged.[28]

Individual hairs are packaged in small cellophane bags or smaller envelopes of clean white paper, each of which is marked with its location and placed in a common envelope. It is incorrect to place the hairs directly in a large envelope.[1,2,3]

Due to the serrated structure of the outer membrane, when hair falls out, it easily gets caught on rough objects. [24]

The method of collecting hairs depends on the location of the finding: on smaller objects that can be transported, and on which hairs are found stuck or stuck together by blood, the area with the hairs is tightly wrapped with white paper, and the paper is secured with adhesive tape.[2,3,6,8,24]

Firmly attached hairs, along with objects that can be transported, are best removed with dry fingers, because using tweezers can damage them and, if the grip is not secure, they can be lost. Sometimes it is necessary to resort to using adhesive transparent tape to safely collect hair fragments: a piece of tape with the material taken sticks to another part of the unused tape, which practically makes a ready-made preparation for microscopic examination of the material.

When taking samples from the head of a known person for the purpose of comparison with disputed samples, we must keep in mind the way in which the specific disputed sample was obtained: if it was obtained by plucking, the comparative sample should also be taken by plucking; about twenty hairs are plucked from near the wound on the head.[1,2,9,10]

Fig. 8: Hair samples from the wound area are taken by plucking, not cutting (Dobričanin, 2004.)[2]

A new application using artificial intelligence could revolutionize the way scientists study hair. The AI model speeds up and simplifies the process of quantifying hair, allowing a microscope to scan slides and collect images of hundreds of hairs at once. In seconds, it can capture a wealth of high-resolution data that is then processed by a deep learning algorithm that captures the color, shape, width and length of each individual hair.[29]

The researchers trained a computer vision model with artificial intelligence to identify hair using VSU's high-performance computing cluster, Kamiak. With the additional help of an Aperio GT450 microscope at the Washington Animal Disease Diagnostic Laboratory, high-resolution imaging of hair fibers has been automated.[29]

The application has many implications, including forensics. The new technology could not only identify the species from which the hair was derived, but also shed light on the age, health, and ethnicity of people, which could help in criminal investigations.[29]

Spit

Traces of saliva are most often found on cigarette butts, postage stamps, and envelopes. In a saliva stain from a secretor, it is possible to determine the presence of amylase and the person's blood group. From a saliva stain, the DNA profile of the person to whom it belongs can be determined.[30]

Regarding the possibility of determining the group in saliva on envelopes and stamps, we must mention the negative impact of glue.[30]

Saliva samples for comparison are taken by having the suspect wet the edge of a clean piece of paper, mark the area with a pencil and let it dry. In

addition, the suspect is instructed to affix the stamp and envelope with his/her saliva, or in cases of cigarette butt searches, to smoke a cigarette with or without a filter, depending on the type of cigarette butt in question.[1,2,3,5,6]

Conclusion

Traces of human origin are of exceptional importance. A large number of unsolved crimes have been solved thanks to this type of forensic examination, after many years.

Conflict of interest: None

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References

1. Di Maio, DJ.; Di Maio, VJM. Forensic Pathology. Boca Raton. CRC Press, 2001.
2. Dobričanin, S. Forensic Medicine, Creative Workshop, Kruševac, 2004.
3. Gorkič, S. Medical forensics. Privredna štampa, Belgrade, 1981.
4. Knight, B.; Saukko, P. Forensic Pathology. Arnold, Oxford University Press, 2004.
5. Milovanović, M. Forensic medicine, Belgrade - Zagreb, 1975.
6. Škavić, J.; Zečević, D. Principles of forensic medical expertise. Zagreb: Naklada Ljevak, 2010.
7. Virkler, K.; Lednev, IK. Analysis of body fluids for forensic purposes: from laboratory testing to non-destructive rapid confirmatory identification at a crime scene. Forensic Sci Int. 2009 Jul 1;188(1-3):1-17. doi: 10.1016/j.forsciint.2009.02.013.
8. Recipon, M.; et al. Detection of invisible biological traces in relation to the physicochemical properties of substrate surfaces in forensic casework. Sci Rep. 2024 Jun 10;14(1):13271. doi: 10.1038/s41598-024-63911-1.
9. Bethard, JD.; DiGangi, EA. Letter to the Editor—Moving Beyond a Lost Cause: Forensic Anthropology and Ancestry Estimates in the United States. J Forensic Sci. 2020;65(5):1791–2. doi: 10.1111/1556-4029.
10. Stull, KE.; et al. Commentary on: Bethard JD, DiGangi EA. Letter to the Editor—Moving beyond a lost cause: Forensic anthropology and ancestry estimates in the United States. J Forensic Sci. 2020;65(5):1791–2. 10.1111/1556-4029.14513. J Forensic Sci. 2021;66(1):417–20. doi: 10.1111/1556-4029.
11. DiGangi EA, Bethard JD. Uncloaking a Lost Cause: Decolonizing Ancestry Estimation in the United States. American Journal of Physical Anthropology. 2021 Jan;175(2):422–436.doi:10.1002/ajpa.24212.
12. Varela Morillas, Á.; Suhling, K.; Frascione, N. Unlocking the potential of forensic traces: Analytical approaches to generate investigative leads. Sci Justice. 2022 May;62(3):310-326. doi: 10.1016/j.scijus.2022.03.005.
13. José, FQ.; et al. Evaluation and identification of blood stains with handheld NIR spectrometer, Microchemical Journal, Volume 133, 2017, Pages 561-566, https://doi.org/10.1016/j.microc.2017.04.038 .
14. Mengual-Pujante, M.; et al. Estimation of Human Bloodstains Time Since Deposition Using ATR FT-IR Spectroscopy and Chemometrics in Simulated Crime Conditions. Chemom. Intell. Lab. Sys. 2024, 251, 105172. DOI: 10.1016/j.chemolab.2024.105172.
15. Gariglio, S.; et al. Determination of time since deposition of bloodstains through NIR and UV-Vis spectroscopy–a critical comparison. Talanta 2024, 278, 126444. DOI: 10.1016/j.talanta.2024.126444.
16. Bauer, M.; Patzelt, D. Protamine mRNA as molecular marker for spermatozoa in semen stains. Int J Legal Med, 117, 2003, pp. 175-179.
17. Rivera, R. et al. The Mechanism of Action of Hormonal Contraceptives and IntrauterineContraceptive Devices. American Journal of Obstetrics and Gynecology, vol. 181, no. 5, Nov. 1999, pp.1263–69.
18. Saric, N. et al. A Preliminary Investigation of Transfer of Condom Lubricants in the VaginalMatrix. Forensic Science International, vol. 325, May 2021, p. 110847.
19. Prachi, K. et al. The Development, Status and Future of Forensics in India. Forensic Science International Reports, vol. 3, June 2021, p. 100215.
20. Pundir, C. et al.The Prevalence of Polycystic Ovary Syndrome: A Brief Systematic Review.Journal of Human Reproductive Sciences, vol. 13, no. 4, Jan. 2020, p. 261
21. Tozzo, P. et al.Combined Statistical Analyses of Forensic Evidence in Sexual Assault: A CaseReport and Brief Review of the Literature. Journal of Forensic Sciences, vol. 65, no. 5, July 2020, pp.1767–73.
22. Zeng, X. et al. Mitochondrial Dysfunction in Polycystic Ovary Syndrome. DNA And Cell Biology,vol. 39, no. 8, Feb. 2020, pp. 1401–09.

23. Myers, SJ. et al.Effect of Menstrual Cycle and Hormonal Contraception on Musculoskeletal Healthand Performance: Protocol for a Prospective Cohort Design and Cross-Sectional Comparison. JMIRResearch Protocols, vol. 13, July 2024, p. e50542.
24. Sharma, R.; et al. Trace element contents in human head hair of residents from Agra City, India Bull Environ ContamToxicol, 72 (2004), pp. 530-534
25. Gilchrist, E.; et al. Probing gunshot residue, sweat and latent human fingerprints with capillary-scale ion chromatography and suppressed conductivity detection. Analyst, 137 (2012), pp. 1576-1583.
26. Kosińska, A.; et al. The smallest traces of crime: Trace elements in forensic science. J Trace Elem Med Biol. 2024 Dec;86:127527. doi: 10.1016/j.jtemb.2024.127527.
27. Klaasse, JR.; et al. TraceBase; A database structure for forensic trace analysis. Sci Justice. 2021 Jul;61(4):410-418. doi: 10.1016/j.scijus.2021.03.001.
28. Sacco, MA.; et al. The Role of Molecular Investigations in Estimating the Time Since Deposition (TSD) of Bloodstains: A Systematic Review of the Literature. Int J Mol Sci. 2024 Jul 8;25(13):7469. doi: 10.3390/ijms25137469.
29. Makkar, J.; et al. Deep Hair Phenomics: Implications in Endocrinology, Development, and Aging. Journal of Investigative Dermatology, 2024; DOI: 10.1016/j.jid.2024.08.014
30. Virkler, K.; Lednev. IK. Forensic body fluid identification: the Raman spectroscopic signature of saliva. Analyst, 135, 2010, pp. 512-517.

Review Article

Sewer Gas Toxicity: A Literature Review

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Abstract

Sewer gas toxicity is still a major concern even today, and we still have deaths reported from sewer gas toxicity especially among the people who work within sewers. These gases are highly toxic when inhaled in large amount or when inhaled for prolonged period of time. Sewer gas is a combination of Hydrogen Sulphide, Ammonia, Carbon-dioxide, Sulphur dioxide, Nitrogen dioxide, and carbon monoxide. Hydrogen sulphide, in combination with CO2 and Methane, formed in sewers, is known as 'sewer gas.' Sulphuretted hydrogen is the principal and dangerous component in sewer gas. It produces multi organ involvement and it is crucial to timely diagnose and provide high quality resuscitation and care to prevent complications including deaths. Therefore, clinicians must be aware about this toxicity.Though manual scavenging has been prohibited by Indian law, still a lot number of lives are lost while cleaning sewage and in manholes. This is due to the toxic gases formed within the sewage due to decomposition, collectively known as sewer gases. The clinical presentation is wide and varied and has high mortality rate, if not treated in time. The treatment includes timely identification. decontamination, specific antidotes including amyl nitrite, sodium nitrite, bronchodilators and even hyperbaric oxygen therapy would be helpful in severe cases. But as always prevention is better than cure. Hence people involved in manual scavenging should be given all safety equipments and adequate protective gears because 'all lives matter'. This is a narrative literature review on sewer gas toxicity to create awareness among clinicians that this toxicological emergency exists, though not widely discussed. According to the National Commission for SafaiKaramcharis (NCSK), 1298 deaths were reported from 1993 to 28thFebruary 2025.

Keywords: sewer gas, hydrogen sulphide, manual scavengers, amyl nitrite

Introduction

Sewers posenumerous dangers for those who work within them. They containa variety of gases that can be extremely toxic when inhaled and result inseveral complications, including death. Exposure to toxic gas is aneminent hazard for sewer workers who work in a closed space; the significant hazard is hypoxia due to the accumulation of methane, carbon dioxide, or hydrogen sulphide and explosive risk as a result of flammable gases. These gases can be

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extremely toxic if inhaled in high concentrations or for a prolonged period. Sewer gas toxicity and related deaths occur still, since manual scavenging system is still prevalent.

Epidemiology and Prevalence

Septic tanks are relatively standard in residential and industrial areas to cater to sewage wastes. Septic tanks are enclosed areas made for the accumulation of decomposed domestic wastes, sewerage, and its resultant gases(1).Natural putrefaction and the mixture of sewage lead to the production of sewage gases. Sewer gas is a combination of Hydrogen Sulphide, Ammonia, Carbon-dioxide, Sulphur dioxide, Nitrogen dioxide, and carbon monoxide. Hydrogen sulphide, in combination with CO2 and Methane, formed in sewers, is known as 'sewer gas.' Sulphuretted hydrogen is the principal and dangerous component in sewer gas.Figure-1 shows the graph of total number of sewer gas or septic tank deaths, state-wise from 1993 till 28th February 2025 in India. According to the National Commission for SafaiKaramcharis (NCSK), 1298 deaths were reported from 1993 to 28th February, 2025.

Toxicity and Exposure

Hydrogen sulphide:

Persons exposed to hydrogen sulphide pose no risks of secondary contamination to a person outside the hot zone (area having highest potential of contamination), though, fatalities have occurred to the rescuers entering the hot zone. Hydrogen sulphide is a colourless, highly flammable and explosive gas produced naturally by decaying organic matter and by specific industrial processes. Hydrogen sulphide has adistinctive rotten-egg odour; yet, olfactory fatigue may occur, and therefore, it may not provide adequate warning of dangerous concentrations. Hydrogen sulphide is primarily absorbed through the lungs; skin absorption is minimal. Exposure by any route can have systemic effects.

Routes of Exposure: (2)

Inhalation:

1. Inhalation is the primary route of sewer gas exposure. The lungs rapidly absorb the gas. Although its strong odour is readily identified, olfactoryfatigue occurs at high concentrations and continuous low concentrations. Hence, the odour is not a reliable indicator of sewer gas's presence, and it may not provide adequate warning of hazardous concentrations.

Skin/eye contact:

Prolonged exposure to sewer gas, even at relatively low levels, can result in painful dermatitis and burning eyes. Frostbite can occur from direct contact with liquid gas. Absorption through intact skin is negligible.

Clinical features

Methane and carbon dioxide act as physical asphyxiants, producing anoxia by displacing oxygen in an enclosed space. Clinical symptoms are thus related to decreased oxygen tension in the blood and include tachycardia, hyperventilation, headache in low-level exposures, proceeding to confusion, loss of consciousness, and death at higher concentrations due to hypoxia(3).

In contrast, H2S and CO are classified as chemical asphyxiants; while CO interferes with oxygen delivery via formation of carboxyhaemoglobin, H2S interferes with cytochrome oxidase and aerobic metabolism, similar to hydrogen cyanide. Symptoms of CO poisoning range from headache, nausea, and dizziness at lower levels (10%–30% carboxyhaemoglobin) to visual disturbance, syncope, and eventually death when carboxyhaemoglobin levels reach 50%. It can produce severe symptoms at much lower concentration if associated with medical conditions that make individuals susceptible tohypoxia(3). H_2S acts as a tissue irritant at lower concentrations (up to 100–150 ppm), causing kerato conjunctivitis, respiratory irritation, lacrimation, and cough. At even this low level, olfactory fatigue/ paralysis occurs, and the warning "rotten egg" smell is lost. Relatively acute pulmonary edema occurs at levels of 300 ppm and higher. Acute exposure to very high concentrations (1000 ppm) causes instantaneous loss of consciousness, rapid apnea, and death if the victim is not immediately moved to fresh air; in these cases, the local irritant effects may not have time to develop (3). Toxic effects of sewer gas on various organ system are described in table 1

Table 1: Clinical Features of Sewer Gas Toxicity

Organ affected	Clinical features
Central Nervous System (CNS)	Loss of consciousness Coma Respiratory paralysis Seizures Death
Respiratory System (RS)	Irritation of the nose, throat Cough, shortness of breath Bronchitis Pulmonary oedema
Cardiovascular System (CVS)	Hypotension Arrhythmias Conduction defects
Gastrointestinal symptoms	Nausea Vomiting
Ocular	Kerato conjuctivitis
Dermal	Burning sensation Itching Painful inflammation

Mechanism of Action of sewer gas:

The hydrogen sulphide toxicity has been proposed mainly due to inhibition of cytochrome oxidase, which plays acrucial role in cellular mitochondrial respiration. In mitochondria, cytochrome oxidase is the final enzyme in respiratory chain, which is inhibited by hydrogen sulphide because of oxidative reduction of one of the enzymatic haems. Consequently, the electron transport chain is interrupted by stopping oxygen to act as final electron acceptor and leading to blockage of oxidative metabolism, which causes anaerobic metabolism and production of lactic acid [(4)]. The characteristic rotten egg odour is detectable at levels as low as 0.025 ppm. At levels between 100 and 150 ppm, the olfactory nerve becomes paralyzed, and the characteristic scent is no longer recognized, which allows for toxic exposures to occur. Levels of 10- 500 ppm cause various respiratory symptoms and fatal at 500- 1000 ppm. [(5)]

Case reports from literature: Several reports of rapid H2S intoxication by the pulmonary route in humans have been published.

A review of toxic inhalation fatalities among US construction workers during the 1990s by Dorevitch et al[(6)]. determined that 1.3% of all construction-related fatalities were due to acute toxic inhalation or oxygen exclusion. Just under 20% of these cases were due to H2S, and 26% occurred in sewers or sewer maintenance holes. The non-H2S sewer deaths were due to CO or oxygen exclusion. Water and sewer workers were among those occupations listed as the highest risk for occupational death due to poisoning—additionally, workers who were attempting to rescue their incapacitated co-workers composed 10% of the fatalities.

While classically associated with H2S exposure, the differential diagnosis for deaths occurring in sewers, like those presented here, includes oxygen exclusion due to high concentrations of Methane or carbon dioxide. Sulphur dioxide and ammonia are also possible agents as by-products of organic decomposition but are less commonly seen as causes of fatalities. Finally, carbon monoxide (CO) is a well-known hazard in confined spaces but is less likely in sewer gas as it is produced by combustion rather than decomposition. However, occasional deaths in sewers/maintenance holes have been attributed to carbon monoxide, which may have accumulated due to the use of gasoline-powered tools in the unventilatedsewer[(6)]. Memchoubi et al. reported two case reports of sewer gas toxicity; both the patients died before they reached the hospital[(7)]. Hariharan at al. reported a case of a 24-year-old male who died after five days of in-hospital treatment[(8)].

Available reports of death in India due to sewer gas toxicity is just the tip of the iceberg. Most of the deaths are reported either as accidental deaths due to some other reason or not reported at all. According to the data of the National Commission for SafaiKaramcharisunder the Ministry of Social Justice and Empowerment, Government of India, a total of 1298 workers lost their lives from 1993 till 28th February 2025 [(16)]. (Figure-1)

Laboratory Tests

All symptomatic exposed patients will require tests which include CBC, blood glucose, and electrolytes. Additional studies for patients exposed to hydrogen sulphide include ECG and renal-function tests. Pulse oximetry or ABG and chest radiography can be helpful in cases of inhalation exposure. If nitrites are used, check methemoglobin levels. (9)

Emergency Department Management

Treatment of massive inhalation of hydrogen sulphide toxicity is mainly supportive. The initial goal of treatment should be attention to the airway, breathing, and circulation. Currently, the treatment approach is not evidence-based (as in most toxicological hazards) and shares some features with the approach to cyanogenpoisoning.[9]

Hospital staff who are away from the scene are not at risk of secondary contamination from patients exposed only to sewer gas; however, staff can bese condarily contaminated by contacting orbreathing vapours from clothing heavilysoaked with sewer gas

Basic Decontamination

Conscious and able patients may assist with their decontamination. Remove and put the contaminated clothing and personal belongings in a double bag. Wash the hair and exposed skin with water for 5 minutes. Be cautious to avoid hypothermia while decontaminating children or the elderly. Use warmers or blankets when appropriate, irrigate the eyes for at least 5 minutes. Remove contact lenses if removable without causing additional trauma to the eye. An ophthalmic anaesthetic may be necessary to ease blepharospasm, and lid retractors may be required to allow adequate irrigation under the eyelids.

Critical Care Area

Shift the patient to a critical care area. Assess and support airway, breathing, and circulation. Children are more susceptible to corrosive agents than adults due to the smaller diameter of their airways. Establish intravenous access in all symptomatic patients. Monitor the cardiac rhythm continuously. Patients who are hypotensive, comatose or have seizures or cardiac arrhythmias should be treated conservatively. Give oxygen by mask to patients who have respiratory symptoms. Treat patients who have bronchospasm with bronchodilators.

Antidotes

Specific treatments for hydrogen sulphide toxicity include administration of amyl nitrite, sodium nitrite. Salbutamol and Ipratropium Bromide nebulizer treatments may be given for associated bronchospasm. Hydrogen sulphide has a higher affinity for methemoglobin than cellular cytochrome oxidases. Nitrite administration results in theformation of methemoglobin and thereby helps to reduce the metabolic toxicity of hydrogen sulphide by allowing for the conversion of hydrogen sulphide to the less toxic sulfmethemoglobin. Nitrites, nonetheless, can also result in hypotension, and methemoglobinemia will further decrease oxygen saturation. Furthermore, there is limited evidence supporting the use of nitrite therapy in hydrogensulphide poisoning. It should be used with caution. Amyl nitrite ampules (0.3 ml) may be inhaled by patients and can be repeated every 3-5 mins. Sodium nitrite is administered 0.33 mL/kg of 3% solution by a slow intravenous push to a maximum of 10 ml. It is important to note that thiosulfate should not be used in the treatment of hydrogen sulphide poisoning.

Nitrite therapy of cyanide antidote kit has been suggested as a therapy for hydrogen sulphide exposure. Amyl nitrite is given by inhalation route for 30 seconds every minute till an intravenous line is established, which is followed by intravenous sodium nitrite 300 mg over 5 minutes—this aid in recovery by forming sulfmethemoglobin, thus removing sulphide from the tissue. The antidotal efficacy of nitrite therapy is debatable. There is only circumstantial evidence that nitrite therapy is effective, and the victims of hydrogen sulphidetoxicity have survived without any sequelae after supportive care alone. Nitrite therapy should not interfere with the establishment of adequate ventilation and oxygenation.

Hyperbaric oxygen therapy may act by a competitive mechanism against H2S at the level of cytochrome oxidase [10,11] and may have a role in the prevention of both short and long-term neurological sequelae[12].

Disposition and Follow-up

Patients who are hypotensive or unconscious should be observed closely for any complication, like hypoxic encephalopathy. As pulmonary edemacan be delayed in onset, patients severely exposed to sewer gas inhalation should be monitored for atleast 24 hours. Moreover, if pulmonary edema is suspected, admit patients to an intensive care unit.

Asymptomatic patients without any signs of pulmonary edema or respiratory or CNS depression and no signs of eye irritation can be discharged after 4 to 6 hours of observation in Emergency Department (ED) with instructions to return to ED immediately if any symptoms develop.

Guidelines for Sewer Cleaning

The employer must take following safety measures when cleaning a septic tank or sewer:[13]

1. Before cleaning: Employers must ensure safety precautions before manual cleaning of a sewer.
    - Having a minimum of three employees present all time and one of whom shall be a supervisor.
    - Cleaning of a sewer to be done only in daylight and for a duration not exceeding 90 minutes at a time, with a compulsory break of 30 minutes between two shifts.
    - Before cleaning, the atmosphere within the confined space is to be tested for oxygen deficiency and the absence of poisonous and combustible gases.
    - To prevent injuries, the employer has to ensure that all the employees who are present on-site during cleaning work are trained and are acquainted with the knowledge to operate all the equipment which are involved in cleaning work and that they use protective gear and safety devices before entering a sewer line.
    - Regular medical check-up of workers, and regular vaccination against respiratory, skin and other occupational diseases to which they are prone, due to exposure to harmful substances and gases in sewers.

The employer is also required to ensure that every worker engaged in cleaning has a life insurance of at least ten lakh rupees, the premium for which shall be paid by the employer.

2. During and after cleaning: The employer is required to ensure that sufficient safety precautions are taken at the time when workers are cleaning a sewer line.
    - Include the presence of rescue equipment such as a tripod and harness system for maneuvering an injured worker to the surface, a basket stretcher or similar device for moving the injured worker to emergency transportation, first aid equipment, or an ambulance nearby.
    - Sewer gas detectors like portable multi gas detector can be used by people entering closed spaces.
    - The smallest gas detection instrument for upto five gases, the Drager X-am 5000 is a new generation detector.
3. Post-cleaning safety precautions have to be ensured by the employer when the worker comes out of the sewer after a session of cleaning. These include the facility for removal of contaminated clothing and wash-up as well as cleaning, dry clothing, and immediate treatment for any cuts/bruises on the skin or problems with a respiratory system suffered during cleaning.

National guidelines against direct manual handling of human excreta: [14]

The direct manual handling of human waste by sanitation workers has been banned in India since 1993 under the Employment of Manual Scavenging and Construction of Dry Latrines (Prohibition) Act, which has also banned the construction and maintenance of dry latrines. The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act went into effect on December 6, 2013, making manual scavenging illegal in India. The barring of Employment as Manual Scavengers and their Rehabilitation Act was notified by Central Government. This Act is a Parliamentary law, binding on all the states. While the earlier 1993 law forbid the employment of manual scavengers and construction of dry latrines, the strong point of the new Act is that it brings unsafe cleaning of sewers and septic

tanks under its domain. Ministry of Social Justice and Empowerment is planning to table "Prohibition of manual scavenger work and their rehabilitation amendment bill in 2020. This bill will ensure sewer cleaning completely machine operated, will also ensure better safety and compensation to the sewer workers.

Conclusion

Sewer lines continue to be health hazards as they produce sewer gases, which can be toxic to human beings. Sewer gas poisoning can be fatal if inhaled in high concentrations or for prolonged periods. H2S direct toxicity and subsequent cellular hypoxic induction may rapidly lead to multi-organic dysfunction and death, depending on the level of gas exposure. Management includes nitrites, hyperbaric oxygen therapy, and hydroxocobalamin. Preventive measures are crucial in preventing lethal exposure to hydrogen sulphide toxicity. Implementation of H2S detection equipment, air-supplied respirators in toxic or oxygen-deficient atmospheres, and confined space safety training could help to prevent most H2Srelated fatalities[15]. However, the mainstay of care relies on early supportive measures. Hypoxic injury to the vital organs can be challenging to treat, and a good outcome may not be possible in severe poisoning cases. Sewer gas toxicity should be kept in mind in any case of sudden death occurring in a confined space, especially in or around a sewer. Several people lose their lives annually while cleaning septic tanks and sewers, even though the Prohibition of Employment as Manual Scavengers and their Rehabilitation (PEMSR) Act, 2013 forbids the practice.

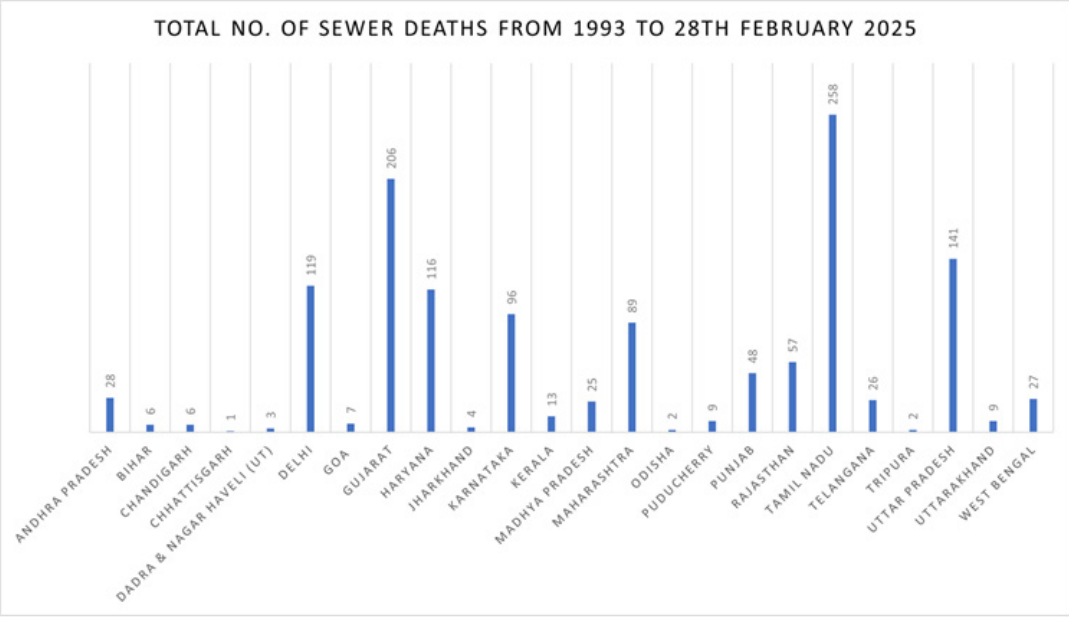

Figure 1: According to the data of the National Commission for SafaiKaramcharis under the Ministry of Social Justice and Empowerment, Government of India, a total of 1298 workers lost their lives from 1993 till 28th February 2025

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References

1. Whorton J. "The insidious foe"--sewer gas. West J Med. 2001 Dec;175(6):427-8. doi: 10.1136/ewjm.175.6.427. PMID: 11733443; PMCID: PMC1275984.
2. Chou, C. H. Selene J, World Health Organization & International Programme on Chemical Safety. (2003). Hydrogen sulfide: human health aspects. World Health Organization. https://apps.who.int/iris/handle/10665/42638
3. Harrison RJ. Chemicals and gases. Prim Care. 2000 Dec;27(4):917-82. doi: 10.1016/s0095-4543(05)70184-6. PMID: 11072294.
4. Namour P. The biogeochemical origin of sewage gases and control of their generation. Journal of Hazardous Materials Advances.2022 Aug;7:100124.

5. Doujaiji B, Al-Tawfiq JA. Hydrogen sulfide exposure in an adult male. Ann Saudi Med. 2010 Jan-Feb;30(1):76-80. doi: 10.4103/0256-4947.59379. PMID: 20103963; PMCID: PMC2850187.
6. Dorevitch S, Forst L, Conroy L, et al. Toxic inhalation fatalities of US construction workers, 1990 to 1999. J Occup Environ Med. 2002;44: 657–662
7. Memchoubi, Keisam S, Kamei R, Chanu L, Nabachandra H. Sewer Gas Poisoning: A Report of Two Cases. J Indian Acad Forensic Med. 2015;37(3):317
8. Hariharan U, Bhasin N, Mittal V, Sood R (2016) A Fatal Case of Septic Tank Gas Poisoning: Critical Care Challenges. J AnesthCrit Care Open Access 6(3): 00228.
9. Graphics M, www.metrographics.com. ManagingHazardous Materials Incidents [Internet]. 2001. Available from: https://www.atsdr.cdc.gov/MHMI/mmg114.pdf
10. Belley R, Bernard N, Cote M, Paquet F, Poitras J. Hyperbaric oxygen therapy in the management of two cases of hydrogen sulfide toxicity from liquid manure. CJEM. 2005;7(4):257-261.
11. Smilkstein MJ, Bronstein AC, Pickett HM, Rumack BH. Hyperbaric oxygen therapy for severe hydrogen sulphide poisoning. J Emerg Med. 1985;3(1):27-30
12. Gunn B, Wong R. Noxious gas exposure in the outback: two cases of hydrogen sulfide toxicity. Emerg Med (Fremantle). 2001;13(2):240-246
13. http://cpheeo.gov.in/upload/5c0a062b23e94SOPforcleaningofSewersSepticTanks.pdf
14. Singh, Tripti & Manish. (2017). MANUAL CLEANING OF SEWERS AND SEPTIC TANKS: WHAT DOES THE LAW SAY? 10.13140/RG.2.2.26343.34722.
15. Sawaya A, Regina AC, Menezes RG. Hydrogen Sulfide Toxicity. [Updated 2024 May 2]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK559264/
16. Total Number of Sewer/Septic Tank Death Cases, Compensation Payment Status and Closed Cases From 1993 [up to 28 th February, 2025] [Internet]. Available from: https://ncsk.nic.in/sites/ default/files/Sewar_death/ Sewer_Death_Cases_2802202505032025.pdf.

Review Article

Emergence of Forensic Nursing in India: A Catalyst for Change in Indian Healthcare System

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Abstract

Introduction: Forensic nursing, an emerging field, provides essential care to victims of trauma, abuse, and sudden deaths. Despite its significance, forensic nursing is relatively new in India. The inclusion of forensic nursing in the nursing curriculum by the Indian Nursing Council marks a progressive step toward integrating legal and healthcare systems, benefiting public health.

Methodology: This article employs literature reviews, and expert opinions to explore the evolution of forensic nursing and suggest strategies to strengthen forensic nursing in India.

Results: The analysis highlights the growing importance of forensic nursing in revitalizing the medico-legal system and meeting the healthcare needs of victims. Integration of forensic nursing fosters collaboration between healthcare and legal professionals, enhancing patient care and justice delivery.

Conclusion: Forensic nursing offers promise for improving healthcare outcomes and promoting justice in India. Continued efforts to expand training programs, raise public awareness, and advocate for policy reforms are crucial for realizing the full potential of forensic nursing in India.

Keywords: Forensic nursing, Nursing in India, forensic nurse examiner, Indian nursing council, Forensic nursing in India.

Introduction

Forensic nursing, a distinctive and evolving field, emerges at the intersection of the longstanding profession of nursing and the pervasive nature of crime in society. Nursing, a discipline with a rich historical legacy dating back centuries, has continually adapted to meet the evolving needs of

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communities. From traditional bedside care to the multifaceted role of healthcare advocacy, nurses have played a vital part in promoting patient's well-being and recovery.[1] Forensic nursing builds upon this legacy, actively engaging with the legal aspects of healthcare and bringing a specialized skill set to aid those affected by trauma, violence, and criminal acts.

In today's world where crime remains an unfortunate reality, forensic nursing serves as a crucial pillar of support, offering a distinctive combination of healthcare expertise and legal insight. Crime impacts all segments of society, transcending social and economic boundaries. In this context, forensic nursing plays a pivotal role in addressing the aftermath of criminal incidents. Beyond the conventional roles, forensic nurses contribute by providing compassionate care and meticulously collecting and preserving evidences that are pivotal in legal investigations.[2]

According to studies, unique fusion of nursing and forensic expertise positions forensic nursing as a comprehensive response to the complex challenges presented by crime. By intertwining the compassionate care inherent in nursing with meticulous attention to legal detail, forensic nursing serves as a bridge between the healthcare and legal systems. Through its application, forensic nursing stands ready to make useful contributions to both individual well-being and the pursuit of justice in communities.[3]

Evolution of forensic nursing globally

Formal acknowledgement of forensic nursing as a sub-speciality dates back to the early 1980s. Ann Wolbert Burgess stands out as a trailblazer among forensic nurse researchers, dedicating her work to exploring issues surrounding sexual assault and interpersonal violence. A significant contribution attributed to Burgess is the conceptualization and development of the notion of rape trauma syndrome, particularly concerning victims of sexual assault.[4,5] Another influential figure in this field is Virginia Lynch, who played a pivotal role in its development. The roots of forensic nursing also trace back to Alberta, Canada, with the introduction of the forensic nurse death investigator role. Pioneered by Virginia Lynch, this discipline, officially recognized in 1991. The International Association of Forensic Nurses (IAFN), established in 1992, defines forensic nursing as a global practice intersecting healthcare and legal systems.[6] In the past 15 years, forensic nursing has gained international adoption, influencing countries such as South Africa, Japan, Hong Kong, and Sweden.[7] With time, education and practice of forensic nursing gained attention globally, with programs active in the US, Canada, Europe, Asia, Africa, and more. Forensic nurses, especially Forensic Nurse Examiners (FNE) play a critical role in addressing challenges like HIV/AIDS, crimes against humanity, and human trafficking in countries like United States.[5] They extend services from mass disaster management to supporting the US military in forensic medical services.[8]

Historical development of forensic nursing in India

The field of forensic nursing in India has evolved steadily. It is driven by various factors such as advancements in healthcare, legal reforms, progress in forensic science, and changing societal views on crime and victim care.[9] It began gaining traction after Virginia Lynch's visit to India in 2002.By 2003, forensic nursing was promoted at national events such as seminars and conferences, gaining interest across the country. It was formally introduced into the nursing curriculum in 2020. Support from international scholars and growing awareness helped solidify its presence, making a model for forensic nursing development in India.[10]

Current state of education and career path for aspiring forensic nurses:

As forensic nursing is a developing field in India, only a few institutes currently offering formal education in this area. However, as awareness grows, many institutions have started introducing specialized programs to train nurses in forensics. Nurses who wish to pursue a career in forensic nursing can enroll in graduate nursing programs approved by the Indian Nursing Council (INC).[11] Forensic nursing has already been included as a mandatory subject in the four-year B.Sc. nursing program under the INC curriculum. For further specialization, nursing students can pursue a postgraduate degree in forensic nursing from universities like National Forensic Sciences University (NFSU), Gandhinagar, Gujrat.[12] Certification courses related to forensic sciences is also offered by certain organizations such as International Association of Forensic Nurses (IAFN), providing opportunities for nurses to gain exposure to forensic aspects within their programs.[13] Additionally nurses who which to study and work in abroad, can pursue online as well as offline courses in forensic nursing from various renowned institutions like Binghamton university, University of Colorado, Johns Hopkins University, St. Petersburg university, University of California etc. [14]

Upon completing the required education, forensic nursing offers a wide range of career opportunities on a global scale. As this field continues to grow and evolve, forensic nurses have numerous opportunities

for career advancement and specialization, allowing them to make meaningful contributions to both healthcare and legal systems. They can pursue various specialized roles, each designed to address specific aspects of patient care and legal processes. Some common career paths include[15]:

- **Sexual Assault Nurse Examiner (SANE):** These professionals deliver holistic care to survivors of sexual assault, performing forensic medical evaluations and collecting crucial evidence for legal proceedings. A retrospective study conducted by Hollender M et al. (2023) reported that patient who received care from a SANE were more often offered recommended services and resources and victims more frequently accepted them as compared to non-SANE encounters.[16]
- **Forensic Nurse Death Investigator:** In this role, nurses collaborate with medical examiners to determine the cause and circumstances surrounding deaths that are suspicious or unexplained. According to Baumann R et al. (2015), forensic nurses use holistic approach to death investigation with a focus of care that includes not only the decedent but the surviving loved ones as they assist families through initial stages of grief in the investigation of death.[17]
- **Forensic Psychiatric Nurse (FPN):** These nurses work in settings such as correctional facilities, forensic hospitals, and mental health centers, providing care to offenders and individuals with mental health disorders involved in the legal system. A study done by Ewalds-Kvist B et al. on 52 nurses reports that FPNs are more competent in issues about violence and conflict to provide security and quality care.[18]
- **Correctional Nursing Specialist:** These nurses deliver medical care, including assessments, diagnoses, and treatment, to individuals in prisons, detention centers, or transitional housing facilities. A study by Barbosa et al.19 reports that prison nursing plays a decisive and comprehensive role that matches the care provided in other healthcare sectors.[19]
- **Legal Nurse Consultant:** Acting as intermediaries, these professionals support attorneys, physicians, and their clients in legal cases. They often work with insurance companies, healthcare organizations, or forensic agencies to provide expert insights.
- **Forensic Gerontology Specialist:** This specialization addresses the legal and human rights issues affecting older adults, focusing on their unique healthcare and advocacy needs.

Scope of Forensic Nursing in Indian Healthcare System

In India, the scope of forensic nursing is evolving, spurred by advocacy from global bodies like the World Health Organization (WHO) and the International Association of Forensic Nurses (IAFN) to integrate forensic content into nursing education.[5] While many prestigious institutions offer B.Sc. (Nursing) courses with limited forensic units, there is a growing recognition of forensic nursing's importance in bridging gaps between the criminal justice and healthcare systems. This integration aims to elevate standards of care for crime victims, the wrongly accused, and those unjustly convicted.[20]The types of forensic nursing practices in India vary based on the intervention point in the forensic process and practice settings, including hospitals, communities, courts, or police stations. However, it's crucial to delineate that the term "forensic" should be reserved for nurses actively involved in client assessment or evaluation with justice-related implications. Working in correctional, institutional, or hospital settings alone does not confer forensic nursing status unless direct contributions to justice pursuits are evident.[21]

Need and major areas where forensic nursing is useful in Indian healthcare system:

As crime rates continue to rise, there is an increasing demand for forensic nursing services, driven by growing awareness of legal rights, legislative reforms, and public consciousness regarding violence and victimization.[22]Reflecting on crime statistics and evolving needs, following below are the primary areas where forensic nursing can be actively practised:

1. ***Crimes against women:*** The National Crime Records Bureau's (NCRB) annual report indicates a substantial increase in crimes against women in India. In 2022, a staggering 4,45,256 cases were recorded. The crime rate against women was reported at 66.4 per lakh population, with a charge-sheeting rate of 75.8. Reports reveals that the majority of crimes against women consisted of cruelty by husband or relatives (31.4%), followed by kidnapping and abduction (19.2%), assault with intent to outrage modesty (18.7%), and rape (7.1%).[23]

Role of Forensic Nurses: Given that nursing is a predominantly female profession, victims often feel more comfortable and open with female forensic

nurses. This can be particularly beneficial in sensitive situations, helping to create a supportive environment for the victim.

2. ***Crime against minors:*** NCRB-2022 report reveals a troubling increase in crimes against minors, with 1,62,449 recorded cases, marking an 8.7% rise from the 1,49,404 cases reported in 2021. Kidnapping and abduction constituted the largest category, accounting for 45.7% of the cases. Additionally, 39.7% of the cases were reported under the Protection of Children from Sexual Offenses Act (POCSO). Also, 1,020 cases were registered under the Prohibition of Child Marriage Act.[24,25]

Role of Forensic Nurses: Forensic nurses are often in a unique position to build trust with victims, who may feel more comfortable and open with them. Forensic nurses are trained to recognize signs of various forms of abuse, including physical, sexual, and psychological, allowing them to intervene early and connect victims with necessary legal and social resources. Their role is integral to both the immediate care and long-term protection of minors, significantly contributing to the efforts to curb and prevent these heinous crimes.[25]

3. ***Elder Abuse:*** Elder abuse is a significant and escalating concern in India, reflecting societal changes and the vulnerabilities of the ageing population. According to the HelpAge India Report (2020), nearly one in six elders experience abuse, with disrespect (47%), verbal abuse (29%), neglect (22%), and physical violence (10%) being the most common forms. The United Nations Population Fund (UNFPA), 2017 report indicates that about 23% of the elderly in India have experienced abuse, with higher incidences reported among women and those in urban areas.[26]

Role of Forensic Nurses: Specialized training of forensic nurses enables them to recognize various forms of elder abuse and collaborate with multidisciplinary teams to ensure care and protection for the elderly.[27]

4. ***Human Trafficking****:* According to the NCRB report, in 2022, a total of 2,250 cases of human trafficking were registered in India, with 6,036 victims identified. Among these victims, 2,878 were children, including 1,059 girls.[23]

Role of Forensic Nurses in Human Trafficking: Forensic nurses are trained to recognize signs of trafficking such as physical injuries, psychological trauma, and subtle behavioural indicators—these nurses are key in uncovering cases that might otherwise go unnoticed. ***Substance Abuse and Drug-Related Crimes****:* The NCRB recorded approximately 80,000 cases under the Narcotic Drugs and Psychotropic Substances (NDPS) Act in 2022.[23]

*Role of Forensic Nurses****:*** Forensic nurses provide medical care to substance abuse victims and gather evidence in drug-related cases.

Implications of Forensic Nursing in India

Forensic nursing, while not widely implemented in Indian hospitals currently, holds immense potential. Introducing forensic nursing practices could lead to following outcomes:

1. *Improved Victim Care:* Forensic nurses would provide comprehensive care to victims of violence, abuse, and trauma, addressing both medical and psychological needs for better recovery outcomes. Trained to identify and manage injuries from violence and abuse, forensic nurses' specialized knowledge ensures thorough documentation crucial for health and legal purposes in India, where such crimes often go unreported or insufficiently addressed.
2. *Enhanced Legal Outcome*: Forensic nurses meticulously document injuries and collect evidence, crucial for legal cases. Their detailed records and expert testimony can significantly influence the fairness and accuracy of judicial proceedings.
3. *Violence Prevention, Public Education and Advocacy*: Forensic nurses play a pivotal role in recognizing and addressing patterns of abuse and violence. Through community education, forensic nurses raise awareness about abuse signs and reporting importance, fostering proactive measures against violence and abuse.[28]
4. *Mental Health Promotion:* Victims of violence often endure psychological trauma. Forensic nurses offer essential mental health support, aiding victims in coping with emotional aftermath in India, where mental health services are underutilized and stigmatized.
5. *Strengthening Healthcare Systems through training and multidisciplinary approach*: Establishing forensic nursing programs enhances healthcare workforce, strengthen professionals and thereby elevates overall care standards across health care institutions. Also, it promotes collaboration among healthcare providers, social workers, law

enforcement, and legal professionals, ensuring coordinated victim support tailored to India's diverse healthcare landscape.

6. *Policy development:* Evidence and data from forensic nursing research can reform India's policies on violence prevention and victim support, guiding more effective strategies and interventions.

Challenges for Forensic Nursing

In the dynamic realm of forensic nursing, characterized by constant evolution and global advancements, India faces a unique blend of challenges and opportunities. Limited awareness, inadequate training, and a lack of standardized protocols are some of the challenges. Currently, dedicated forensic nursing professionals are scarce in prominent institutes of national importance such as All India Institutes of Medical Sciences, where nurses often assist in medico-legal cases but lack formal recognition in this role.[22] The introduction of specialised designations for forensic nurses would significantly improve the management of medico-legal cases, leading to more efficient justice delivery and enhancing professionalism within healthcare and forensic medicine.[29] Therefore, recommendations and suggestions shall be directed from Indian Nursing Council and the Ministry of Health and Family Welfare. Advocating for the creation as well as acceptance of forensic nursesz could enhance awareness and emphasize the positive prospects of this field, encouraging nursing students to consider it as a rewarding career choice.

Fostering Evidence-Based Forensic Nursing in India: Key Strategies and Initiatives

Building a culture of evidence-based practices (EBP) in forensic nursing is essential for ensuring high-quality care, advancing professional standards, and contributing to the improvement of forensic services.[30,31] Below are strategies to foster such a culture in countries like India:

1. *Establishing Designated Posts*: Assign specific roles and responsibilities to designated forensic nursing positions within healthcare institutions. This ensures that professionals with specialized knowledge and training lead forensic nursing efforts, emphasizing the importance of their contributions.
2. *Defining a Code of Ethics for Forensic Nurses*: Develop a comprehensive Code of Ethics specific to forensic nursing. This code should outline the ethical principles, values, and standards that guide the practice of forensic nurses, fostering a shared commitment to integrity, professionalism, and patient-centred care.
3. *Clear Job Descriptions for Forensic Nurses*: Define clear and detailed job descriptions for forensic nurses, outlining their responsibilities, expectations, and scope of practice. This clarity ensures that forensic nurses understand their role and can effectively contribute to evidence-based practices.
4. *Developing Forensic Nursing Protocols*: Establish standardized protocols for forensic nursing practices. These protocols should cover aspects such as evidence collection, documentation, victim support, and collaboration with legal agencies. Standardization ensures consistency and adherence to best practices in forensic nursing.
5. *Encouraging Collaborative Practice for Knowledge Exchange*: Foster a culture of collaboration among forensic nurses, legal professionals, law enforcement, and other healthcare providers. Encourage regular interdisciplinary meetings, case discussions, and knowledge exchange sessions to enhance collaboration and shared success in evidence-based practices.
6. *Encouraging Nursing Process Application in Forensic Services*: Promote the application of the nursing process in forensic services, incorporating EBP principles at each stage:
    - Assessment: Identify forensic situations and potential victims systematically.
    - Planning: Approach investigations with a structured plan based on best practices.
    - Intervention: Document situations, collect evidence, conduct interviews, provide appropriate care, and report to legal agencies, adhering to evidence-based guidelines.
    - Evaluation: Conduct post-intervention reviews to assess the effectiveness of forensic nursing practices and identify areas for improvement.

Mastering Forensic Nursing: Core Concepts and Practices from McCracken for future forensic nurses:

The ABCs of Forensic Nursing, outlined by McCracken (2001), offer essential core concepts and practices for professionals, guiding them in evidence gathering, victim support, legal

aspects, and interdisciplinary cooperation, thereby ensuring top-tier care and justice delivery by nurses. McCracken emphasizes the importance of precision, empathy, and professionalism, providing forensic nurses with the necessary knowledge and competencies to navigate the intricacies of their practice effectively. From evaluating crime scenes to providing expert testimony, the ABCs of Forensic Nursing furnish a framework for delivering top-tier care and contributing to the pursuit of justice across various forensic contexts.[32] (Refer to Figure 1).

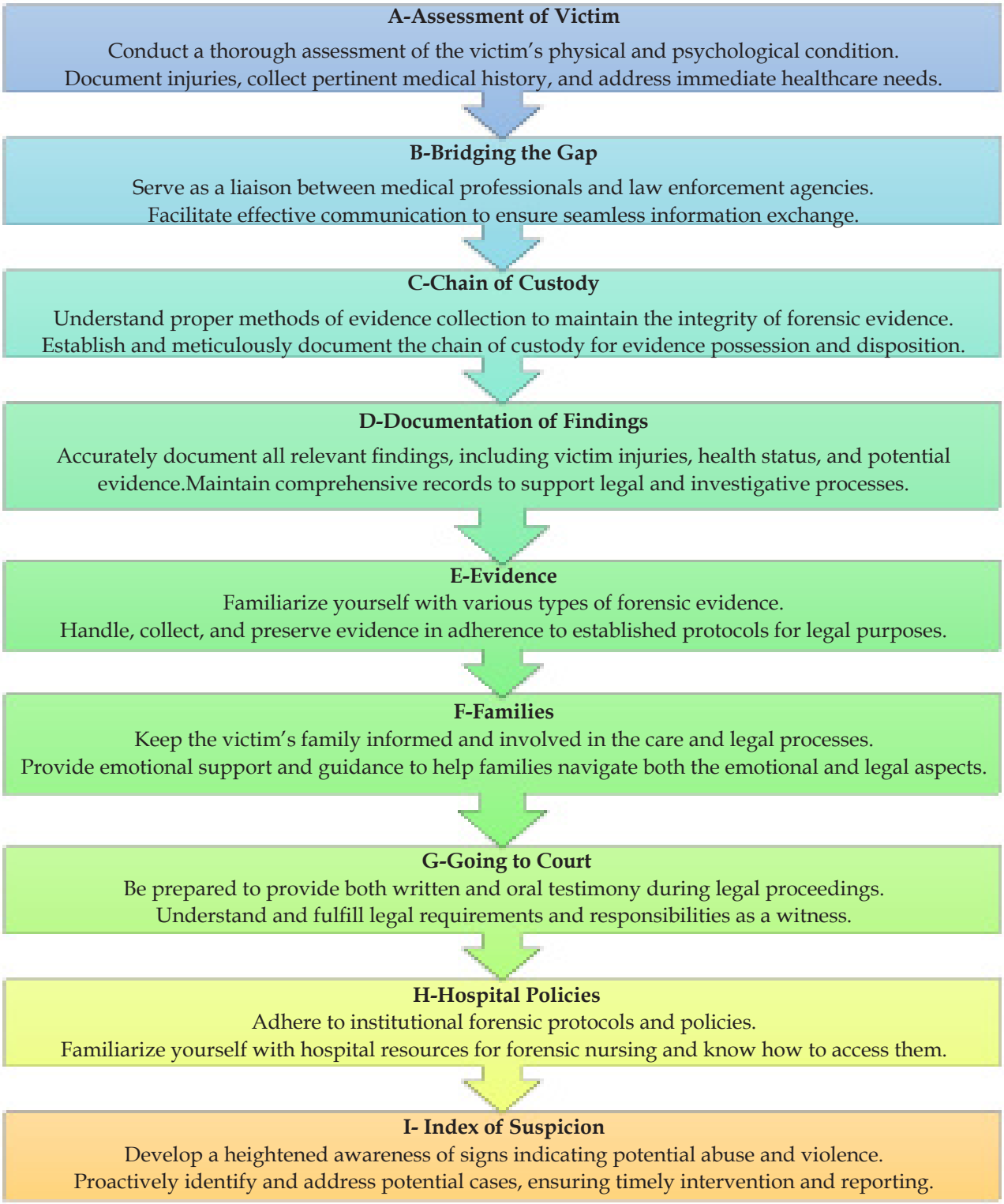

Figure 1: ABCs of Forensic Nursing

Building a Successful Career in Forensic Nursing: To build a successful career in forensic nursing, following steps can be taken:

1. **Practical Exposure**: Work in emergency departments, trauma centers, or mental health units to understand the interplay between healthcare and legal needs. Also, volunteering with NGOs or organizations supporting victims of violence can provide valuable insights into victim advocacy.
2. **Networking and Memberships**: Join professional bodies like the Indian Society of Forensic Medicine or the International Association of Forensic Nurses (IAFN) to stay updated on developments and opportunities.
3. **Continuous Learning**: Attend conferences, webinars, and workshops focused on forensic science, criminal justice, and advanced nursing practices. Develop skills in documentation, courtroom testimony, and forensic evidence handling.
4. **Government and NGO Opportunities**: Government agencies like the National Commission for Women (NCW) and various state-run healthcare programs often require professionals with forensic expertise.[33] Also Collaborate with NGOs focusing on gender-based violence and child abuse, where forensic nurses play a vital role.

Conclusion

In conclusion, the implementation of a comprehensive and multidisciplinary education and training program for nurses in forensic nursing emerges as a vital resource to reduce the backlog of cases for forensic physicians. The inherent capabilities of nurses in possessing fundamental information, skills, and attitudes can significantly enhance forensic investigations and patient care within the forensic sciences domain. However, amidst the broad scope of forensic nursing, challenges such as feasibility, ethical considerations, and potential role conflicts with other forensic professionals require focused attention. Policymakers must take a central role in addressing these issues by clearly defining job descriptions and providing guidelines, ensuring a seamless integration of forensic nursing. By doing so, the collaboration between nurses and other forensic professionals can be optimized, leading to more efficient, ethical, and impactful forensic practices.

Research Highlights:

1. **What is the current knowledge?**

Forensic nursing is a well-established field in many foreign countries, where nurses work in collaboration with law enforcement and healthcare systems to provide care for victims of violence, trauma, and crime, as well as to collect evidence. However, in India, forensic nursing is a relatively new concept, with limited literature and research available on the subject.

2. **What is new here?**

- This article highlights the potential of forensic nursing in India.
- It outlines the scope of forensic nursing within the Indian healthcare system.
- Focuses on key areas where forensic nursing can be applied.
- Discusses the challenges and opportunities of forensic nursing in the Indian context.
- Explains key strategies and initiatives for fostering evidence-based forensic nursing practices in India.

Conflict of interest: Nil

Source of funding: Nil

References

1. Patterson D. Interdisciplinary team communication among forensic nurses and rape victim advocates. Soc Work Health Care. 2014;53(4):382–97. doi: 10.1080/00981389.2014.884040.
2. Sharma S, Joseph J. The paradigm of forensic nursing for nursing aspirants in India: Promises, caveats & future directions. J Forensic Leg Med. 2022;86:102321. doi: 10.1016/j.jflm.2022.102321.
3. Valentine JL, Sekula LK, Lynch V. Evolution of forensic nursing theory: Introduction of the constructed

theory of forensic nursing care: A middle-range theory. J Forensic Nurs. 2020;16(4):188. doi: 10.1097/JFN.0000000000000287.

4. Burgess AW, Piatelli MJ, Pasqualone G. Criminalistics and the forensic nursing process. J Forensic Nurs. 2011;7(2):97–104. doi:10.1111/j.1939-3938.2011.01105.x.
5. Vitale E. The forensic nursing in sexual assaults: The immunochemical diagnosis and prevention of its adverse effects. ImmunopharmacolImmunotoxicol. 2012;34(2):232–43. doi: 10.3109/08923973.2011.596842.
6. International Association of Forensic Nurses—Research.Educate.Lead. [Internet]. [cited 2024 Jul 15]. Available from: https://www.forensicnurses.org/
7. Lynch VA. Forensic nursing. Diversity in education and practice. J PsychosocNursMent Health Serv. 1993;31(11):7–14. doi: 10.3928/0279-3695-19931101-04.
8. Lynch VA. Forensic nursing science: Global strategies in health and justice. Egypt J Forensic Sci. 2011;1(2):69–76. doi: 10.1016/j.ejfs.2011.04.001.
9. Dash SK, Patel S, Chavali K. Forensic nursing—Global scenario and Indian perspective. J Forensic Leg Med. 2016;42:88–91.
10. Gorea RK. Development of forensic nursing in India—Step by step. 2005 Jan 1 [cited 2024 Oct 17];27(4):207. Available from: https://www.researchgate.net/ publication/ 236624191_ Development_of_ Forensic_ nursing_ In_India_-_Step_by_ Step #fullTextFileContent
11. Freedberg P. Integrating forensic nursing into the undergraduate nursing curriculum: A solution for a disconnect. J Nurs Educ. 2008;47(5):201–8. doi: 10.3928/01484834-20080501-05.
12. National Forensic Sciences University. [cited 2025 Jan 29]. Available from: https://nfsu.mha.gov.in/
13. Doğan MB, Eycan Ö, Yazıcı A, Gülatar B, Çapan M, Temel SM. Evaluation of teaching forensic nursing course on undergraduate nursing student's forensic nursing knowledge. Egypt J Forensic Sci. 2022;12(1):52. doi: 10.1186/s41935-022-00307-0.
14. International Association of Forensic Nurses. Forensic Nursing Schools - International Association of Forensic Nurses [Internet]. International Association of Forensic Nurses. 2023 [cited 2025 Jan 29]. Available from: https://www.forensicnurses.org/ page/ ForensicNursingSchools/
15. Flarey D. Exploring the role of forensic nursing in healthcare [Internet]. AIHCP. 2024 [cited 2025 Jan 29]. Available from: https://aihcp.net/2024/09/24/exploring- the-role-of-forensic-nursing-in-healthcare/
16. Hollender M, Almirol E, Meyer M, Bearden H, Stanford K. Sexual assault nurse examiners lead to improved uptake of services: a Cross-Sectional study. Western Journal of Emergency Medicine [Internet]. 2023 Aug 11;24(5). Available from: https://doi.org/10.5811/westjem.59514
17. Baumann R, Stark S. The role of forensic death investigators interacting with the survivors of death by homicide and suicide. Journal of Forensic Nursing [Internet]. 2015 Jan 1;11(1):28–32. Available from: https://doi.org/10.1097/ jfn.0000000000000058
18. Ewalds-Kvist B, Algotsson M, Bergström A, Lützén K. Psychiatric Nurses' Self-Rated Competence. Issues in Mental Health Nursing [Internet]. 2012 Jun 29;33(7):469–79. Available from: https://doi.org/10.3109/01612840.2012.663460
19. Barbosa ML, Medeiros SG, Chiavone FBT, Atanásio LLM, Cavalcanti Costa GM, Santos VEP, et al. Nursing actions for liberty deprived people: a scoping review. Esc Anna Nery. 2019;23(3):e20190098.
20. Wright DK, Vanderspank-Wright B, Holmes D, Skinner E. Forensic nursing and the palliative approach to care: An empirical nursing ethics analysis. Int J PalliatNurs. 2017;23(8):378–85. doi: 10.12968/ijpn.2017.23.8.378.
21. Renjith V, S N, George A, Mhalkar V, Raju N. Forensic nursing. Indian J Forensic Med Toxicol. 2016;10:180–3. doi: 10.5958/0973-9130.2016.00085.2.
22. Jaiswal AK, Shokeen S. Forensic nursing in India—Importance of introducing forensic nursing in Indian scenario. IP Int J Forensic Med Toxicol Sci [Internet]. 2024 Sep 15 [cited 2024 Oct 23];9(3):87–90. Available from: https://www.ijfmts.com/html-article/22911
23. National Crime Records Bureau's (NCRB) annual report (2022). Gov.in [Internet]. [cited 2024 Oct 23]. Available from: https://www.ncrb.gov.in/uploads/ nationalcrimerecordsbureau/custom/1701607577CrimeinIndia2022Book1.pdf
24. Protection of Children from Sexual Offences Act, 2012. [Internet]. 2012. Available from: http://indiacode.nic.in/handle/123456789/2079
25. Newton M. The forensic aspects of sexual violence. Best Pract Res Clin ObstetGynaecol. 2013;27(1):77–90. doi: 10.1016/j.bpobgyn.2012.08.020.
26. Caring for Our Elders Institutional Responses India Ageing Report 2023. UNFPA India [Internet]. 2023 Sep 26. Available from: https://india.unfpa.org/en/ publications/caring-our-elders-institutional-responses-india-ageing-report-2023

27. Elderly Abuse, Elder Abuse Prevention, Elder Abuse Laws—HelpAge India [Internet]. [cited 2024 Jul 16]. Available from: https://www.helpageindia.org/elder-abuse/

28. Ferguson C. The forensic nurse and violence prevention and response in public health. Ucriverside [Internet]. 2014 May 21; Available from: https://www.academia.edu/7114138/ The_forensic_nurse_and_violence_prevention_ and_response_in_public_health

29. Gorea RK. Development and future of forensic nursing in India. Int J Nurs Educ. 2009;1:145.

30. Nilendu D. Enhancing forensic education: Exploring the importance and implementation of evidence-based education system. Egypt J Forensic Sci. 2024;14(1):6. doi: 10.1186/s41935-023-00375-w.

31. Martin T, Maguire T, Quinn C, Ryan J, Bawden L, Summers M. Standards of practice for forensic mental health nurses—Identifying contemporary practice. J Forensic Nurs. 2013;9(3):171–8. doi: 10.1097/JFN.0b013e31827a593a.

32. McCracken L. The forensic ABCs of trauma care. Can Nurse. 2001;97(3):30–3

33. National Commission for Women [Internet]. Digitalindiacorporation.in. 2016 [cited 2025 Jan 29]. Available from: https://uatncwwomen.digitalindiacorporation.in/ncw-cells/new-initiative-cell/

Review Article

Genomic Portraiture: The Science and Ethics of DNA Phenotyping in Identity Prediction

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Abstract

Forensic DNA phenotyping (FDP) has emerged as a groundbreaking tool in criminal investigations, enabling the prediction of externally visible characteristics (EVCs) such as eye color, hair color, and skin color from DNA samples. This capability provides valuable leads in cases with limited traditional evidence. The IrisPlex system, developed to predict eye color with high accuracy, marked a significant advancement in FDP, setting the stage for further developments in the field. This review traces the evolution of FDP technologies, starting with the IrisPlex system, which employs specific single nucleotide polymorphism (SNP) markers to predict eye color. In forensic DNA phenotyping (FDP), the transition from IrisPlex to HIrisPlex and HIrisPlex-S has greatly improved the process. Eye color was correctly predicted by IrisPlex, and forensic application was increased by HIrisPlex's addition of hair color prediction. Skin color prediction is incorporated into the most recent HIrisPlex-S system, which offers a more thorough phenotypic profile. These developments enhance the precision and pertinence of criminal investigations. A new era in forensic science should be ushered in by future studies that improve predictive accuracy, broaden characteristic analysis, and tackle ethical issues.

Keywords: Forensic DNA Phenotyping (FDP), External Visible Characters (EVCs), Single Nucleotide Polymorphism (SNPs), HIrisplex-S, Criminal Investigation

Introduction

In general, forensic DNA phenotyping (FDP) is a collection of methods used to analyze biological materials taken from crime scenes in order to deduce the biogeographical heritage and externally visible physical characteristics of human Individual, such as eye, hair, and skin color. FDP technology have been used in a few high-profile instances across several jurisdictions to gather intelligence for criminal investigations and give information pertinent to particular target[1]. The use of forensic genetic

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technologies in the criminal justice system has changed historically with the introduction of FDP. First, it causes forensic science to refocus its attention from creating evidence to producing intelligence that is useful for criminal investigations. Second, by grouping "suspect" groups that have genetic heritage and/or outwardly noticeable traits in common, FDP shifts the locus from individualization that is, the identification of single individuals to collectivization. Cole refers to this process as the "convergence of individual and collective identity." Third, single nucleotide polymorphisms (SNPs) are used in FDP. In the realm of forensic genetics, these genetic markers are distinguished by their informational richness, integrate appearance, and race[1]. Outside the realm of forensics, DNA prediction is used in paleogenetics and anthropology to reconstruct the appearance of deceased individuals using (ancient) DNA analysis of (old) human remains. A number of EVCs, including eye, hair, skin color, body height, male head hair loss, head hair type, and face shape, have shown improvements in the genetic understanding of human appearance in recent years. The first genes associated with other EVCs, such as ear morphology and facial hair and graying have recently been discovered[2].

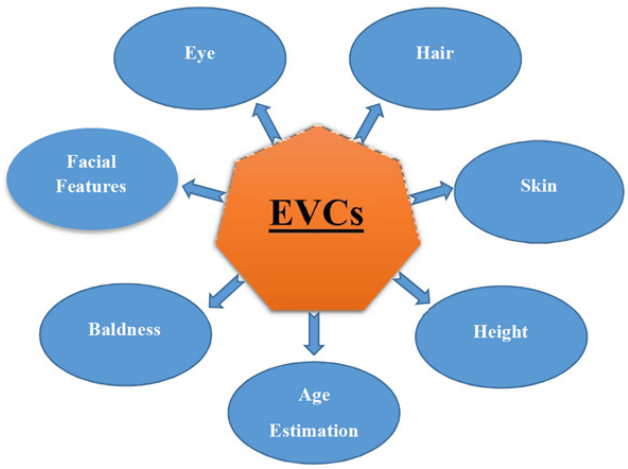

Fig 1. Various Externally Visible Characteristics Predicted by FDP

Actually, FDP analysis may be very important in the forensic domain if normal DNA analysis proves to be unfeasible in the lack of a comparative sample or extensively decomposed, or traces of DNA found on crime scene. By analyzing biological material from unidentified bodies or from identified biological evidence discovered during crime scene investigation, phenotypic studies use DNA sequence analysis to predict exterior somatic features. It helps locate victims of disasters and missing people. The genetic basis of human pigmentation features is well recognized since they are simpler EVCs that are regulated by a small number of genes. Similar to common diseases, complex features involve a large number of genes, each of which contributes only slightly to the variance in phenotype.While EVCs are considered complex traits, multiple genes contribute to the phenotype in addition to environmental factors[3].

Predictions of Phenotype Characteristics Using DNA Markers

FDP is the technique of determining externally visible characteristics for forensic purposes from biological materials. Examples of these include height, facial features, complexion, iris, and hair color. FDP provides a lot of information about the subject (victims and suspects) without requiring a reference sample while comparing EVCs of an individual. Two unknown/reference samples must be compared in order to perform STR profiling analysis. If such a pair is not found, the only option is to search a DNA database that has the profiles of potential suspects. The STR markers' repeats, which range in length from approximately 100 to 300 base pairs, present another drawback. In many cases, the biological evidence from the crime scene is too damaged that it is impractical to extract DNA samples that would provide sufficient information for a precise identification. Due to the challenges associated with applying classic STR markers methods in some circumstances, a number of studies have made it possible for police investigations to benefit from the use of genetic predictions of EVCs for victim identification and suspect tracking.

Eye

Eye color is the most important visible character of humans in forensic sample analysis. It has a very diverse color in the population. The quantity of iris pigment melanin and melanosomes number in the iris's external layer predict this color variation. Blue eyes have low melanin pigment and melanosomes than dark eyes[4]. A complex genetic trait, eye color deviates from the classical paths of Mendelian inheritance and is now considered to be polygenic, i.e., controlled by interactions between multiple genes, any one of which may be incompletely dominant and regulated by other genes[5]. The

IrisPlex System, which comprises of six single nucleotide polymorphisms spread across color genes was one of the earliest phenotyping procedures developed and validated. This approach can identify between brown & blue eyes with a large level of perfection (>90%) with around 30pg DNA input, which has been tested in both homogenous and mixed populations[4]. The European DNA Profiling Group (EDNAP) investigated the IrisPlex assay in a multi-center exercise involving approximately 20 labs, and it was discovered to be simple to apply and extremely authentic. Although, the exactness was lower in the Asiatic population, indicating that future research should be conducted in this community. Upcoming study is also required to uncover new genetic variants and improve the accuracy of existing variants[6].

Hair

Hair colour is among the most obvious distinctive feature with a range of phenotypes. The two types of melanin that cause the majority of variations in hair colour are red/yellow pheomelanin and brown/black eumelanin. People with red hair have more pheomelanin than eumelanin in their hair, whereas people with dark hair have more eumelanin and people with blond hair have less of both types of melanin. In 2013, the HIrisplex software was developed, which added 18 hair color markers to the six pre-existing Irisplex SNPs[4]. Current hair prediction models suffer a hurdle in that they are only accurate for adult populations. As a result, precise hair prediction is difficult for those whose hair color fluctuates over their lives. In the future, quantitative hair color prediction should be prioritized because there is less study on this topic[6].

Skin

Skin pigmentation variation originated as an evolutionary reaction to the strength of ultraviolet light across globe regions. Using 36 indications spread across 16 pigmentation genes, a global prediction model known as the HIrisPlex-S system was developed with this evolutionary barrier taken into consideration. The prediction accuracy ranged from 83% to 97% for the three-category scale and 72% to 97% for the five-category scale. For some of these genes, including HERC2, SLC24A5 and SLC45A2, some of these associations had previously been reported in admixed populations, suggesting that they may have potential uses in the future.

Facial Symmetry

When investigating phenotyping, one of the primary goals is to anticipate the facial form of each EVC. Facial symmetry measurement described as the "Quantification of some facial morphology" such as lip thickness, forehead height or chin protrusion, nose wing width, nose tip shape. Face morphology is investigated using distances between facial markers such as lip thickness, nose width[8]. Some of the genetic markers linked to face traits are first discovered in investigations on syndromes and facial abnormalities. Some of these indicators are then connected to craniofacial development, resulting in the normal variation in facial appearance. For example, the PAX3 gene encodes a transcription factor found in neural crest cells that was linked to Waardenburg syndrome and later identified with the nasion location[9]. Other potential genes, such as PRDM16 and TP63, have been found using PAX3-like patterns. However, like with height determination, each of these genetic markers appears to contribute just slightly to overall facial morphology[4]. The investigation of facial symmetry consist of, LYPLAL1 rs5781117, PRDM16 rs4648379, DKK1 rs1194708, TNFSF12 rs80067372, and SUPT3H rs227833, EDAR rs3827760, PAX3 rs7559271, CACNA2D3 rs56063440[10].

Fig. SNP markers for Eye, Hair and Skin[7]

Age Estimation

It has been discovered that utilising DNA methylation detection technologies is advantageous

for determining an individual's age. Over the course of a person's life, their levels of DNA methylation change; they peak in childhood and decline in adulthood. With as few as seven indicators, these alterations can be assessed and utilised to accurately determine an individual's age from biological samples of various origins (different tissues and bodily fluids) and situations (either from human remains or from a crime scene)[4]. studies have been done to determine the association between T-cell numbers and age as well as to predict the genes that generate age. Age is estimated by quantifying the sjTREC, as they decrease with age, as reported by Zubakov et al. (2010)[11],[12]. Recent advancements in the field of epigenetics have made it possible to estimate an individual's age thanks to the use of DNA methylation detection methods, since methylation directly affects age. Childhood is characterised by a higher degree of methylation, which declines with age. Plus, CpG candidate markers show a lot of potential. This variance can be utilised with biological samples to accurately determine an individual's age[6].

Baldness

FDP predicts male baldness by analyzing specific genetic markers associated with hair loss. The method focuses on genes like AR (androgen receptor) and EDA2R, which influence the likelihood of developing male pattern baldness. It is scientifically established that male pattern baldness, or androgenic alopecia, has a substantial hereditary component. The major loci potentially involved are those on the q12 region of the X chromosome, which contains AR/EDA2R genes directly linked to the production of androgen receptor and ectodysplasin A2 receptor, respectively, on the 20p11 region, and on the genes EBF1, TARDBP, and HDAC9 with predictive potential[4]. The role of 29 SNPs in determining MBP in European individuals of varying ages was confirmed by Marcińska et al: rs929626 in EBF1, rs12565727 (chr1), rs756853 in HDAC9, rs10502861 in SLC12A2, 8 SNPs on chromosome 20 (rs61374441, rs19980761, rs201571, rs6047844, rs913063, rs1160312, rs6113491 and rs2180439) and 17 SNPs on Xq12 (rs4827379, rs1385699, rs1352015, rs1041668, rs2497938, rs2497935, rs962458, rs6152, rs12396249, rs4827545, and rs7885198)[13].

Height

Only a small number of genes have been linked to human height up till 2008. The number of markers increased to 180 in 2010 and nearly 700 in 2014 after more association studies were conducted in 2008, which found 54 loci that directly correlated with variations in height. The majority of these genes are expressed in significant tissues like the growth plate and are connected to growth-signalling pathways like the fibroblast growth factor. Estimation of height is based on ACAN, DNM3, SDR16C5 EFEMP1, FBXW11, GH region, GHSR, GPR126, HHIP, HMGA1, HMGA1, IHH, LCORL, SOCS2, MICA, NOG, NPR3, PML, PPIF etc genes.

CURRENT PHENOTYPIC APPROACH

Sample Collection

Samples for FDP are collected in various ways depending on sample types. The samples and their collection methods are given below:

Table 1: DNA extraction from various biological samples (Richard Li)

Biological Sample	Collection Methods
Bone	Collect in sterilized container
Blood	Collect in EDTA vial or use sterilized swab
Hair	Collect in sterilized container
Tissue	Collect in sterilized container or normal saline
Semen	Collect in sterilized container by swabbing
Saliva	Collect in sterilized container by swabbing

DNA Extraction

- **Tissue -** Extraction of DNA from tissue can be performed using PCI (Phenol Chloroform Isoamyl alcohol) method. In this method, phenol is used for separating DNA from other cell debris. Isoamyl alcohol works as an anti-foaming agent in this method. Extracted DNA is purified using ethanol and eluted in Tris-EDTA for storage.
- **Bone -** Bones should be broken into small pieces or powder using TissueLyser. Bone samples must be treated with diluted bleach, and then irradiated with Ultraviolet light for 30 min, before being powdered as much as possible. Put the bone pieces or powder in EDTA for 2-3 days before performing DNA extraction. After 2-3 days, the PCI method or QIAmp DNA Investigator kit can be used for DNA extraction from bones.

- **Hair -** In hair, mtDNA and nuclear DNA are present which are used for analysis. The nuclear DNA is present in the root of hair which can be extracted using various methods such as PCI method or PrepFiler™ BTA Automated Forensic DNA Extraction Kit etc.

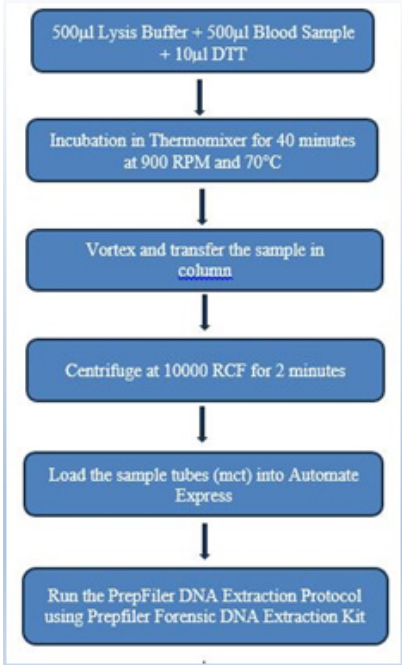

Fig. 3 DNA Extraction from Blood, Tissue, Saliva or Semen (Soft Tissue)

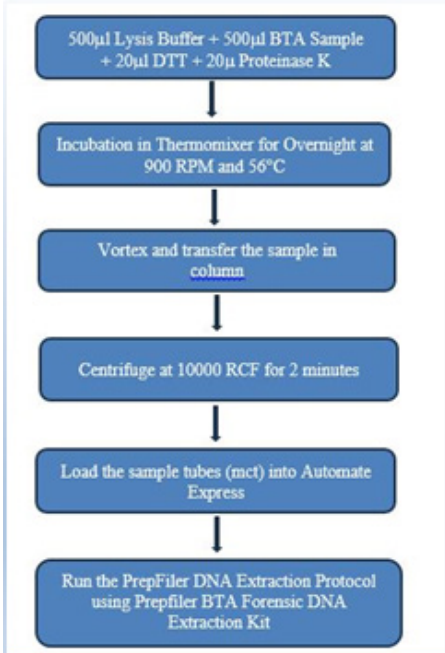

Fig. 4 DNA Extraction from Bone, Teeth or Adhesive (BTA, Hard Tissue)

Phenotyping

In cases where forensic DNA analysis is necessary, STR analysis is generally used for identification person of interest by generating STR profile of person and matching of this profile with reference STR profile or DNA databases such as CODIS. However, if both are unavailable for any reason, we can use DNA phenotyping technique for identification of a person.

The phenotyping for eye color prediction initially used the IrisPlex system having six SNPs; rs12913832, rs1800407, rs12896399, rs16891982, rs1393350 and rs12203592 from the HERC2, OCA2, SLC24A4, SLC45A2 (MATP), TYR and IRF4 genes respectively. The analysis of these SNPs follows a similar procedure as the HIrisPlex system[14].

The HIrisPlex system uses given steps for analyzing forensic samples, which includes hair –

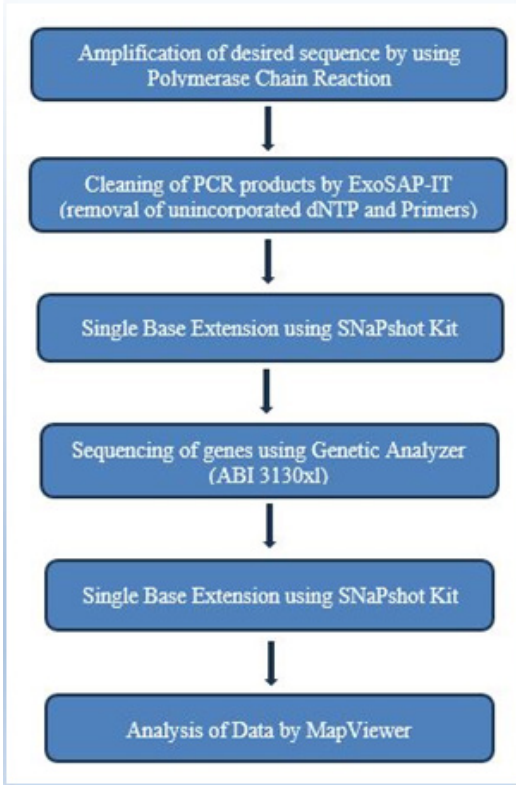

Fig. 5 Sample analysis using HIrisPlex System[16]

The skin colour prediction using HIrisPlex-S system is based on 36 SNPs from 16 genes (**SLC24A5**, **IRF4**, **MC1R**, **OCA2**, **SLC45A2**, **HERC2**, **TYR**, **RALY**, **DEF8**, **PIGU**, **ASIP**, **SLC24A4**, **TYRP1**, **KITLG**, **ANKRD11** and **BNC2**)[16]. The procedure of

the HIrisPlex-S system is performed in several steps, which includes sample collection, DNA extraction, PCR amplification, SBE, Gene sequencing and Phenotype prediction using 36 SNPs.

HOW DOES FDP DIFFER FROM GENOTYPING?

With the development of DNA fingerprinting from RFLP in the 1980s to STR analysis in the 1990s, forensic identification became quicker and more effective. CODIS is compared with STR profiles produced by genetic analyzers to look for matches. However, accuracy decreases in the absence of reference DNA. Forensic DNA Phenotyping (FDP) is employed in these situations. FDP examines SNPs connected to observable characteristics including eye color and facial features, in contrast to STR-based genotyping. Kits like SNapShot are used for sequencing and analysis, which helps in situations when there are no direct DNA matches. In FDP, the reference data is not required because with the help of SNP, The EVC's are predicted with more accuracy. So, if there is only a body part found on a crime scene such as hand, ear, hair etc. and the generated STR profile does not have any match, FDP can construct the EVC and predict the suspect or victim[17].

CHALLENGES AND LIMITATIONS

FDP has limitations due to its probabilistic nature and lack of high accuracy. It predicts the most probable appearance of a suspect or victim based on biological samples but is not conclusive. This is because genes responsible for externally visible characteristics (EVCs) are influenced by various factors, and traits can be modified through hair dye, contact lenses, or surgeries. Moreover, the genomic regions used for phenotyping may only be linked to EVCs rather than causing them. FDP also requires a sufficient DNA sample, and if the amount is too low (approx. 30-40 ng), the results become unreliable. In contrast, DNA genotyping is more accurate as it relies on direct matching, making it more useful in forensic analysis.

LEGAL ASPECTS:

In forensic DNA phenotyping, if the questioned is matched with an innocent person with a slight variation, it will cause a negative impact on the person's social life and not even someone's personal life but the society and its justice system that is directly correlated to us. The oppose of the application of FDP in social view is high, arguing that the information obtained by such analysis could result in racial and ethnic prejudice. In India and other countries, there is no legal framework for forensic DNA phenotyping. In DNA fingerprinting, the non-coding region of DNA is used for discrimination, but in FDP, the coding region is used, which makes it tough to establish and implement regulations.

ETHICAL ASPECTS:

In FDP, ethical considerations are a top priority. In situations involving FDP, the privacy of individuals may become public knowledge. One of the factors contributing to concerns is the fact that some diseases have genetic roots that an individual doesn't wanted to disclose, and FDP does not have any regulations to stop this from happening. Another ethics related question under consideration is the accuracy of FDP data. There is a lack of accuracy and high error rate in FDP, which can be caused by environmental factors or by other means. This affects the FDP data and questions the admissibility of phenotypic data in court as evidence. Finally, one last ethical consideration is the access to the data created by phenotyping and its storage.

RECENT ADVANCEMENTS IN FDP:

Reliability and accuracy in estimating age, ancestry, and appearance from crime scene DNA are critical to the effectiveness of FDP in criminal casework. A prediction model for estimating attributes using epigenetic data and a validated multiplex genotyping tool for evaluating predictive DNA markers are examples of FDP technologies. Probability estimation uses an error-based model to forecast age and a likelihood ratio (LR) framework for ancestry. Improvements in FDP have increased multiplex capacity and sensitivity, especially in MPS technology. Using programs like Geno Geographer and forensic BGA tools, recent MPS-based technologies improve predictions for age, appearance, and ancestry.

VALIDATION

Established in 2017, the VISible Attributes Through GEnomics (VISAGE) Consortium the main

goal of the VISible Attributes through GEnomics (VISAGE) Consortium is to develop and confirm new, reliable molecular and statistical methods for utilizing DNA to predict appearance, ancestry, and age. The VISAGE ET A&A assay was evaluated and validated with assistance from five VISAGE Consortium laboratories. Tests were dispersed among labs to lower MPS expenses while maintaining validity. In order to enable quicker suspect identification from crime scene DNA, advancements are being made to get around forensic restrictions. The VISAGE Consortium uses enormous parallel sequencing to provide tools for predicting the age, appearance, and lineage of suspects. Through international assessments, comparisons, and conferences, the European DNA Profiling (EDNAP) Group guarantees the accuracy of forensic DNA technology.The IrisPlex System's repeatability across 21 laboratories has so far been satisfactorily certified by EDNAP. Additionally, it has evaluated the age prediction using an examination of DNA methylation[18].

Conclusion

In conclusion, FDP stands at the intersection of science, ethics, and law enforcement, offering unprecedented insights into predicting physical traits from genetic data. While it holds huge potential for aiding criminal investigations and providing valuable leads in cases where traditional methods fall short. The implications for privacy, potential misuse, and the inherent limitations of accuracy underscore the importance of careful oversight and implementation. As this continues to advance, it is imperative that we navigate its complexities with a keen awareness of human rights, ensuring that FDP contributes positively to justice while upholding ethical standards and protecting the dignity of all.

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References

1. Granja R, Machado H. Forensic DNA phenotyping and its politics of legitimation and contestation: Views of forensic geneticists in Europe. Social Studies of Science. 2020;53(6):850-68.
2. Pośpiech E, Chen Y, Kukla-Bartoszek M, Breslin K, Aliferi A, Andersen JD, et al. Towards broadening Forensic DNA Phenotyping beyond pigmentation: Improving the prediction of head hair shape from DNA. Forensic Science International: Genetics. 2018;37:241-51.
3. Fabbri M, Alfieri L, Mazdai L, Frisoni P, Gaudio RM, Neri M. Application of Forensic DNA Phenotyping for Prediction of Eye, Hair and Skin Colour in Highly Decomposed Bodies. Healthcare. 2023;11(5):647.
4. Marano LA, Fridman C. DNA phenotyping: current application in forensic science . Research and Reports in Forensic Medical Science. 2019;Volume 9:1-8.
5. White D, Rabago-Smith M. Genotype–phenotype associations and human eye color. Journal of Human Genetics. 2010;56(1):5-7.
6. Pushpesh K, Umema A, Manisha R. Forensic DNA phenotyping: A promising tool to predict human appearance for forensic purposes. GSC Biological and Pharmaceutical Sciences. 2023;23(2):034-41.
7. External visible characteristics prediction through SNPs analysis in the forensic setting: a review. Frontiers in Bioscience-Landmark. 2021;26(10):828.
8. Luquetti D, Claes P, Liberton DK, Daniels K, Rosana KM, Quillen EE, et al. Modeling 3D Facial Shape from DNA. PLoS Genetics. 2014;10(3):e1004224.
9. Alshehhi A, Almarzooqi A, Alhammadi K, Werghi N, Tay GK, Alsafar H. Advancement in Human Face Prediction Using DNA. Genes. 2023;14(1):136.
10. Li Y, Zhao W, Li D, Tao X, Xiong Z, Liu J, et al. RETRACTED ARTICLE: EDAR, LYPLAL1, PRDM16, PAX3, DKK1, TNFSF12, CACNA2D3, and SUPT3H gene variants influence facial morphology in a Eurasian population. Human Genetics. 2019;138(6):681-9.
11. Yamanoi E, Uchiyama S, Sakurada M, Ueno Y. sjTREC quantification using SYBR quantitative PCR for age estimation of bloodstains in a Japanese population. Legal Medicine. 2018;32:71-4.
12. Cho S, Ge J, Seo SB, Kim K, Lee HY, Lee SD. Age estimation via quantification of signal- joint T cell receptor excision circles in Koreans. Legal Medicine. 2014;16(3):135-8.
13. Prokunina-Olsson L, Marcińska M, Pośpiech E, Abidi S, Andersen JD, van den Berge M, et al. Evaluation of DNA Variants Associated with Androgenetic Alopecia and Their Potential to Predict Male Pattern Baldness. Plos One. 2015;10(5):e0127852.

14. Walsh S, Liu F, Ballantyne KN, van Oven M, Lao O, Kayser M. IrisPlex: A sensitive DNA tool for accurate prediction of blue and brown eye colour in the absence of ancestry information. Forensic Science International: Genetics. 2011;5(3):170-80.
15. Walsh S, Liu F, Wollstein A, Kovatsi L, Ralf A, Kosiniak-Kamysz A, et al. The HIrisPlex system for simultaneous prediction of hair and eye colour from DNA. Forensic Science International: Genetics. 2013;7(1):98-115.Walsh S, Chaitanya L, Breslin K, Muralidharan C, Bronikowska A, Pospiech E, et al. Global skin colour prediction from DNA. Human Genetics. 2017;136(7):847-63.
16. MacLean C, Lamparello A. Forensic DNA Phenotyping in Criminal Investigations and Criminal Courts: Assessing and Mitigating the Dilemmas Inherent in the Science. Recent Advances in DNA & Gene Sequences (Formerly Recent Patents on DNA & Gene Sequences). 2015;8(2):104-12.
17. Canales Serrano A. Forensic DNA phenotyping: A promising tool to aid forensic investigation. Current situation. Spanish Journal of Legal Medicine. 2020;46(4):183-90.
18. Xavier C, de la Puente M, Mosquera-Miguel A, Freire-Aradas A, Kalamara V, Ralf A, et al. Development and inter-laboratory evaluation of the VISAGE Enhanced Tool for Appearance and Ancestry inference from DNA. Forensic Sci Int Genet. 2022;61:102779.

Original Article

A Morphometric Forensic Analysis using Cranio-Facial & Odontological Indices in Stature Estimation

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Abstract

Purpose: Forensic anthropology involves the examination of human remains for medicolegal purposes. Age, sex, and stature are critical aspects of identifying unknown individuals. Stature estimation can be achieved through various morphometric indices. The aim of the present study was to estimate and correlate the stature of an individual using odontometric and craniofacial indices.

Methods: The study included 100 subjects from the Haryana population. Odontometric and craniofacial measurements were taken, and different indices were calculated using standardized formulas. Data analysis was conducted using SPSS (Statistical Package for Social Science).

Results: A significant correlation was observed between odontometric and craniofacial indices and an individual's stature. The left central incisor index and right canine index showed better correlation with stature in both males and females. The highest variance was observed with the nasal index in both genders.

Conclusions: The findings indicate a positive correlation between odontometric and craniofacial indices and stature. These results can aid forensic investigations by improving methods of identification.

Key words: Forensic, Anthropology, Cranio-facial, Odontology, Indices, Stature, Statistics etc.

Introduction

Anthropology is the science of human beings, human conduct and societies in the past and present time. Forensic anthropology is a specialized branch of anthropology which involves the application of knowledge and techniques of physical anthropology to solve the problems of medicolegal significance for the purpose of legal investigation. Identification of unknown is the prime question to be answered by a forensic anthropologist. It is a comprehensive science

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that implies the cognition of human osteology & biological anthropology to resolve the cases. It also provides a detailed apprehension of the morphology, reactive norms, growth and development of the human body that help in the individual identification of any person. Besides all above, it may have the broad application in the forensic identification of human, which applies to both the dead and the livings individual[1]. Anthropometry comprises of systematic measurements of the human body which includes skeleton remains of individual. Different parameters such as somatometry, cephalometry, osteometry, craniometry and odontometry are used in anthropometry[12, 18]. Somatometry is a branch of anthropometry which deals with the quantitative measurements of different parts of body including mainly head and face[2].

Stature is considered as the one of the valuable parameters of forensic anthropology. It is used for identification of a person which helps in the investigation process[14]. It is the height of individual in upright position. It has a greater and positive correlation with all the body part of human. Anthropologist or forensic experts can measure various body dimensions and put these anthropometric measurements into a regression equation based on gender and race. This can be helpful in estimating the height of individual[11] Odontometry and cranio-facial anthropometry can be used for height estimation of an individual as growth of the measurements of face, head and teeth is little different from the measurements of the other parts of body[5-6, 8, 18].The present study was designed to correlate the stature of an unknown with cranio-facial indexes and odontological indices in Haryana population.

Methods

(A) Aim & Objectives: Maxillary anterior teeth and cranio-facial measurements are one of the important tools for determination of stature in forensic & legal medicine. The aim of the present study was to estimate the stature from maxillary odontometric and cephalometric measurements and correlate various tooth, cranial and facial indices with the height of individual. The objectives framed for the study was as follows:

- To measure height of individual
- To correlate stature with following
    - o Intercanine width of maxilla.
    - o Interincisior width of maxilla.
    - o Left central incisor index of maxilla.
    - o Right central incisor index of maxilla.
    - o Left lateral incisor index of maxilla.
    - o Right lateral incisor index of maxilla.
    - o Left canine index of maxilla.
    - o Right canine index of maxilla.
- To measure and correlate stature with following
    - o Maximum length of head and maximum breadth of head.
    - o Facial length and facial width.
    - o Nasal length and nasal breadth.
    - o Ear height and ear breadth.
- To establish the correlation between above mentioned anthropometric measurements.

(B) Study design and setting: Cross-sectional in design

(C) Characteristics of study participants:

The sample size of 100 participants (comprising 50 males and 50 females) was determined to ensure gender parity and to facilitate comparative analysis across sexes. The age range of 15–30 years was selected to capture a demographically relevant cohort for the study objectives, which focus on youth and young adults in Haryana. A purposive sampling technique was employed to specifically recruit individuals within this age group and geographic region, thereby aligning the sample with the study's contextual and research requirements. This approach allows for targeted data collection while maintaining internal validity within the defined population parameters. Measurements were taken with the help of vernier calliper, divider, measuring tape only after the signing the written consent by them. The study protocol was

approved by Institutional Human Ethical Committee (IHEC), Maharshi Dayanand University, Rohtak with the reference number IHEC no. 02/06.05.2017 Dated on 06-05-2017 at 2:00 PM.

(D) Inclusion and Exclusion criteria

Apparently healthy individuals with no physical deformity and only those people belonging to Haryana were included in the study. People from other regions, those with poorly endocrinal disorders, metabolic disorders & orthognathic surgery or trauma were excluded from the study.

(E) Methodology of odonotometry parameters (Figure 1)

1. **Measure Height of individual: -** Subject was allowed to stand up on a horizontal plane with his heals joined, stretching the body erect. The height of the individual was taken with the use of a non elastic measuring tape from vertex to feet.
2. **Maxillary left/right central incisor index: -** Index was calculated as, Height of teeth (incisal edge to cervical line)/ Width of teeth (mesiodistal width)*100
3. **Maxillary left/right lateral incisor index: -**Index was calculated as, Height of teeth (incisal edge to cervical line)/ Width of teeth (mesiodistal width)*100
4. **Maxillary left/right canine index: -**Index was calculated as ,Height of teeth (incisal edge to cervical line)/ Width of teeth (mesiodistal width) *100
5. **Intercanine width of maxilla: -**Measured from left canine to right canine.
6. **Interincisor width of maxilla**: - Measured from left lateral incisor to right lateral incisor.

(F) Methodology of cranio-facial anthropometry

The various anthropometric measurements used in the present study are described below[11, 15] **(Figure 2)**

1. **Cranial Index:** It is the ratio of maximum length of head to the maximum breadth of head.
   - Head Length: - It is measured as the straight distance between glabella and opisthocranion.
   - Head Breadth: - It is measured as the straight distance between the two eurya (euryon to euryon).
   - Head Circumference: - It is measured as the maximum circumference of the head, taken just above the level of the eyebrow ridges, extending from a point slightly above the glabella to a position near the top of the occipital bone.
2. **Facial index:** It is the ratio of facial height to the facial width.
   - Facial Height: It is measured as the straight distance between nasion (root of nose) and ganthion in the mid saggital plane.
   - Facial Width: It is measured as the straight distance between two zygia (zygion to zygion).
3. **Nasal index:** It is the ratio of nasal height to the nasal breadth.
   - Nasal Height: It is measured as the straight and vertical distance between nasion (root of nose) and nasal base.
   - Nasal Breadth: It is measured as the straight distance between two alaria (two lateral sides of nose).
4. **Ear index:** It is the ratio of ear length to ear breadth.
   - Ear Height: It is measured as the straight and vertical distance between supra aurale and aurale base.
   - Ear Breadth: It is measured as the distance between the two most lateral points of the ear

Results

The present study comprised of 50 males & 50 females belonging to different districts of Haryana. The data collected was analysed with statistical software program SPSS (Statistical Package for Social Science) version 22.

(A) Result and observations of odontometric parameters

The result of teeth measurement showed a significant correlation between the stature & left central incisor index (0.215). Therefore, we may conclude that there is a significant positive correlation between left central incisor index and height which means that higher the left central incisor index, taller will be individual.

The descriptive statistics for the eight parameters was recorded. It was observed that the mean stature for males was 172.9. Stature was observed to be higher in males as compared to females. Among the maxillary anterior teeth measurements, right lateral incisor index was observed to be the largest and inter incisor width as the smallest measurement. Inter incisor width was showing the minimum variance while right canine index was found to have the maximum variance among males (Table 1).

In females, a highly significant correlation was found between the stature & right canine of maxillaryanterior teeth (0.30203). Therefore, we may conclude that there is a significant positive correlation between right canine of maxillary anterior teeth and height which means that higher the right canine index, taller will be individual. The descriptive statistics for the measurements of the eight parameters were recorded in the study subjects. It was observed that the mean stature for females was 160.75. Stature was observed to be higher in males as compared to females. Among the maxillary anterior teeth measurements, left lateral incisor was observed to be the largest (mean= 115.75) and inter canine width (mean= 3.846) as the smallest measurement. Inter canine width was observed to have the minimum variance while right central incisor was found to have the maximum variance among females (Table 2).

Pearson's correlation and regression analysis between the stature and left central incisor index is highly significant in males as compare to other maxillary anterior teeth indices. In female, the significance of Pearson's correlation and regression analysis between the stature and right canine index is high as compared to other maxillary anterior teeth.

(B) Result and observations of craniofacial parameters

The results of the present study showed a significant higher correlation within the dimensions of some craniofacial measurements. Ear index obtained was found to be highly correlated with stature in males while in females, facial index showed the least correlation with stature.

The descriptive statistics for the measurements of the six parameters were recorded in the male study subjects (Table 3). It was found that the mean stature in case of male population was 173.91. Stature was found to be higher in males as compared to female population. Among the craniofacial measurements for the male subjects, ear index (mean = 140.87) was found to be having the highest value and facial index (mean= 98.81) showed the lowest value. Mean for cranial index, circumference of head and nasal index for male subjects was 115.44, 56.9 and 120.35 respectively. Facial index was showing the least variance and nasal index was showing the highest variance in males. In case of males, a higher and positive correlation was found between all the craniofacial indices and stature except for cranial index. The correlations of various indices varied between 0.080156 for ear index and 0.058 for circumference of head in male study subjects (Table 4).

The descriptive statistics for the measurements of the six parameters were recorded in the female study subjects separately. It was found that the mean stature in case of females was 161.6 (Table 5). Among the craniofacial measurements of females, ear index was found to be having the highest mean value (mean=143.68) and facial index (mean=102.52) showed the lowest value. Mean for cranial index, circumference of head and nasal index for females subjects was 114.6, 53.94 and 131.96 respectively. Least variance was showed by facial index while nasal index showed the highest variance in female population. In case of females, a statistically positive correlation was obtained between all craniofacial indices and stature. Correlations varied between 0.3841 for facial index and 0.2239 for nasal index in case of female study subjects (Table 6).

Table 1: Showing Correlation & Descriptive statistics analysis for odontometric parameters recorded for males

Parameters	No	Range	Max.	Min.	Sum	Mean	SD	Variance	Correlation
Left central incisor index	50	55.15	137.5	82.35	5635.98	112.71	82.65	6832.37	0.215
Left lateral incisor index	50	33.33	133.33	100	5782.84	115.65	64.49	4159.13	-0.0924
Left canine index	50	90.48	157.14	66.66	5854.69	117.09	113.39	12858.6	0.0814
Right central incisor index	50	50	137.5	87.5	5750.53	115.01	76.88	5911.44	0.182
Right lateral incisor index	50	48.33	141.66	93.33	5840.94	116.81	82.97	6884.76	0.055
Right canine index	50	65.21	146.46	81.25	5726.03	114.52	113.50	12883.1	0.158
Inter canine width	50	1.7	5.3	3.6	230.8	4.61	5.16	26.69	0.132
Inter incisor width	50	1.3	4.4	3.1	196.8	3.93	5.47	29.94	0.146
Height	50	22.86	185.4	162.5	8628.6	172.57	38.06	1448.76	_
Age	50	15	30	15	1082	21.64	31.26	977.52	_

Table 2: Showing Correlation & Descriptive statistics for the odontometric parameters recorded for females

Parameters	No.	Range	Max.	Min.	Sum	Mean	Sd	Variance	Correlation
Left central incisor index	50	45.89	140	94.11	5698.8	113.97	72.29	5226.07	-0.0079
Left lateral incisor index	50	45.45	145.5	100	5787.9	115.75	75.20	5656.46	-0.1766
Left canine index	50	42.86	128.6	85.71	5492.6	109.85	67.22	4518.64	0.24338
Right central incisor index	50	38.62	127.5	88.88	5410.2	108.20	117.18	13732.07	0.07321
Right lateral incisor index	50	55.95	133.3	77.38	5600.1	112.00	86.03	7402.42	-0.2293
Right canine index	50	41.96	135.7	93.75	5475.8	109.51	61.13	3737.01	0.30203
Inter canine width	50	0.8	4.25	3.45	192.3	3.84	1.29	1.66	-0.0705
Inter incisor width	50	1.3	5.1	3.8	225.69	4.51	1.74	3.03	0.00973
Height	50	17.78	172.7	154.9	8037.8	160.75	27.00	729.32	_
Age	50	15	30	15	1106	22.12	27.33	747.28	_

Table 3: Descriptive statistics showing stature and craniofacial dimensions among male population

Parameters	N	Range	Max	Min	Sum	Mean	SD	Variance
Height	50	22	186	164	8695.9	173.91	39.468	1557.99
Cranial index	50	44.58	142.85	98.27	5772.4	115.44	73.922	5464.51
Circumference of head	50	6	59	53	2845	56.9	9.219	85
Facial index	50	21.41	109.31	87.9	4940.5	98.81	98.81	1486.81
Nasal index	50	87.31	180.64	93.33	6428.8	128.57	128.57	14485.56
Ear index	50	41.58	158.97	117.39	7043.8	140.87	140.87	4128.06

Table 4: Correlation obtained between stature and various craniofacial indices in males

Parameters	Correlation
Cranial index	-0.1324
Circumference of head	0.058
Facial index	0.0455
Nasal index	0.0134
Ear index	0.080

Table 5: Descriptive statistics obtained between stature and various craniofacial dimensions amongfemale population

Parameters	N	Range	Max	Min	Sum	Mean	SD	Variance
Height	50	18	169	151	8080	161.6	28.46	810
Cranial index	50	51.12	145.45	94.33	5730.9	114.6	74.51	5552.9
Circumference of head	50	7.5	58.5	51	2697	53.94	73.37	178.82
Facial index	50	29.05	118.94	89.89	5126.02	102.52	60.77	3693.46
Nasal index	50	61.6	163.07	101.47	6598.16	131.96	145.2	21105.8
Ear index	50	33.38	161.64	128.26	7184.22	143.68	61.86	3827.76

Table 6: Correlation observed for stature and various craniofacial indices in females

Parameters	r
Cranial index	0.208186
Circumference of head	0.205736
Facial index	0.384133
Nasal index	0.223925
Ear index	0.053627

Figure 1: Showing the odontometric parameters used in the study

(A) Height of tooth (B) Width of tooth
(C) Intercanine width (D) Interincisor width

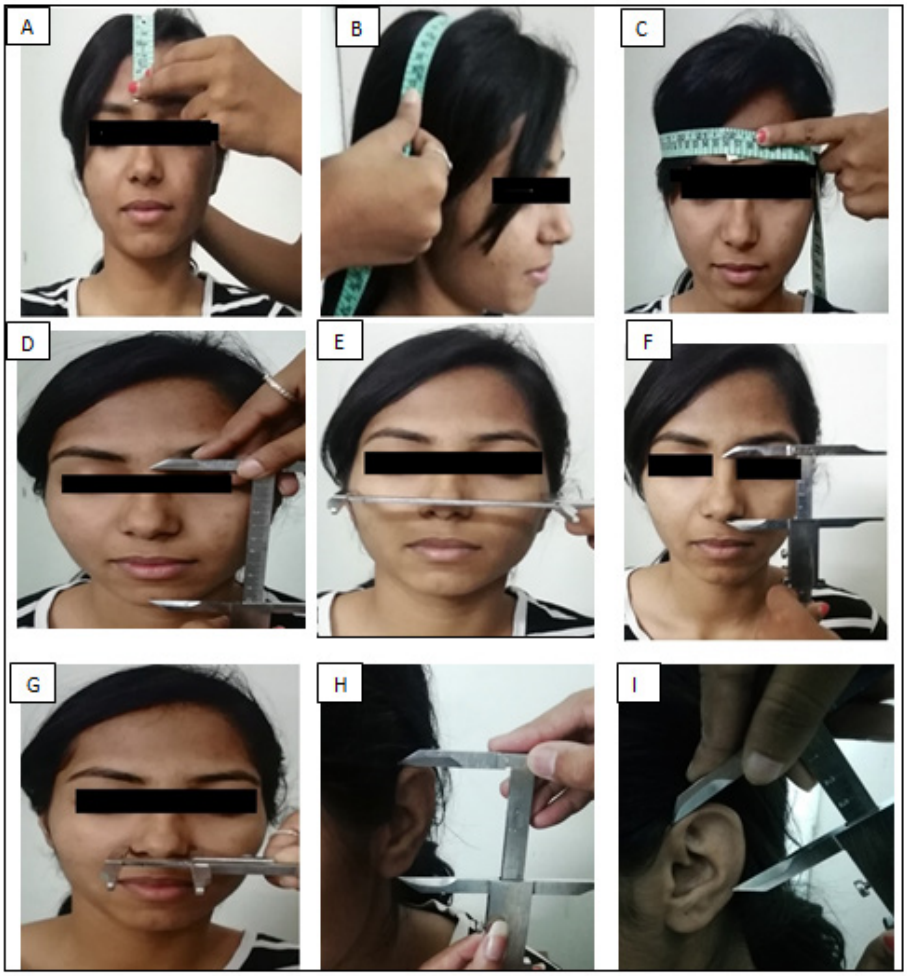

Figure 2: Showing the measurements used in the study A) Head Length B) Head Width C) Head Circumference D) Facial Height E) Facial Width F) Nasal Height G) Nasal Breadth H) Ear Height I) Ear Breadth

Discussion

In forensic science, the identification of a person from mutilated body or fragmentary remains has become an important aspect. In addition to age, sex, ancestry and stature are other biological parameters that characterize an individua[l9,20]. Human teeth and skull growth perform an indispensable function for clinical study material in both living and non-living population to make investigations like in anthropology, genetics odontogenic & forensic studies. Studies related to stature estimation from odontometric parameters & cephalometric parameters aimed to provide the valuable data pertaining to the stature of the individual[21].

Present study found a very significant correlation of odontometric indices with stature of the individual which is in accordance with the previous studies[4, 6-7, 10, 16, 22]. In present study, left central incisor index showed significant correlation in males while in females, the right canine index showed high correlation with stature.

In the present study, the correlation was found to be maximum for ear index and minimum for cranial index in males. In females, correlation was found to be maximum for facial index and minimum for ear index. Krishanconducted a study on 996 adult male Gujjars from North India, establishing a strong and positive correlation between five cephalofacial measurements and stature[11].Sahni*et al*. (2010) studied the seven facial measurements to estimate stature in 300 healthy subjects from northwest India[18]. They estimated that the stature determined through regression analysis of seven facial measurements closely matched the

mean actual stature in both males and females, whereas the difference was found to be larger when using multiplication methods. Shrestha*et al.* (2015**)** assessed head length stature to predict the stature of an individual[19]. They established definite correlation between stature and head length. Furthermore another studies showed cephalic dimensions had highest and positive correlation with that of stature than facial dimensions[1, 12, 15].

Conclusions

The present study concludes that both odontometric and craniofacial measurements are reliable adjuncts for stature estimation and can play a significant role in forensic identification, especially in scenarios involving mass disasters or mutilated remains. These parameters provide valuable data when long bones are unavailable, aiding in the identification process.

However, the study is limited by its small, region-specific sample and restricted age range (15–30 years), which may affect the generalizability of the findings. The cross-sectional design and exclusion of individuals with craniofacial or dental anomalies further limit its applicability in real-world forensic cases.

Future studies should include larger, more diverse populations and wider age ranges to improve external validity. Incorporating advanced imaging techniques and exploring AI-driven predictive models could enhance accuracy and broaden the utility of these methods in forensic science.

Key Points

- The study's findings can enhance forensic identification methods by providing a reliable means of estimating stature from odontometric and craniofacial measurements.
- Aiding in crime investigations and disaster victim identification.
- Examination of human remains for medicolegal purposes.

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References

1. Agnihotri AK, Kachhwaha S, Googoolye K, Allock A. Estimation of stature from cephalo-facial dimensions by regression analysis in Indo-Mauritian population. J Forensic Leg Med. 2011;18(4):167-72. https://doi.org/10.1016/j.jflm.2011.02.006
2. Eboh DEO. Determination of stature from combined maxillary anterior teeth and head dimensions among the Efik and Ibibio of South-South Nigeria. Ann Bioanthropol. 2016;4(1):53. https://doi.org/10.4103/2315-7992.190459
3. Gondivkar SM, Gadbail AR, Vedpathak PR, Sarode S, Sarode G, Mankar M, Patil S. Odontometric and skull anthropometric parameters as a forensic tool in stature estimation: A cross-sectional analysis. World J Dent. 2017;8(3):202-6.
4. Gupta A, Kumar K, Shetty DC, Wadhan V, Jain A, Khanna KS. Stature and gender determination and their correlation using odontometry and skull anthropometry. J Forensic Dent Sci. 2014;6(2):101-6.
5. Hinduja S, Tamgadge S, Tamgadge A. Odontometry and skull anthropometry: A possible tool for stature estimation using minimum armamentarium. Int J Forensic Odont. 2018;3(1):6-11.
6. Hossain MZ, Munawar KM, Rahim ZH, Bakri MM. Can stature be estimated from tooth crown dimensions? A study in a sample of South-East Asians. Arch Oral Biol. 2016;64:85-91.
7. Jani Y, Parikh S, Dudhia B, Bhatia P, Patel P, Patel R. Body height from tooth size: A novel study on stature estimation by odontometric parameters. J Indian Acad Oral Med Radiol. 2018;30(3):275. https://doi.org/10.4103/jiaomr.jiaomr_105_18
8. Kalia S, Shetty SK, Patil K, Mahima VG. Stature estimation using odontometry and skull anthropometry. Indian J Dent Res. 2008;19(2):150.
9. Kanjani V, Rani A, Kanjani D. Morphometric analysis of the orbital aperture in North Indian population: A retrospective digital forensic study. Int J Appl Basic Med Res. 2019;9(2):85. https://doi.org/10.4103/ijabmr.ijabmr_404_18
10. Khangura R, Sircar K, Grewal D. Four odontometric parameters as a forensic tool in stature estimation. J Forensic Dent Sci. 2015;7(2):132. https://doi.org/10.4103/0975-1475.146367
11. Krishan K. Estimation of stature from cephalo-facial anthropometry in North Indian population. Forensic Sci Int. 2008;181(1–3):52.e1-52.e6. https://doi.org/10.1016/j.forsciint.2008.08.001

12. Kurian CP, Shetty S, Shetty V, Shetty M. Stature estimation using craniometric analysis in the adult population of Dakshina Kannada - A cross sectional study. Indian J Forensic Med Toxicol. 2019;13(2):44. https://doi.org/10.5958/0973-9130.2019.00083.5

13. Lai PS, Noor MHM, Abdullah N. Stature estimation study based on pelvic and sacral morphometric among Malaysian population. Bull Natl Res Cent. 2021;45(1). https://doi.org/10.1186/s42269-021-00601-2

14. Laxman NK. A study of determination of stature in Hyderabad population from external ear morphometry. Med Leg Updat. 2019;19(1):164-8. https://doi.org/10.37506/mlu.v19i1.906

15. Obaje S, Ibegbu A, Hamman W, Waitieh-Kabehl A. A regression analysis to determine personal stature from craniofacial parameters of Idoma tribe in Nigeria. J ExpClin Anat. 2017;16(2):116. https://doi.org/10.4103/jeca.jeca_13_17

16. Prabhu S, Acharya AB, Muddapur MV. Are teeth useful in estimating stature? J Forensic Leg Med. 2013;20(5): 460-4. https://doi.org/10.1016/j.jflm. 2013.02.004

17. Reddy M, Reddy V, Wadhwan V, Venkatesh A. Correlation and estimation of stature from cephalofacial measurements: A study on Western Uttar Pradesh population. J Forensic Dent Sci. 2018;10(2):101. https://doi.org/10.4103/jfo.jfds_30_16

18. Sahni D, Sanjeev N, Sharma P, Harjeet N, Kaur G, Aggarwal A. Estimation of stature from facial measurements in Northwest Indians. Leg Med. 2010;12(1):23-7. https://doi.org/10.1016/j.legalmed.2009.10.002

19. Shrestha R, Shrestha PK, Wasti H, Kadel T, Kanchan T, Krishan K. Craniometric analysis for estimation of stature in Nepalese population—A study on an autopsy sample. Forensic Sci Int. 2015;248:187.e1-187.e6. https://doi.org/10.1016/j.forsciint.2014.12.014

20. Švábová P, Caplova Z, Beňuš R, Chovancová M, Masnicová S. Estimation of stature and body weight from static and dynamic footprints – Forensic implications and validity of non-colouring cream method. Forensic Sci Int. 2022;330:111105. https://doi.org/10.1016/j.forsciint.2021.111105

21. Wankhede KP, Kamdi NY, Parchand MP, Anjankar VP, Bardale RV. Estimation of stature from maxillofacial anthropometry in a Central Indian population. J Forensic Dent Sci. 2012;4(1):34-7.

22. Yadav AB. An odontometric approach for estimation of stature in Indians: Cross-sectional analysis. J ClinDiagn Res. 2016. https://doi.org/10.7860/jcdr/2016/18406.7386.

Original Study

Odontometric Study of Premolars - A Convenient Method for Gender Determination

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Abstract

Introduction: Determining the sex of an individual is indeed a crucial step in forensic medicine, as it provides valuable information for various investigative and identification purposes. Teeth are decent source for gender determination. Odontometrics offers a benefit of being simple, speedy, and low cost.

Aim: To verify the premolar Odontometric differences in sex determination.

Methodology: Mesiodistal and buccolingual measurements of premolar crown were calibrated for males and females on 50 pairs of plaster models (25 pairs from both sex) from age group 20-30 years. First and second premolars of Upper and lower jaws of both left and right sides were examined with regard to their mesiodistal (MD) and buccolingual (BL)measurements and the intra-arch premolars linear distance measured from lingual-lingual cusp (3- cusp premolars were excluded from study) tips using divider and digital vernier calliper.

Result: The Statistical study incorporated the use of SPSS version 23. Significant difference was noted in the odontometrics of premolars and lingual-lingual cusp distance. This difference was significant in males. Sexual dimorphism was noted in Mandibular left 1st premolar and maxillary left 2nd premolar with Mesiodistal measurement. The Buccolingual measurements of all the 2nd premolars demonstrated a significant male predominance.

Conclusion: It was observed in this study that the use of 2nd premolar buccolingual measurements and linear distance between lingual-lingual cusps of intra arch premolars of opposite side may be used in odontometrics as an aid to determine the sex, males showed a significantly higher odontometrics.

Keywords: Odontometric, Premolars, Sexual-dimorphism.

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Introduction

In the realm of specialized fields, forensic dentistry holds significance in identifying both the living and the deceased, the utilization of skeletal remains and dentition holds paramount importance. Gender determination holds crucial significance, significantly narrowing down the pool of potential matches by half.[1] The assessment of morphological characteristics of the pelvis and skull forms the foundation for the most frequently employed techniques. In forensic studies, it is not uncommon to recover the skull and pelvic bones in a fragmented state. Therefore, teeth can serve as an additional tool for sex determination, given their high resistance to destruction and fragmentation when compared to other tissues. The metric and non-metric analyses of dentition have been instrumental in human research, serving as a central focus in the field of dental anthropology.[2]

"Sexual dimorphism" denotes variations in size, build, and appearance between males and females. This concept extends to dental identification, as it is often asserted that no two mouths are alike.[3]

Teeth, as distinctive organs, are encased in the hardest structure found in the human body—enamel. Teeth are resistant to physical, thermal, mechanical and chemical destruction. Especially in scenarios of skeletal deterioration, teeth play a critical role in identification, serving as resilient elements that retain essential information crucial for forensic investigations.[4]

Tooth size variations, shaped by both genetic and environmental influences, are documented in literature, portraying differences between and within racial groups. The most comprehensive model to explain these variations aligns with a polygenic mode of inheritance. Lundstrom's investigation, involving 97 pairs of like-sex monozygotic and dizygotic twins, showcased a heightened correlation in mesiodistal tooth size within monozygotic twins. The study's findings supported the conclusion that genetic factors play a significant role in determining tooth size. Furthermore, tooth size variations have been noted among various ethnic groups, encompassing North American Caucasians, Negroes, Mongoloids, Dominicans, Egyptians, Mexicans, Nigerians, British, and more.[5]

In the modern world, The increased incidence of mass disasters (plane crashes, fires, earthquakes etc.) bodies are frequently found in decomposed, carbonized or fragmented conditions. It is common to find dental arches as the only preserved structures, thereby making it possible to identify the corpses, because teeth are the most resistant, hard and stable structures of the human body and also because individuals do not have identical dental features.[6] While the DNA technique stands as the most accurate method, its applicability is limited and cannot be universally employed in all cases. The simplicity, speed, and cost-effectiveness of odontometric methods make them paramount in the efficient determination of gender.

The width of the arch is majorly determined in the canine and premolar region. Many studies highlight the importance of odontometrics in forensic identification, limited research has focused on premolars—particularly the intra-arch distance between lingual cusps and their potential for sex determination. While molars and canines are often studied for sexual dimorphism, premolars remain underexplored, especially in terms of their buccolingual, mesiodistal, and cusp tip measurements.

This study aims to fill this gap by using a simple, low-cost method to examine premolar measurements and identify patterns that help determine gender. These dental differences are especially useful in forensic cases where teeth may be the only well-preserved remains.

Materials and Method

This observational, cross-sectional study was conducted using maxillary and mandibular dental models. A total of 50 dental models (25 males and 25 females), aged between 20 and 30 years, were randomly selected from the working models available in the Department of Orthodontics and Dento-facial Orthopaedics at Narsinhbhai Patel Dental College and Hospital, Gujarat, India. The age and gender of the patients were obtained from departmental records, and informed consent was taken from all participants. Inclusion criteria specified that participants included in the study had a full set of natural teeth with no hard tissue abnormalities. Those with developmental

anomalies, regressive changes, or dental restorations were excluded.

First, the models were categorized and information of respective individuals was tabulated into Excel sheet. With the aid of a digital Vernier calliper (Stainless - 150mm/6) measured the mesiodistal (MD) distance (utmost distance between the proximal surfaces of premolars) (Figure 1) and buccolingual (BL) measurement (distance between the extreme points of the buccal and lingual surfaces of the premolar crowns) (Figure 2). In addition, the intra-arch premolars linear distance measured from lingual-lingual cusp (3 cups premolars were excluded from study) tips distance between the lingual cusps of corresponding (homologous) premolars in each quadrant (Figure 3) was measured. The collected data were entered into a database and analysed using SPSS version 23. Descriptive statistics, Friedmans test was done for intra-gender comparison and independent t-test was done for inter-Gender comparison.

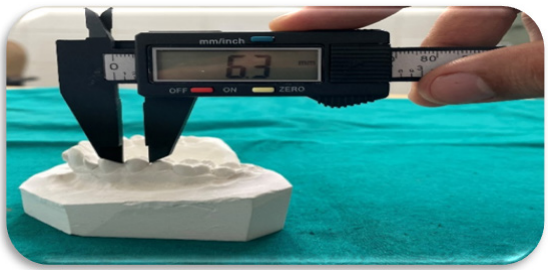


Figure-1. Mesio-Distal distance

Figure-2. Bucco-Lingual distance

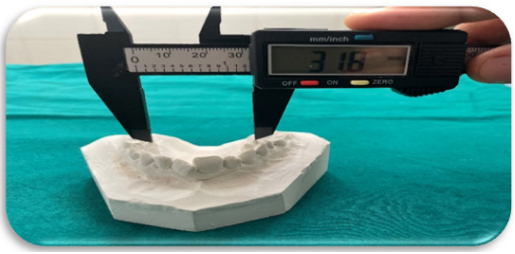


Figure-3. Lingual-Lingual Premolars cusp distance

Results

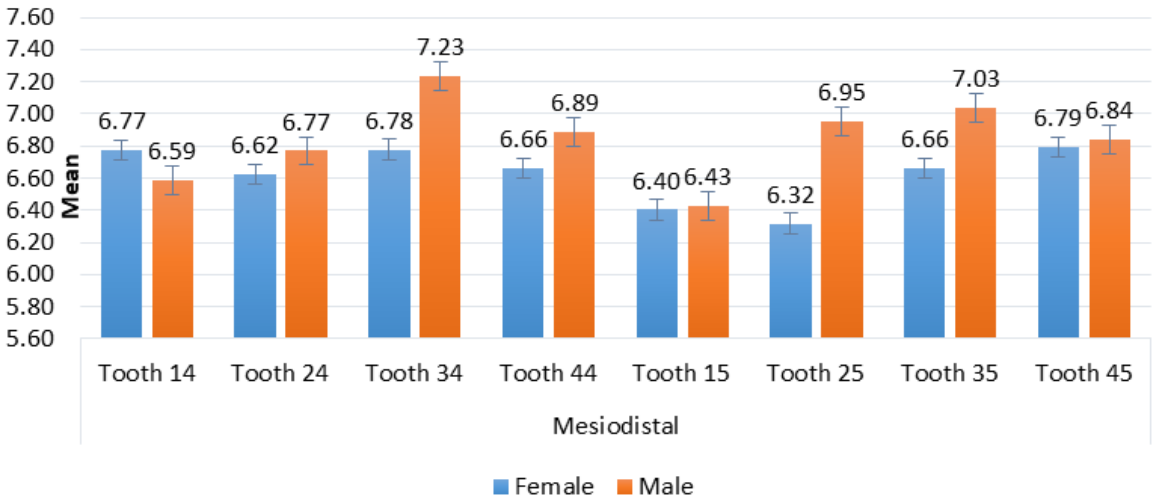
Sexual dimorphism was assessed through odontometric measurements using mesiodistal and buccolingual measurement of all premolars, and lingual-lingual cusp distance (arch width) of bilateral premolars. The measurements were charted and data was analysed using SPSS version 23. Descriptive statistics, Friedmans test for intragender comparison and independent t- test was used for inter gender comparison. Table-1 presents the comparative data between male and female subjects.

- Mesiodistal Measurements:
  - Significant differences were observed in the lower left 1st premolar (tooth 34), upper left 2nd premolar (25), and lower left 2nd premolar (35), with p-values of 0.005, 0.003, and 0.029 respectively.
  - The overall p-values for all teeth measured in this category were significant for both males ($p = 0.022$) and females ($p = 0.010$), indicating a notable level of sexual dimorphism.
- Buccolingual Measurements:
  - Statistically significant differences were noted in the lower right 1st premolar (44; $p = 0.008$), upper right 2nd premolar (15; $p < 0.001$), upper left 2nd premolar (25; $p = 0.036$), lower left 2nd premolar (35; $p < 0.001$), and lower right 2nd premolar (45; $p = 0.005$).
  - Overall, the differences in buccolingual dimensions between sexes were highly significant ($p < 0.001$) for both jaws.
- Lingual-Lingual Cusp Distance:
  - All cusp-to-cusp distances between the premolars of opposing quadrants (14–24, 15–25, 34–44, and 35–45) showed highly significant differences between males and females, with p-values < 0.001, except for 34–44 which had $p = 0.001$.

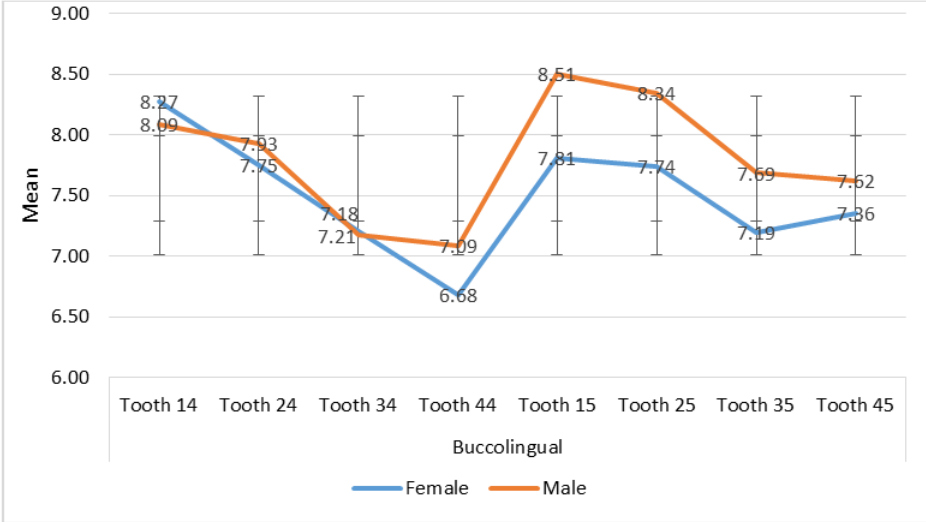
Table 1: Comparison of various parameters

Measurement	Tooth	Female		Male		P-value
		Mean	Std. Dev.	Mean	Std. Dev.	
Mesiodistal	14	6.77	0.48	6.59	0.48	0.246 NS
	24	6.62	0.47	6.77	0.29	0.287 NS
	34	6.78	0.44	7.23	0.63	0.005*
	44	6.66	0.57	6.89	0.51	0.143 NS
	P value	**0.395 NS**		**0.153 NS**		
	15	6.40	0.67	6.43	0.73	0.906 NS
	25	6.32	0.61	6.95	0.80	0.003*
	35	6.66	0.37	7.03	0.57	0.029*
	45	6.79	0.60	6.84	0.57	0.795 NS
	P value	**0.010***		**0.022***		
Buccolingual	14	8.27	0.76	8.09	0.50	0.317 NS
	24	7.75	0.59	7.93	0.80	0.384 NS
	34	7.21	0.67	7.18	0.53	0.864 NS
	44	6.68	0.40	7.09	0.62	0.008*
	P value	**<0.001****		**<0.001****		
	15	7.81	0.60	8.51	0.52	<0.001**
	25	7.74	1.37	8.34	0.32	0.036*
	35	7.19	0.37	7.69	0.38	<0.001**
	45	7.36	0.37	7.62	0.25	0.005*
	P value	**<0.001****		**<0.001****		
L-L Cusp distance	14-24	29.17	1.91	31.91	1.01	<0.001**
	15-25	33.06	2.17	35.21	0.98	<0.001**
	34-44	28.81	2.01	30.95	2.26	0.001*
	35-45	31.82	2.16	34.42	1.89	<0.001**
	P value	<0.001**		<0.001**		

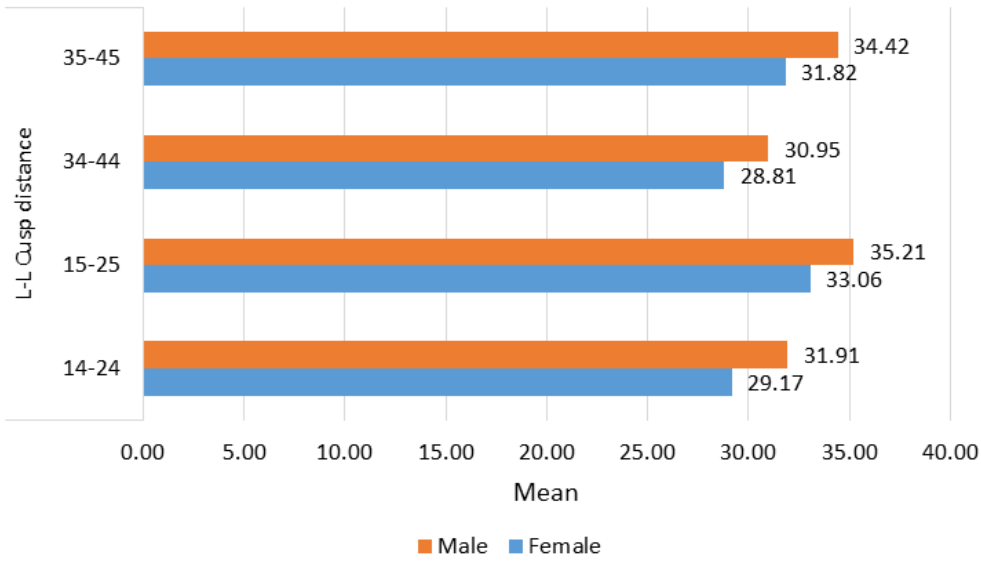
**Highly significant (p<0.001), *-Significant (p<0.05), NS – Not significant (p>0.05)



Graph 1: Mesio-distal measurement premolars



Graph 2: Bucco-lingual measurement of premolars



Graph 3: Lingual – lingual cusp distance

Discussion

Sex determination is a significant aspect in the identification of an individual. Numerous methodologies for identification are presently employed. Withstanding environmental challenges, dentition proves to be an enduring and valuable asset in the field of identification. Amidst the array of gender determination methods like DNA analysis and bone ossification examination, odontometry holds a crucial role. Its applicability as an adjunct method is highlighted by its simplicity, reliability, ease of measurement, and cost-effectiveness, making it especially useful in studies involving large populations.

The present study analyzed buccolingual, mesio-distal measurements of maxillary and mandibular premolars and arch width in premolar region (Table 1) for its application in sex determination. In line with study by Saeed Hossain khan et al; the evaluation of mandibular canines and second premolars, mesio-distal measurements revealed a significant male predominance, with larger dimensions compared to females in both arches (Graph 1). The Buccolingual measurements of all the 2nd premolars was significantly higher in males as compared to females (Graph 2).

Another study by Eleni Zorba et al; The findings revealed a notable sexual dimorphism in all measured dimensions of both upper and lower canines, as well as upper and lower first premolars. According to Garn et al. Notably, the teeth neighbouring the canines, such as the first premolar, exhibit a higher degree of sexual dimorphism compared to other dental structures.[7] In a study conducted by Ashwini Shena, Nithyathe outcomes revealed a consistent pattern where mesiodistal and buccolingual dimensions of maxillary canines, premolars, and molars in males surpassed those observed in females.[8]

The lingual-lingual distance (arch width), between the lingual cusps of premolars in different quadrants showed significant sexual dimorphism in both upper and lower jaw (Graph 3). Study conducted by Rastogi et al; measured the distance between the lower premolars by drawing a straight line between the occlusal grooves of the teeth and results revealed a sex-related difference.[3] Another study done by G. Agnihotri; Results demonstrated a substantial gender difference, revealing that males exhibit greater arch width in both premolars and molars when compared to females.[9] According to, Medha Rajiv Ranjan, Yuvaraj Babu. K, their investigation demonstrated that odontometric measurements, specifically the second maxillary inter-premolar distance, emerged as a reliable parameter for gender determination.[10]

Conclusion

Odontometric measurements, particularly the buccolingual dimensions of the second premolars and the linear distance between lingual-lingual cusps of intra-arch premolars, show significant sexual dimorphism and can serve as reliable indicator in sex determination. Males consistently exhibited higher values in these parameters, reinforcing their forensic relevance.

The limitation of the study is in its potential application in diverse population, age-related and orthodontic influences on tooth dimensions. This opens gate for further exploration into varied ethnic and regional groups with higher sample size for universal application of these parameters to be used as a reliable and economical method for sex determination of incapacitated jaw bones.

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Conflict of interest: The authors reported no conflict of interest during the study.

References

1. Joseph AP, Harish RK, Rajeesh MP, Vinod Kumar R. How reliable is sex differentiation from teeth measurements. Oral Max Path J 2013; 4:289-292.
2. Zorba E, Moraitis K, Manolis SK. Sexual dimorphism in permanent teeth of modern Greeks. Forensic science international. 2011 Jul 15;210(1-3):74-81.
3. Rastogi P, Jain A, Kotian S, Rastogi S. Sexual dimorphism–An odontometric approach. Anthropology. 2013;1(2):1-4.
4. Lakhanpal M, Gupta N, Rao NC, Vashisth S. Tooth dimension variations as a gender determinant in permanent maxillary teeth. JSM Dent. 2013;1(1):1014.
5. Khan SH, Hassan GS, Rafique T, Hasan MN, Russell MS. Mesiodistal crown dimensions of permanent teeth in Bangladeshi population. Bangabandhu Sheikh Mujib Medical University Journal. 2011;4(2):81-7.
6. da Silva Andrade R, Fernandes LC, Bento MI, de Lima KC, Rabello PM, Santiago BM. Odontometric study of premolars for sex determination. RevistaCientífica do CRO-RJ (Rio de Janeiro Dental Journal). 2019 May 21;4(1):73-8.
7. Garn SM. Sexual dimorphism in the buccolingual tooth diameter. J. Dent. Res. 1967; 46:963-72.
8. Ashwini S. Assessment of Tooth Metrics in Gender Determination-A Cross-Sectional Study. J Forensic Investigation. 2015;3(1):3.
9. Agnihotri G, Gulati M. Maxillary molar and premolar indices in North Indians: A dimorphic study. Internet J Biol Anthropol. 2008;2(1):1-5.
10. Ranjan MR, Babu YK. Determination of gender using odontometric measurement of maxilla. Journal of Pharmaceutical Negative Results. 2022 Oct. 4;1486-9.

Original Research Article

Comparison of SOFA and APACHE II in Predicting Mortality, Morbidity in Cases of Acute Poisoning and Correlation with Biomarkers of Severity

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Abstract

Introduction: The aim of this research was to compare SOFA and APACHE II scores for the ability to predict mortality and morbidity among patients of acute poisoning. The secondary aim was to relate these scores with biomarkers of severity to determine their prognostic value. Acute poisoning is one of the most important health problems across the globe, a major contributor to the emergency admissions leading to increased morbidity and mortality. Prognosticating measures like SOFA and APACHE II are essential in prioritizing the patients and planning their management. This study assesses their relative roles in predicting the outcome in patients with acute poisoning presenting to the emergency of a tertiary care hospital in Northern India.

Materials & Methods: This was a prospective observational study conducted at a tertiary care centre in Northern India, where 85 patients who had acute poisoning were recruited. The severity score tools were applied and they were compared with the severity markers. The performance of the scores was assessed and the sensitivity and the specificity were analyzed using Receiver Operating Characteristic (ROC) curve analysis.

Results: The SOFA score has been proven to best APACHE II in terms of predictive accuracy. Both scoring systems were found to correlate significantly with NLR, Serum Amylase, and Lactate, with SOFA exhibiting greater sensitivity and specificity.

Conclusion: SOFA serves better in predicting mortality amongst cases of acute poisoning than APACHE II. Strong correlations with critical biomarkers further reinforce the clinical significance of SOFA score.

Keywords: SOFA, APACHE II, Acute Poisoning, Morbidity, Mortality

Introduction

Acute poisoning is one among the significant public health challenges, particularly in low- and middle-income countries, where easy access to toxic substances like pesticides, household chemicals, and pharmaceuticals contributes to high rates of both accidental and intentional poisonings. Globally, the

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World Health Organization (WHO) estimates that approximately 100,000 deaths occur annually due to poisoning, with a substantial portion of these cases occurring in Southeast Asia and Sub-Saharan Africa[1]. In India, the burden of acute poisoning is especially pronounced in rural and agricultural areas, where the extensive use of pesticides, such as organophosphates and aluminium phosphide, poses a significant risk[2].

The clinical management of poisoning cases is complex, as the prognosis can vary widely depending on the type and quantity of the substance ingested, the time to treatment, and the patient's physiological response. Poisoning often leads to multi-organ failure, and the accurate prediction of patient outcomes is critical to determining the level of care required. In this context, scoring systems like the Sequential Organ Failure Assessment (SOFA) and Acute Physiology and Chronic Health Evaluation II (APACHE II) are commonly used in critical care settings to assess illness severity and predict mortality.

SOFA assesses the extent of organ dysfunction, with a particular focus on respiratory, cardiovascular, hepatic, coagulation, renal, and neurological function, while APACHE II evaluates a combination of physiological variables, such as blood pressure, temperature, oxygenation, and hematologic parameters etc.[3,4]. Neutrophil to lymphocyte ratio is a biomarker of severity which was used to predict the outcome in organophosphorus poisoning[5]. Serum amylase level was also used to assess the outcome in organophosphorus and paraquat poisoning.[5,6] Similarly serum lactate level was also used to predict outcome of patients in organophosphorus and aluminium phosphide poisoning [7,8].

This study was conducted to compare the prognostic accuracy of SOFA and APACHE II in predicting mortality and morbidity among patients with acute poisoning admitted to a tertiary care hospital in Northern India. It also addresses the limitations of previous researches by comparing the SOFA and APACHE II scoring systems as prognostic tools for all types of acute poisoning cases presenting in the emergency department. Our study sought to evaluate the feasibility of using one scoring system for determining patient outcomes across various types of acute poisonings. Also, it aimed to correlate the SOFA and APACHE II scores with biomarkers of severity, including Neutrophil-Lymphocyte ratio, serum lactate, and serum amylase levels, which can provide additional insights into the severity of poisoning.

Materials and Methods

Study Design and Population This prospective observational study was conducted over an 18-month period at a tertiary care centre in Northern India. A total of 85 patients were included in the study, the sample size was calculated based on a previous study by Silakhori et al[9], utilizing the diagnostic accuracy of SOFA and APACHE II. The power and level of significance was 80% and 5% respectively[9].

The inclusion criteria required patients to be 18 years or older and admitted with a diagnosis of acute poisoning. Patients with pre-existing chronic conditions, such as heart disease or chronic kidney disease, or those with mixed poisonings (more than one type of toxin) were excluded from the study to maintain a focused study population.

Data Collection and Parameters

Upon admission, detailed demographic data, including age, gender, and residential status (urban or rural), were recorded. Clinical parameters, such as heart rate, blood pressure, respiratory rate, oxygen saturation, and requirement for ventilatory support, were also documented. Laboratory parameters, including Neutrophil-Lymphocyte Ratio (NLR), Serum Amylase, and Serum Lactate, were collected as part of the routine blood investigations.

SOFA and APACHE II scores were calculated at the time of admission using validated scoring systems. The SOFA score assesses organ function across six domains (respiratory, cardiovascular, hepatic, coagulation, renal, and neurological), while APACHE II is a more complex scoring system that evaluates physiological variables, including age, chronic health status, and additional acute physiological disturbances.

Statistical Analysis

All statistical analyses were performed using SPSS software (version 26.0). Descriptive statistics were used to summarize demographic and clinical characteristics. Continuous variables were expressed

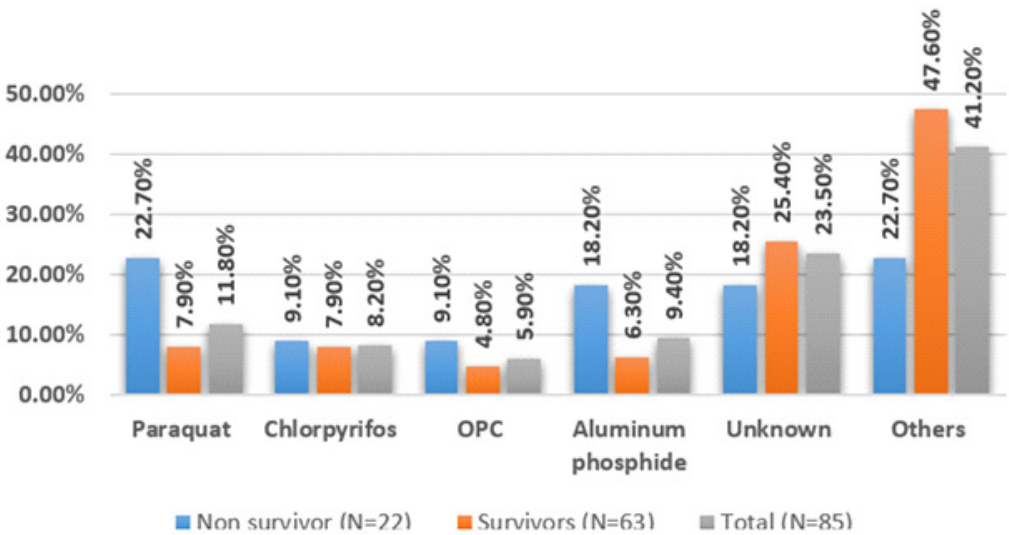
as means and standard deviations, while categorical variables were represented as percentages. The Student's t-test was used to compare continuous variables between survivors and non-survivors, and the chi-square test was used for categorical variables. Receiver Operating Characteristic (ROC) curve analysis was employed to evaluate the predictive accuracy of SOFA and APACHE II scores, and the area under the curve (AUC) was calculated for both scoring systems. Correlations between SOFA/ APACHE II scores and biomarkers were assessed using Pearson correlation coefficients.

Results

Demographic details of the patients who were enrolled.

Table 1: Demographic Characteristics and Age Distribution of Patients

Parameter	Non-survivor (N=22)	Survivor (N=63)	Total (N=85)
Mean Age (years)	35.8 ± 10.6	29.5 ± 11.7	30.8 ± 11.5
Female (%)	7 (31.8%)	19 (30.2%)	26 (30.6%)
Male (%)	15 (68.2%)	44 (69.8%)	59 (69.4%)
Urban (%)	12 (54.5%)	37 (58.7%)	49 (57.6%)
Rural (%)	10 (45.5%)	26 (41.3%)	36 (42.4%)



The most common poison consumed was "Others" (41.2%) which included miscellaneous agents like paracetamol, benzodiazepine, corrosives, tricyclic antidepressants, glyphosate. It was followed by unknown poisons (23.5%), paraquat (11.8%), aluminum phosphide (9.4%), chlorpyrifos (8.2%), and OPC (5.9%). In the non-survivor subgroup, 22.7% consumed paraquat and "Others," while in the survivor subgroup, 47.6% consumed "Others." The difference in paraquat and "Others" consumption between the survivor and non-survivor subgroups was statistically significant (**p=0.045** and **p=0.033**, respectively)

Figure 1: Types of Poisoning Agents and Mortality rate

Vital Signs on Admission

Non-survivors had significantly oxygen saturation compared to survivors, while the rest of the parameters did not show statistical significance with mortality

Table 2: Vital Signs on Admission in Survivors vs. Non-survivors

Variable	Non survivor (N=22)	Survivor (N=63)	Total (N=85)	p-value
Heart Rate (beats/min)	102.1 ± 25.8	92.7 ± 25.1	94.8 ± 25.7	0.072
Respiratory Rate (breaths/min)	21.9 ± 6.7	21.5 ± 6.2	21.6 ± 6.3	0.788
Oxygen Saturation (%)	86.8 ± 12.7	93.1 ± 6.2	91.0 ± 8.5	0.003
Capillary Blood Glucose (mg/dL)	112.5 ± 67.8	109.4 ± 49.7	110.2 ± 53.6	0.807
Temperature (Celsius)	37.2 ± 1.4	37.3 ± 1.4	37.3 ± 1.4	0.777
Arterial pH	7.27 ± 0.19	7.31 ± 0.16	7.30 ± 0.16	0.222
History of Organ Insufficiency	4 (18.2%)	4 (6.3%)	8 (9.4%)	0.101

Ventilation, Inotropic Support, and Hospital Stay. The requirement for mechanical ventilation, inotropic support, and longer ICU stays was higher among non-survivors, highlighting the severity of poisoning in these patients.

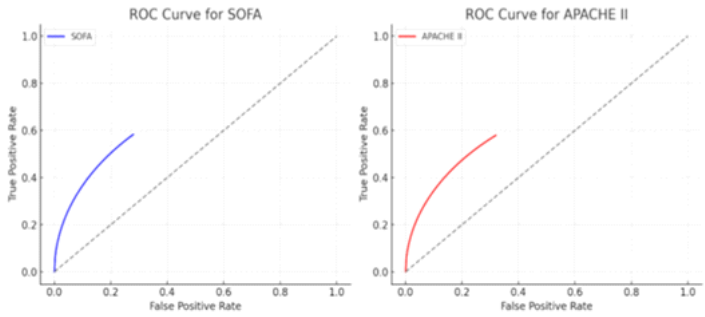
Table 3: Ventilation, Inotropic Support, and Hospital Stay in Survivors vs. Non-survivors

Variable	Non survivor (N=22)	Survivor (N=63)	Total (N=85)
Inotrope Support	16 (72.7%)	21 (33.3%)	37 (43.5%)
Mechanical Ventilation	14 (63.6%)	17 (27.0%)	31 (36.5%)
Days of Invasive Ventilation	4.2 ± 4.3	3.9 ± 3.6	4.0 ± 3.8
Days of Non-Invasive Ventilation	3.5 ± 4.7	3.2 ± 4.0	3.3 ± 4.2

SOFA vs. APACHE II in Predicting Mortality SOFA demonstrated superior predictive accuracy compared to APACHE II, with higher sensitivity and specificity for mortality prediction.

Table 4: Analysis of SOFA and APACHE II

Metric	SOFA	APACHE II	p-value
AUC (95% CI)	0.83 (0.75-0.90)	0.78 (0.69-0.85)	<0.001
Sensitivity (%)	84	79	
Specificity (%)	72	68	
Positive Predictive Value (%)	58	54	
Negative Predictive Value (%)	89	86	



The area under the curve (AUC) for the SOFA score was 0.83 (95% CI: 0.75-0.90), and for the APACHE II score, it was 0.78 (95% CI: 0.69-0.85). The difference in AUC between the two scores was statistically significant (p<0.001). The SOFA score had a sensitivity of 84%, specificity of 72%, positive predictive value (PPV) of 58%, and negative predictive value (NPV) of 89%. The APACHE II score had a sensitivity of 79%, specificity of 68%, PPV of 54%, and NPV of 86%.

Figure 2: Receiver-operation characteristic Curve showing the comparative efficacy of SOFA and APACHE II in predicting the mortality and morbidity in patients of acute poisoing

Discussion

This study aimed to compare the performance of the Sequential Organ Failure Assessment (SOFA) and Acute Physiology and Chronic Health Evaluation II (APACHE II) scoring systems in predicting mortality among patients with acute poisoning. The results demonstrated that SOFA compared to APACHE II was a more reliable predictor of mortality. SOFA's higher sensitivity (84%) and specificity (72%), along with its stronger correlation with key biomarkers such as serum lactate and Neutrophil-Lymphocyte Ratio (NLR), makes it an important and invaluable tool in clinical settings where rapid assessment of patient outcomes is essential.

The significance of the study lies in its focus on high risk population of acute poisoning patients, where early identification of those at higher risk of mortality can drastically improve outcomes through timely interventions. Poisoning often leads to multi-organ failure, which is the core of the SOFA score assessment. This is particularly evident in cases of pesticide poisoning, such as organophosphates and aluminum phosphide, which accounted for a significant proportion of the poisoning cases in this study. Aluminum phosphide, in particular, is known for its high fatality rate due to rapid onset of cardiovascular and metabolic failure, which aligns with the study's finding that aluminum phosphide poisoning had the highest mortality rate among the agents involved. This is supported by other studies showing similar fatal outcomes in aluminum phosphide poisoning, where SOFA was used to track organ dysfunction as a result of systemic toxicity and shock [8,9]

SOFA's emphasis on assessing the extent of organ dysfunction gives it an advantage in poisoning cases where the progression to multi-organ failure can be rapid. Poisoning can disrupt multiple physiological systems simultaneously, which SOFA is well-equipped to capture through its focus on respiratory, cardiovascular, hepatic, and renal systems. Cardiovascular collapse, often seen in cases of pesticide poisoning, is a leading cause of mortality in these patients, and the ability to track this parameter in real time makes SOFA particularly valuable in triaging the patients.

Compared to SOFA, APACHE II's overall predictive power was lower, with an Area Under the Curve (AUC) of 0.78 compared to SOFA's 0.83. APACHE II's approach of incorporating broader physiological parameters, such as chronic health conditions and age, may be less suited to poisoning cases where acute, rapid deterioration could be the primary concern. While APACHE II provides a more holistic view of patient health, it may not capture the nuances of sudden, poisoning-related organ dysfunction as effectively as SOFA.[10]

One of the key findings of this study is the strong correlation between SOFA scores and biomarkers, particularly Serum Lactate, amylase levels and NLR. Elevated Serum Lactate levels were significantly associated with increased mortality, reinforcing its role as a critical marker of metabolic dysfunction and tissue hypoxia in acute poisoning cases. Lactate, a product of anaerobic metabolism, is often elevated in conditions of systemic hypoxia and poor perfusion, both of which are common in severe poisoning. The close correlation between high SOFA scores and elevated Lactate levels suggests that metabolic disturbances are a crucial aspect of the prognosis in poisoned patients. This aligns with previous studies that have identified lactate as an important prognostic marker in other critical conditions, such as sepsis and trauma, where organ failure is a leading cause of death [11,5]

Similarly, the NLR, a marker of systemic inflammation, was found to correlate strongly with both SOFA and APACHE II scores. This is consistent with the understanding that inflammation plays a significant role in the progression of multi-organ failure in poisoning cases. The immune response to toxins can exacerbate tissue damage, leading to further organ dysfunction and higher mortality rates.[12]. The study's findings suggest that the inclusion of biomarkers such as Lactate and NLR alongside clinical scoring systems like SOFA can enhance the predictive accuracy of these tools. This has practical implications for the management of poisoned patients, as real-time measurement of these biomarkers could be integrated into routine ICU assessments to identify patients at higher risk of deterioration.

The findings of this study have several important implications for clinical practice. Given the focus of SOFA on organ dysfunction and its strong correlation with key biomarkers, it can be used to triage patients more effectively in emergency department. In resource-limited settings, where access to advanced diagnostics may be limited, the simplicity of SOFA makes it a particularly valuable tool.[2] The study also highlights the need for early intervention in high-risk poisoning cases. Patients who required mechanical ventilation or inotropic support had significantly higher mortality rates than those who did not, indicating that the need for intensive interventions is a strong predictor of poor outcomes. The identification of high-risk patients based on SOFA scores and biomarker levels could enable clinicians to initiate more aggressive treatments earlier in the clinical course, potentially improving survival rates and also helps in prognosticating the patient and their relatives. This aligns with global trends in critical care, where early identification of organ dysfunction is increasingly recognized as a key determinant of patient outcomes.[13]

Another important implication of this study is SOFA's applicability in resource-limited settings. Poisoning is a major public health issue in low- and middle-income countries, where the use of pesticides and other toxic substances is widespread. In such settings, the availability of complex diagnostic tools may be limited, and the ability to make rapid, data-driven decisions is crucial. SOFA's reliance on easily measurable clinical parameters makes it a practical option for these environments. Moreover, its strong correlation with biomarkers like Lactate and NLR, which can be measured with relatively simple laboratory tests, further enhances its utility in these settings.[14]

In our study, SOFA score demonstrated superior predictive accuracy and correlated better with biomarkers, such as lactate and NLR, particularly in severe or rapidly deteriorating cases. Similar to this research, researches by Kim et al[15] on organophosphate poisoning, by Zhang et al[16] on critically illmultiorgan failure patients and by Beigmohammadi et al[17] on ICU admitted COVID-19 patients, highlighted the advantages of SOFA compared to APACHE II. SOFA score was deemed to be better for acute poisonings, organ failure, and cases with rapid clinical deterioration. Conversely, the APACHE II score has shown better predictive power in specific poisoning types, particularly aluminum phosphide and paraquat poisoning, as evidenced by studies conducted by Pannu et al[10]. and Lee et al[18], Fengjun et al[19]. respectively.

While this study establishes SOFA as a superior tool compared to APACHE II for predicting mortality in acute poisoning cases, further research is needed to validate these findings across different types of poisonings and in larger, multi-center trials. The integration of additional biomarkers, such as procalcitonin or C-reactive protein (CRP), could also be explored to further enhance the predictive accuracy of SOFA. Additionally, the role of serial SOFA measurements in tracking the progression of organ dysfunction over time warrants further investigation.[15]

Conclusion

This study highlights the superior performance of SOFA over APACHE II in predicting mortality in acute poisoning cases. SOFA's higher sensitivity and specificity, along with its stronger correlation with key biomarkers such as Serum Lactate and NLR, make it a more reliable prognostic tool. The results suggest that SOFA is particularly valuable in cases where multi-organ failure occurs rapidly, as is often the case in severe poisonings involving agents like aluminium phosphide.

The study is limited by its single-centric design and relatively small sample size, which may affect the generalizability of the results. It did not incorporate serial SOFA or APACHE II measurements to evaluate the progression of organ dysfunction over time. Other commonly used biomarkers, such as CRP and procalcitonin, were not included in the study outcomes.

Given its simplicity and real-time assessment of organ dysfunction, SOFA can be effectively used in both high-resource and resource-limited settings to guide clinical decision-making. The findings also underscore the importance of integrating biomarker data, particularly Serum Lactate and NLR, with clinical scoring systems to improve the accuracy of

prognosis and optimize patient outcomes. Further research is needed to validate these findings across different types of poisonings and to explore the potential of combining SOFA with additional biomarkers for more precise risk stratification.

Ethical Clearance: Institutional ethical committee of Government Medical College & Hospital 32, Chandigarh approved this study on 7.11.22 ref no.GMCH/IEC/796R/2022/219

Conflicts of Interest: None

Source of funding: Nil

List of abbreviations:

APACHE II: Acute Physiology and Chronic Health Evaluation II

SOFA: Sequential Organ Failure and Assessment

ROC: Receiver Operating Curve

WHO: World Health Organization

NLR: Neutrophil and Lymphocyte Ratio

OPC: Organo phosphorous poisoning

AUC: Area Under Curve

References

1. World Health Organization. Poison control and unintentional poisoning [Internet]. Available from: https://www.who.int/data/gho/data/themes/topics/indicator-groups/poison-control-and-unintentional-poisoning
2. Ahuja H, Mathai AS, Pannu A, Arora R. Acute Poisonings Admitted to a Tertiary Level Intensive Care Unit in Northern India: Patient Profile and Outcomes. J Clin Diagn Res. 2015 Oct;9(10):UC01-4.
3. Calculator: Sequential Organ Failure Assessment (SOFA) score in adults - UpToDate. [cited 2022 Aug 6]. Available from: https://www.uptodate.com/contents/calculator-sequential-organ-failure-assessment-sofa- score-in-adults
4. Sequential Organ Failure Assessment (SOFA). [cited 2022 Aug 6]. Available from: https://reference.medscape.com/calculator/268/sequential-organ-failure-assessment- sofa
5. Dungdung A, Kumar A, Kumar B, Preetam M, Tara RK, Saba MK. Correlation and prognostic significance of serum amylase, serum lipase, and plasma cholinesterase in acute organophosphorus poisoning. J Fam Med Prim Care 2020;9:1873–7.
6. Huang C, Bai L, Xue X, Peng L, Jiang J, Zhang X. Hyperamylasaemia as an early predictor of mortality in patients with acute paraquat poisoning. J Int Med Res 2020;48:300060520910037.
7. Lee JH, Lee YH, Park YH, Kim YH, Hong CK, Cho KW, et al. The difference in C-reactive protein value between initial and 24 hours follow-up (D-CRP) data as a predictor of mortality in organophosphate poisoned patients. Clin Toxicol (Phila). 2013 Jan;51(1):29–34.
8. Erfantalab P, Soltaninejad K, Shadnia S, Zamani N, Hassanian-Moghaddam H, Mahdavinejad A, Damaneh BH. Trend of blood lactate level in acute aluminum phosphide poisoning. World J Emerg Med. 2017;8:116-120
9. Silakhori S, Dadpour B, Khadem Rezaiyan M, Ar S, Mirzakhani F. Comparing APACHE II, APACHE IV, SAPS II, and SOFA Predictive Power in Poisoned Patients Admitted to the Intensive Care Unit. Int J Med Toxicol Forensic Med. 2020;10.
10. Pannu AK, Jhuria L, Bhalla A, Sharma N. PGI score: prospective validation and correlation with SOFA, SAPS-II, and APACHE-II scores for predicting outcomes in acute aluminum phosphide poisoning. Toxicol Res (Camb). 2022; 11:361–6.
11. Yuan S, Gao Y, Ji W, Song J, Mei X. The evaluation of acute physiology and chronic health evaluation II score, poisoning severity score, sequential organ failure assessment score combine with lactate to assess the prognosis of the patients with acute organophosphate pesticide poisoning. Medicine (Baltimore) 2018;97:e10862
12. Mittal C, Singh S, Kumar-M P, Varthya SB. Toxicoepidemiology of poisoning exhibited in Indian population from 2010 to 2020: a systematic review and meta-analysis. BMJ Open. 2021;11:e045182.
13. Nair RK, Prabhu G, Gaude GS. Profile of poisoning cases and their outcome in a tertiary care center. *J Assoc Physicians India*. 2017;65(6):40-45.
14. Farooqui WA, Uddin M, Qadeer R, Shafique K. Trajectories of vital status parameters and risk of mortality among acute organophosphorus poisoning patients – a latent class growth analysis. BMC Public Health 2020 12;20:1538

15. Kim YH, Yeo JH, Kang MJ, Lee JH, Cho KW, Hwang S, et al. Performance assessment of the SOFA, APACHE II scoring system, and SAPS II in intensive care unit organophosphate poisoned patients. J Korean Med Sci 2013;28:1822–6

16. Zhang XM, Zhang WW, Yu XZ, Dou QL, Cheng AS. Comparing the performance of SOFA, TPA combined with SOFA and APACHE-II for predicting ICU mortality in critically ill surgical patients: A secondary analysis. Clin Nutr. 2020 Sep;39:2902–9.

17. Beigmohammadi MT, Amoozadeh L, Rezaei Motlagh F, Rahimi M, Maghsoudloo M, Jafarnejad B, et al. Mortality Predictive Value of APACHE II and SOFA Scores in COVID-19 Patients in the Intensive Care Unit. Can Respir J. 2022;2022:5129314.

18. Lee JH, Hwang SY, Kim HR, Kim YW, Kang MJ, Cho KW, et al. Effectiveness of the sequential organ failure assessment, acute physiology and chronic health evaluation II, and simplified acute physiology score II prognostic scoring systems in paraquat-poisoned patients in the intensive care unit. Hum Exp Toxicol. 2017 ;36:431–7.

19. Fengjun J, Wen Z, Taoning W, Yaying Y, Kai K, Liu M. [Analysis of risk factors for prognosis of patients with acute paraquat intoxication]. Zhonghua Wei Zhong Bing Ji Jiu Yi Xue. 2015 ;27:906–10.

20. Greene SL, Dargan PI, Jones AL. Acute poisoning: understanding 90% of cases in a nutshell. Postgrad Med J. 2005 Apr;81(954):204–16.

21. Müller D, Desel H. Common causes of poisoning: etiology, diagnosis and treatment. Dtsch Arztebl Int. 2013 Oct;110(41):690-9.

Original Research Article

An Autopsy Based Study on Pattern of Homicidal Deaths and Profile of Victims In Chennai

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Abstract

As an ultimate and heinous crime against humanity, homicide has ripple effects that go beyond the loss of life and castsseriousrepercussions on the family. The pattern of homicides within a community can reflect its social stressors and provide useful insights for law enforcement strategies. The pattern of injuries can assist in identifying the cause of death and possibly, understanding of the manner of death. Thus, autopsies provide much information about such unlawful incidents as murder in the state. This was a retrospective study carried out in Chennai on 41 homicidal deaths autopsied in the year 2023.

On analysis, the most affected age group was 21-30 years, and the male-to-female ratio was 2.2:1. Epidemiologically, 15 cases (36.5%) were illiterate, 22 cases (53.6%) belonged to low socioeconomic status, 25 (60.9%) were married, 34 cases (82.9%) were brought dead to the hospital, 24 (58.5%) were unemployed, and 13(31.7%) were of personal vengeance. Cause of death was accounted to multiple cut injuries in 16(39%) cases, followed by 10(24.5%) cases of stab injuries.

The study suggested that homicide represents a significant public health burden, and the results indicated the trends of homicides in the region. The study explored the various reasons behind homicides and the possible sociocultural influences, personal enmity or revenge was the predominant one.

Key words: Homicide, Victim profile, Assault, Socio-demographic.

Introduction

Homicide is a widely prevalent serious crime across the globe and in India. Offenses against the human body are now covered in the new Indian criminal code, Bharatiya Nyaya Sanhita (BNS). They include "culpable homicide" defined in section

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100,"murder" in section 101,and "assault" defined in section 130 of BNS.

Homicide is the ultimate crime and has ripple effects beyond loss of human life. Murder is the most extreme form of violence and the highest level of aggression found in all cultures.[1]Though the terms "murder" and "homicide"are used interchangeably, they are distinct from each other; homicide is a common term for the killing of a human being, while murder defines the specific legal category of criminal homicide of a State. Violent crimes like murder get a disproportionate amount of media coverage, which has a significant impact on public policy, public perceptions of crime, and public fear of crime.[2]

Culpable homicide is defined as causing death by an act with the intention of causing death or with the intention/knowledge of causing such bodily injury likely to cause death. Culpable homicide does not amount to murder if the act was done under grave sudden provocation, if in good faith of the right of private defense of person or property, and if caused without premeditation.[3]

With Goal 16 of the 2030 Agenda for Sustainable Development, member states of United Nations (UN) have committed to significantly reducing all forms of violence and related death rates. In 2021 homicide cases registered globally was 458000, averaging 52 individuals per hour. African continent recorded 176000 cases, America 154000 cases and Asia reported 109000 cases. This form of violence has continued to shape the lives and livelihoods of people, and not just of those in armed conflicts. [4]

The latest National Crime Records Bureau (NCRB) data showed that a total of 28,522 murders were reported in 2022. Uttar Pradesh recorded the most murders (2490) followed by Bihar (2930) and Maharashtra (2295). Tamil Nadu with 1690 murder cases registered, was placed seventh from the top behind West Bengal (1696). Crime Rate (calculated per one lakh of population) was 2.2 in the year 2022.[5]

Homicides may result from a variety of injuries and mechanisms involving blunt and sharp force trauma, gunshots and strangulation. Less common methods involve immersion, incineration and poisoning. Methods vary greatly among different communities and countries, often influenced by the availability of a particular weapon. For forensic experts and crime investigators, it is important to be aware of local patterns of homicide.[6]

Homicide statistics are a proxy for violent crime and a robust indicator of levels of violence within states. Medicolegal autopsies not only give the cause of death but also give other details related to legal incidents in the state where conducted. There were fewer studies to analyze the pattern of injuries in homicidal deaths in our region. Through this study, it was anticipated that key personnel involved in criminal investigation would gain much-needed awareness on the socio-demographics of victims of homicide.

Aims

Our study aimed to determine the epidemiological characteristics relating to homicidal deaths in central areas of Chennai.

1. To examine the pattern of injuries in homicides and type of weapons producing them.
2. To analyse the victim profile of homicides in the region.

Materials and Methods

Following formal IEC approval, a cross-sectional retrospective study was carried out at Kilpauk Medical College in Chennai from January to December 2023. Out of 3146 postmortem examinations conducted, 47 cases were deemed to be of homicides. Our study focussed on the 41 cases that provided enough background and history regarding the homicidal attack/assault and intent based on key factors. The cases with insufficient information on the motive, inconclusive cases like dowry death, suspected suicidal poisonings and cases of advanced putrefaction were excluded. Thus, the cases of homicidal deaths with adequate history and corresponding findings, were considered for the study.

Socio-demographic data like sex, age, socioeconomic status, occupation etc.and the details of the homicide like nature of injuries& weapons, presence of defence wounds, the time and place of attack were collected. All relevant information was collected from documents in the inquest report or FIR, treatment details, photographs of the scene of the

crime, postmortem reports, forensic lab reports, and final opinion reports. The anatomical distribution of the injuries and their characteristics documented were noted and studied with regards to the weapons used. All gathered data was processed in Microsoft Excel sheets and summarized using descriptive statistics to deduce results of the study.

Results and Discussion

The incidence of homicide deaths in 2023 in the region was 1.5%. The results obtained from the study sample of 41 homicide cases are described here.

1. **Gender wise and age group distribution.**

Among the victims, 28 cases (68.2%) were males and 13 cases (31.7%) were females, giving a ratio of 2.2:1. Violence and violent deaths are more commonly associated with men. Similar ratio was demonstrated by Vij A et al.[7] in Mangalore where 71 were males and 18 were females among the 89 victims of homicide. The fact that men are more likely to be violent and aggressive by nature, and that there are aggravating factors like more involvement in fights, drug and alcohol usage, explain the study's preponderance of male victims.

The common age group affected in our study was 18-30 years, comprising 63.4% of cases, followed by 30 – 40 years with 10cases (24.3%) seen, (Fig.1) which is consistent with a study in Pondicherry in 2021.[8] But a study in Bengaluru differed from ours' where most of homicide victims belonged to 31-40 years, contributing to 40%, while the least age group involved was 11-20 years.[9] This was also reflected in Trivandrum by Dileeph et.al.[10] where young adult males (31–40 years) were the most common group involved (24.9%). Singh OG et al.[11] also reported that maximum number of victims (around 30%) in homicidal deaths were from 21 to 30 years.

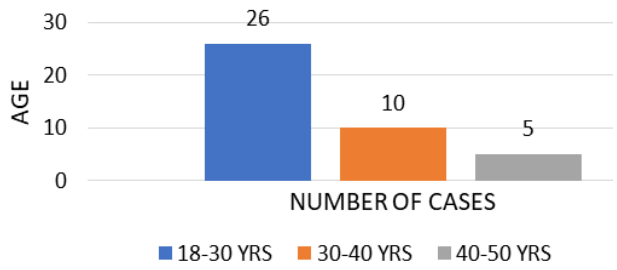

Figure 1: Age group wise distribution of victims.

2. **Marital status and occupation of victims.**

Among 41 victims studied, 25 cases (60.9%) were married, 10 cases (24.3%) were unmarried, and 6 were divorced (Figure 2). By occupation, half of the homicidal victims, 21(51.2%) were unemployed including housewives), 9(21.9%) were employed in companies, and 6(14.6%) were self-employed with shops and small businesses. Only 3 cases (7.3%) involved students. The male victims employed were as diverse as industry workers, drivers, farmers, construction workers, etc doing outskirt work, whereas most of the females were housewives. This had been reflected in a study by Mohanty et al.[12] who found that most of the victims were either labourers (23.73%) or farmers (22.03%) among males and housewives (14.41%) among females.

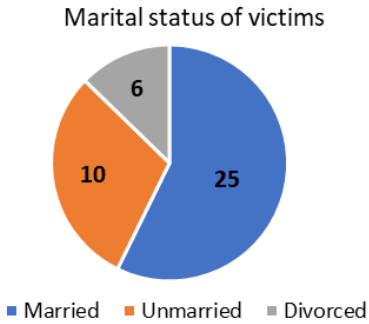

Figure 2: Marital status of victims.

3. **Education and socio-economic status of the victims.**

About 15 cases (36%) were illiterate and 8 cases (19.5%) completed primary education, 12 cases (29.2%) had completed high school and 6(14.6%) had been to college (Figure 3). As homicide victims maximally belonged to the illiterate and low level of education, there might be a strong link between low literacy and high criminal activity rates. But this aspect contrasted with a study in Nagpur[13] where most victims (n-50, 27.9%) had completed only primary school education and 46 cases (25.7%), secondary school education while 14 victims (7.8%) were illiterate. And none of the females had completed even graduation. There can be an association between crime and literacy level, as low literacy rates can make it harder for people to find and keep employment, which also can increase the temptation to turn to illegal means of earning a living.

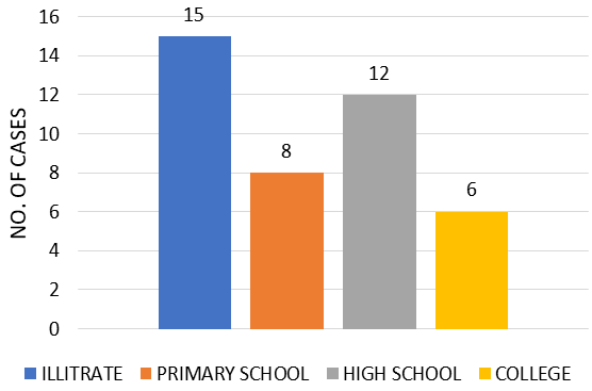

Figure 3: Education level of the deceased.

On analysis, 22(53.6%) belonged to low socioeconomic status, 14(34.1%) were medium, and 5(12.2%) cases belonged to high economic status. Hence, it can be inferred that the maximum victims of homicide were illiterates, workers, and belonged to lower socioeconomic status. These findings are consistent with the studies done by Singh OG [11], Mohanty S, [12] Patel DJ, [14] and Shaw JP et al. [15] This may be explained by high job mobility/joblessness, life frustration, marital discord, ignorance, and poverty in the lower socioeconomic class, all of which can lead to the precipitation of crimes. This holds good especially in big cities owing to the high cost of living, and committing crime becomes a matter of survival, as in gang rivalry.

4. Time and place of occurrence.

It was discovered that, just like the popular belief among public, homicide rates were highest at night and late evening. The number of homicides committed over a 24-hour period is displayed in the graph (Figure 4).

On looking at the time of incidence, 18 cases (43.9%) of homicides were observed to have happened between 6.00 pm and 12.00 am, consistent with studies done by Patel DJ, [14] and Hugar BS. [16] Between 12.00 am and 6.00 am, 8 cases (19.5%) were seen. A study in Rajkot in 2010, had observed more cases (39%), w.r.t time of incidence during 06:01 pm-12:00 midnight, followed by 00:01am-06:00am.

When the place of the incident was examined, 18 cases (43.45%) occurred in the victim's house or surrounding premises, 17 cases (41.46%) on the road, and 6(14.63%) in other places. This depiction was found to be consistent with the study done by Dileeph N, [10] but few other studies[12,17] observed that in 60% cases, the act was committed outside the house of the victims.

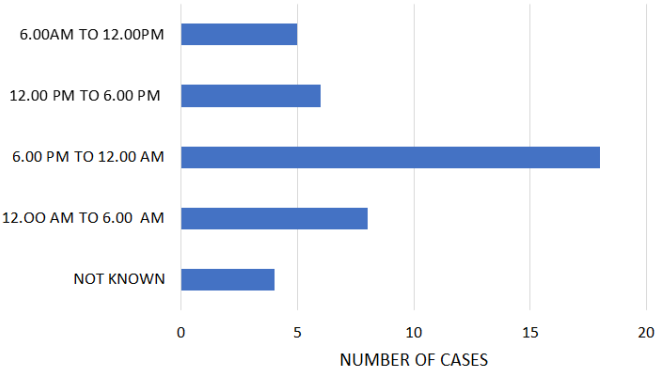

Figure 4: Time of occurrence of the offence among the study sample.

5. The motive behind homicide.

On probing the reasons behind the homicide, 13 cases (31.7%) were consequent to personnel vengeance, 12 cases (29.2%) related to family or marital issues. Both sudden provocation and gang rivalry were accounted for 8 cases (19.5%) each. In 9 cases (21.9%) of homicides, there was a single perpetrator, whereas in 32 cases (78.1%), multiple individuals were involved.

According to a study by Rathod VV, [13] the motives for murder included financial or property disputes in 24% of the cases, while personal conflicts led to homicide in 21% of cases. The most frequent occurrences were found in individuals aged 20 to 40 years. Contributing factors for interpersonal violence in this age group amounted to quarrels in 43% of instances, romantic relationships in 31%, and substance abuse, including alcohol and drugs, in 18% of cases.

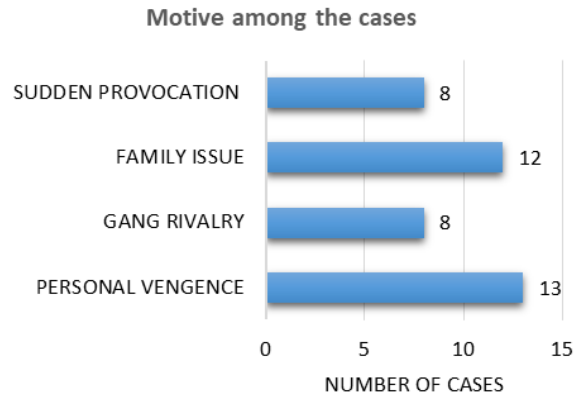

Figure 5: Analysis of precipitating factors in the study group.

6. The pattern of traumatic injury and type of weapon used.

Out of the traumatic cases, 38% of cases were caused by sharp force, while nearly 45% of cases were caused by blunt forces. (Table 2). On probing further, heavy blunt weapons were used in 14 cases, and in 7 cases, heavy sharp weapons were used. Hospital records data revealed that 34 cases (82.9%) were brought dead which is consistent with studies done in regions of Mangalore[7] and Surat. [18] A study by Shaw JP[15] had observed fatal mechanical injuries in 77% homicidal deaths, amongst which, sharp force was used in 31 cases (40.3%) and blunt force was used in 26 cases (33.7%). The violent asphyxia deaths were seen in 14% cases.

The material used or means adopted in homicides included cloth or rope used for throttling in four instances, while poison was employed in one case. A study in Imphal [16] on a total of 97 cases of homicides found that blunt weapon, firearms, and bomb blasts were the commonest methods employed. Multiple injuries and head injuries were the leading causes of death.

Defence injuries were identified in 24 cases (58.5%), out of which cut injuries to the back of the right forearm were found in 10 cases (24.3%) and the back of the right wrist in 12 cases (29.3%). Cut injury at the base of the left thumb was noted in 4 cases. These findings align with the research conducted by Mohanty SS et al. [12] which reported a defence wound incidence of 25.4% among cases. Most of the remaining cases did not present with defence wounds, which may be attributed to factors such as assaults by multiple attackers, being attacked while under intoxication or asleep, and sudden unexpected assaults.

7. The location of injury and cause of death.

Upon examining the locations of injuries, head injuries were found in 24cases (58.5%), aligning with the studies by Vij A. [7] and Dileeph N. [10] Conversely, stab wounds to the neck were recorded in 4 cases (9.7%), which contrasts with the research conducted by Jhaveri S et al. [18], where neck injuries (16.8%) were the most prevalent, followed by head injuries (15.9%). In our study, stab injury to the chest was observed in 4 cases(9.75%), and stab injury to the abdomen in 3 cases (7.3%). A combination of injuries by both blunt and sharp weapons were noted in 8 cases (19.5%).

Table 1: Causes of death among study group.

S.NO	CAUSE OF DEATH	NUMBER OF CASES		TOTAL
		MALE	FEMALE	
1	Shock and haemorrhage due to multiple cut injuries (due to blunt force)	13(31.7%)	5(12.2%)	18(43.9%)
2	Shock and haemorrhage due to multiple stab injuries (due to sharp force)	7(17.2%)	3(7.3%)	10 (24.5%)
3	Shock and haemorrhage due to multiple injuries to the head (either blunt or sharp force used)	4(9.7%)	2(4.8%)	6(14.5%)
4	Asphyxia due to throttling	3(7.3%)	1(2.4%)	4(9.7%)
5	Asphyxia due to strangulation	1(2.4%)	1(2.4%)	3(7.3%)
6	Poison ingestion	Nil	1(2.4%)	1(2.4%)
TOTAL		28	13	41

Upon analyzing the causes of death, shock and haemorrhage resulting from multiple cut wounds were found in 17 cases (41.5%), with 13 males (31.7%) and 4 females (12.2%). This finding aligns with a study conducted in Surat [21], where similar observations were noted in 40.5% of cases. Shock and haemorrhage due to multiple stab injuries were seen in 10 cases(24.5%) in our study and due to multiple injuries to the head alone was seen in 6cases (7.3%). Homicides by throttling and strangulation were seen in 4 cases (9.7%) and 3 cases (7.3%) respectively (Table 1). Firearm injuries were not observed in the study sample, comparable toa study in South Kerala. [11]

Pic 1. Scalp chop wounds

Pic 2. Chop wounds – on right shoulder and front of right arm.

Pic 3. Assault wounds on the back of head

Pic 4. Incised wound on forehead.

Summary and Conclusion

1. 63% of victims were of the age group 18–30 years, while 24% belonged to the age group 31–40 years. 68% of all victims were male.

2. 61% of victims were married and51% were unemployed.

3. 36% of victims were illiterate, and 53.6% belonged to low socioeconomic status.

4. 43% of cases happened during 06pm-12 midnight, followed by 19% of cases during 01am-06am.

5. The predisposing factors were personal enmity/revenge and gang rivalry rather than money/property-related issues in the region.

6. In 45% of the cases, the victims had sustained sharp force injuries, while in 38% blunt force injuries. Found dead or brought dead victims were 83%.

7. The head was the most common site of injury in 58% of cases, followed by the neck, the chest, and abdomen.

These findings largely align with most studies in current forensic literature and suggest that homicide represents a significant public health burden. The nature and pattern of injuries are crucial to arriving at the manner of deaths. The results of our study encourage exploring the reasons behind homicide and possible influences on the victims. Probing the sociocultural components is important because they give information about the events and the circumstances that led up to the crime.

Since the study imparts information on the characteristics and overall nature of each murder, the public, researchers, and individuals involved in resolving criminal incidents, its observations cannot be overlooked. An in-depth knowledge of the injury causation and causative factors is essential, particularly in providing the criminal justice authorities with a better comprehension of murder.

Recommendations:

It is essential to enhance our understanding of the factors behind murders and mechanics of homicide and to develop effective evidence-based prevention strategies that address the issue on both individual and macro levels. It is necessary to monitor crime effectively and enforce laws rigorously to maintain a society free from violence. Unless the State takes strong decisive steps, targets under sustainable development goal to significantly reduce all forms of violence and related deaths rates by 2030 will remain unachieved.

Conflict of interest: None

Ethical clearance: Obtained from the Institutional Ethics Committee. (No.1120/2024/IEC, dated 20.2.2024). The confidentiality of deceased's information was maintained.

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References

1. Mohanty MK. Variants of homicide: a review. Journal of Clinical Forensic Medicine [Internet]. 2004 Aug 1;11(4):214–8.
2. Kamaluddin M, Shariff N, Matsaat G. Mechanical profiles of murder and murderers: An extensive review. Malays. J. Pathol. 2018 Apr 1;40(10).
3. K S Narayan Murty O P Reddy. Essentials of forensic medicine and toxicology.35th ed Jaypee; 2023.p 223-226.
4. UNODC Global Study on Homicide [Internet]. 2023. Available from: https://www.unodc.org/documents/data-and-analysis/gsh/2023/GSH23_ExSum.pdf

5. National Crime Records Bureau [Internet]. 2023. Crime in India 2022. Available from: https://www.ncrb.gov.in/uploads/nationalcrimerecordsbureau/custom/1701607577CrimeinIndia2022Book1.pdf
6. Sterling SO, Byard RW. Homicides. In Forensic and Legal Medicine. 2023 Dec 20 (pp. 428-443). CRC Press.
7. Vij A, Menon A, Menezes RG, Kanchan T, Rastogi P. A retrospective review of homicides in Mangalore, South India. Journal of forensic and legal medicine. 2010 Aug 1;17(6):312-5.
8. Slater S, Subramanyam S. An autopsy study on injuries in homicidal deaths due to weapons. Indian J Forensic Community Med 2021;8(3):157-160.
9. Rao D. An autopsy study of 68 cases of murder suicides. International Journal of Forensic Science & Pathology. 2014 Apr 17; 2:24-7.
10. Dileeph N, Sharija S, Stanley A, Valsala K, Sujisha SS, Prabhakaran N. The Trend of Homicides in South Kerala from 2002-2016: A Retrospective Forensic Autopsy-Based Study. Journal of Forensic Science and Medicine. 2021 Oct 1;7(4):111-6.
11. Singh OG, Gupta BD. Evaluation of Mechanical Injuries in Homicidal Deaths (A retrospective study of 5 years). Journal of Indian Academy of Forensic Medicine. 2007 Sep;29(3):18-22.
12. Mohanty, S. Homicide in southern India- A five-year retrospective study. Forensic Medicine and Anatomy Research, 2013; 1: 18-24.
13. Rathod VV, Choudhary UK, Ghormade PS, Ajay NK. Study of socio-demographic profile of victims in cases of deaths due to homicide. Indian Journal of Forensic and Community Medicine. 2020;7(2):66-71.
14. Patel DJ. Analysis of homicidal deaths in and around Bastar region of Chhattisgarh. Journal of Indian Academy of Forensic Medicine. 2012 Jun;34(2):139-42.
15. Shah JP, Vora DH, Mangal HM, Chauhan VN, Doshi SM, Chotaliya DB. Profile of Homicidal Deaths in and around Rajkot Region, Gujarat. Journal of Indian Academy of Forensic Med. 2013;35(1):33-6.
16. Hugar BS, YP GC, SH J. Pattern of homicidal deaths. Journal of Indian Academy of Forensic Medicine. 2010 Sep;32(3):194-8.
17. Shivkumar, B.C., Vishwanath, D. and Srivastava, P.C. Trends of Homicidal deaths at a tertiary care centre, Bengaluru. Indian Acad Forensic Med. 2011;33(2):120-15.
18. Jhaveri S, Raloti S, Patel R, Brahbhatt J, Kaushik V. Profile of Homicidal Deaths: a Three Year Study At Surat Municipal Institute of Medical Education and Research, Surat During 2011 -2013. National Journal of Community Medicine. 2014 Dec 31;5(04):406-9.
19. Das NG, Singh TB. An Autopsy Based Study on Patterns of Injury in Homicidal Deaths in Imphal. Journal of Indian Academy of Forensic Medicine. 2023 Jun;45(2):109-11.

Original Research Article

Correlation of 128-Slice Computed Tomography Scan and Autopsy Findings in Fatal Craniocerebral Trauma

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Abstract

Background: Head injury remains a major cause of morbidity and mortality worldwide. While computed tomography (CT) scans serve as a critical diagnostic tool in detecting intracranial lesions, forensic autopsy remains the gold standard for definitive assessment. This study evaluates the diagnostic accuracy of 128-slice CT scans in identifying fatal head injuries by comparing imaging findings with autopsy results.

Methods: A retrospective observational study was conducted on 60 cases of fatal head injuries admitted to A.J. Institute of Medical Sciences & Research Centre between December 2016 and April 2018. CT scan findings were systematically compared with autopsy results, with a focus on intracranial haemorrhages and contusions. Sensitivity, specificity, and concordance between imaging and post-mortem findings were analyzed using IBM SPSS Statistics (Version 17).

Results: Among the 60 cases, 90% were males, with road traffic accidents accounting for 86.67% of cases. The sensitivity of CT scans for different types of hemorrhages was as follows: subarachnoid hemorrhage (60.71%), subdural hemorrhage (58%), extradural hemorrhage (40.9%), and intracerebral hemorrhage (11.11%). Contusion detection was highest in the frontal lobe (90.32%) and lowest in the corpus callosum (16.67%). Smaller contusions and posterior cranial fossa lesions were frequently missed on CT scans.

Conclusion: While CT scans play a valuable role in forensic and clinical assessments, they exhibit limitations in detecting smaller hemorrhages and contusions. The study underscores the need for high-resolution imaging, contrast-enhanced CT, and serial imaging to improve diagnostic accuracy. Future research should focus on MRI integration, AI-assisted imaging, and multicentric studies to enhance forensic radiology.

Keywords: Head injury, CT scan, autopsy, forensic radiology, intracranial hemorrhage, contusions, forensic imaging.

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Introduction

Head injury is a significant cause of morbidity and mortality worldwide, with road traffic accidents being the primary contributor. Computed tomography (CT) scans are indispensable in diagnosing intracranial injuries, but forensic autopsy remains the definitive method for determining the extent of injuries. This study aims to evaluate the diagnostic accuracy of 128-slice CT scans in identifying fatal head injuries by correlating their findings with autopsy results.

Aims and Objectives

1. To correlate post-mortem examination findings with 128-slice CT scan findings in fatal head injuries.
2. To identify lesions that CT scans may fail to detect but are present at autopsy.
3. To compare findings with national and international studies.
4. To recommend improvements in imaging protocols to reduce discrepancies between CT scan and autopsy findings.

Need for the Study:

1. **Accuracy Evaluation:** This study assesses CT scan reliability in fatal head injuries by comparing CT findings with autopsy results, quantifying concordance and discordance.
2. **Missed Lesion Detection:** It identifies lesions missed by CT but found at autopsy, aiming to improve imaging protocols and interpretation.
3. **Forensic Impact:** The research clarifies CT's strengths and limitations in forensic head injury investigations, addressing potential legal implications.
4. **Clinical and Radiological Advancement:** By comparing findings with other studies, it aims to enhance CT protocols, leading to better clinical and forensic outcomes.
5. **Regional Data Contribution:** This study adds to regional head injury data, reflecting local injury patterns and diagnostic practices.

Research Gaps in the Study

1. **Limited Sample & Regional Focus:** Findings from 60 cases in a single institution may not be generalisable.
2. **Lack of Advanced Imaging:** MRI and post-mortem CT angiography (PMCTA) were not included, limiting the detection of subtle injuries.
3. **Histopathological Correlation:** Microscopic analysis of brain injuries was not extensively compared with CT findings.
4. **Temporal Evolution:** The impact of time on lesion detectability between imaging and autopsy was not analysed.
5. **Mechanism-Specific Analysis:** No subgroup analysis based on different injury mechanisms.
6. **Inter-Observer Variability:** Differences in CT and autopsy interpretations were not assessed.
7. **Clinical Implications:** The role of improved imaging in real-time clinical decision-making was not discussed.

Materials and Methods

Study Design

This retrospective observational study analyzed data from a cohort of fatal head injury cases. The study systematically compared CT scan findings with autopsy results to determine diagnostic concordance.

Sample Size and Selection

A total of 60 fatal head injury cases were selected to provide meaningful statistical comparisons. The study period (December 2016-April 2018) was chosen to ensure consistency in imaging and autopsy protocols.

Institutional record availability and ethical considerations constrained the number of eligible cases. Including only those with complete documentation ensured data reliability and minimized bias. While the sample provides valuable insights, future studies with larger multicenter datasets are recommended to improve generalizability.

Rationale for Sample Size Selection – explanation.

- The sample size of **60 fatal head injury cases** was determined based on statistical power, feasibility, and practical constraints. Given the **retrospective** nature of the study (December 2016–April 2018), a larger sample

was not feasible due to the limited availability of cases with both **complete CT scan and autopsy records**.

- Previous forensic radiology and neuropathology studies have used **comparable or smaller sample sizes**, demonstrating reliability in identifying diagnostic trends. The study focuses on **fatal head injuries**, a subset of forensic cases, making large-scale sampling challenging. However, the selected cases encompass a **diverse range of intracranial hemorrhages and contusions**, ensuring statistical representation of common traumatic brain injury patterns.
- The chosen sample size allows for **adequate calculation of sensitivity, specificity, and concordance** between CT and autopsy findings, particularly in detecting smaller hemorrhages and posterior fossa lesions, which are often missed on CT scans.

Additionally, **institutional record availability and ethical considerations** constrained the number of eligible cases. Including only those with **complete documentation** ensured data reliability and minimized bias. While the sample provides valuable insights, future studies with **larger multicenter datasets** are recommended to improve generalizability

Consent

- Written informed consent from the next of kin was not obtained**.** As the study was conducted on cases that underwent **medicolegal autopsy**, the bodies were under the jurisdiction of the **state**, and consent for examination was granted by the **investigating officer**. In all cases, **requisitions were received from the investigating officer**, ensuring compliance with legal procedures.
- Since all cases were **medicolegal (MLC) in nature**, there was **no direct interaction** between the autopsy physician and the relatives of the deceased. Consequently, **written informed consent from the next of kin was not obtained**.
- Furthermore, as the study followed a **retrospective observational design**, only **existing autopsy and CT scan findings were analysed**. Given the nature of the study, obtaining consent from all cases was **not feasible**, as the data was derived from records of previously conducted medico-legal examinations.

Data Collection

- **Ethical Considerations:** The study was conducted following ethical principles, with approval from the institutional ethics committee (Ref No: AJEC/REV/175/2016, dated 29/11/2016).
- **Hospital Records Review:** Data included demographics, clinical history, injury mechanism, and Glasgow Coma Scale (GCS) scores.
- **CT Scan Analysis:**
  - 128-slice CT scans were reviewed by a radiologist blinded to the autopsy findings.
  - Findings included intracranial haemorrhages, skull fractures, cerebral oedema, and other abnormalities.
  - The timing of CT scans post-injury was documented.
- **Autopsy Findings:**
  - Detailed macroscopic documentation of haemorrhages, skull fractures, and brain contusions/lacerations.
- **Comparative Analysis:**
  - Systematic comparison of CT and autopsy findings.
  - Concordance and discordance analysis.
- Statistical Analysis:
  - IBM SPSS Statistics (Version 17) was used for analysis.
  - Sensitivity, specificity, positive predictive value, and negative predictive value of CT scans were calculated..

Inclusion Criteria

1. All fatal head injury cases were admitted during the study period.
2. Availability of 128-slice CT scan reports.
3. Complete autopsy records.

Exclusion Criteria

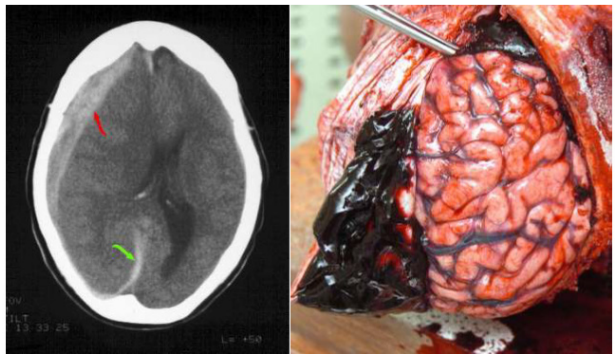
1. Cases with total structural distortion of cranial contents precluding interpretation.
2. Cases where either a CT scan or autopsy was not performed.

Results

- 90% of cases were male, with the most affected age group being 20–30 years (25%).
- **Primary cause of injury:** Road traffic accidents (86.67%), followed by falls (11.67%) and assaults (1.67%).

Table 1: Correlation of Head Injury Lesions at Autopsy and CT Scan

Lesion Type	Detected at Autopsy	Detected at CT Scan	Not Detected at CT Scan
Intracranial Hemorrhages	58	55	3
Contusions	53	40	13

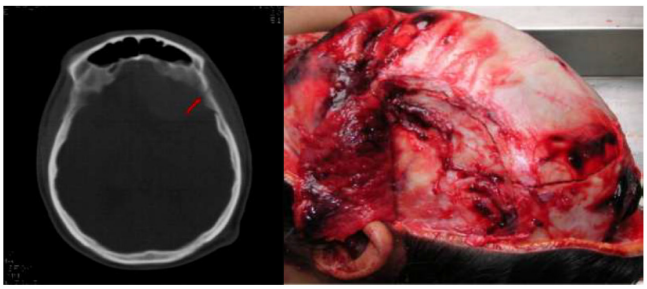


PICTURE 1. A. CT SCAN SHOWING SUBDURAL HEMATOMA WITH LOSS OF NORMAL GREY-WHITE MATTER DIFFERENTIATION.

PICTURE 1.B. BRAIN SHOWING FLATTENED PALE GYRI AND NARROWED SULCI –WITH SUBDURAL HEMATOMA (PM NO 64/17).

Table 2: Sensitivity of CT Scan in Detecting Hemorrhages

Hemorrhage Type	Detected at Autopsy	Detected at CT Scan	Sensitivity (%)
Extradural (EDH)	22	9	40.9%
Subdural (SDH)	50	29	58%
Subarachnoid (SAH)	56	34	60.71%
Intraventricular (IVH)	43	18	41.86%
Intracerebral (ICH)	9	1	11.11%



PICTURE 2 A. CT SCAN SHOWING LINEAR SKULL FRACTURE THROUGH THE TEMPORAL SQUAMOSA (ARROW) AND SCALP CONTUSION.

PICTURE 2 B. AUTOPSY (PM NO. 245/17) SHOWING FISSURE FRACTURE (ARROW) OF VAULT OF SKULL INVOLVING LEFT PARIETAL BONE AND SCALP EXTRAVASATION

Discussion

CT scans demonstrated limitations in detecting certain intracranial injuries, particularly small contusions and posterior cranial fossa lesions. The findings were consistent with previous studies that reported similar challenges in the CT-based detection of haemorrhages and contusions.

Conclusion

While CT scans are valuable, forensic autopsy remains the gold standard in detecting intracranial injuries. Improved imaging protocols, high-resolution CT scans, and contrast enhancement are recommended to reduce discrepancies.

Limitations of the Study

1. **Sample Size Constraints:** The study was limited to 60 cases, which may restrict the generalizability of the findings. A larger dataset could provide more robust statistical insights.
2. **Retrospective Design:** The study relied on existing records, which may introduce biases due to variability in imaging and autopsy documentation.
3. **Absence of MRI Data:** MRI could provide additional insights into subtle brain injuries, particularly diffuse axonal injuries, which CT scans may miss.
4. **Timing of CT Scans:** The interval between injury and CT scan varied, potentially affecting lesion detectability.
5. **Limited Assessment of Radiological Expertise:** Variability in radiologists' interpretations may have influenced sensitivity findings.

Future Research Recommendations

1. **Larger, Multicentric Studies:**Conduct similar studies across multiple centres with larger sample sizes to validate findings.
2. **Prospective Studies:** A prospective study design with standardized imaging and autopsy protocols would improve data accuracy.
3. **MRI Integration:** Future studies should explore the role of MRI alongside CT and autopsy to assess its effectiveness in forensic investigations.
4. **Advanced Imaging Techniques:** Evaluating the benefits of ultra-high-resolution CT scans and dual-energy CT scans for improved detection of subtle injuries.
5. **Artificial Intelligence (AI) in Imaging:** Exploring AI-assisted CT scan analysis to enhance the detection of intracranial haemorrhages and contusions.
6. **Longitudinal Studies on Evolving Lesions:** Examining how intracranial lesions progress over time with serial imaging could provide further forensic and clinical insights.

Conflict of Interest: NIL

Source of Funding: NIL

References

1. Ramamurthi B. Road Accidents: Epidemiology and Prevention. Neurology India. 1995; 43:9-15.
2. Puvanachandra P, Hyder Aa. The Burden of Traumatic Brain Injury in Asia. Pakistan Journal of Neurological Science. 2009; 4(1):27-32.
3. Goyal MK, Verma R, Kochar S, Asawa S. Correlation of CT scan with Postmortem Findings of Acute Head Trauma Cases. J Indian Acad Forensic Med. 32(3): 208-211.
4. Bordignon KC, Arruda WO. CT Scan Findings in Mild Head Trauma. Arq Neuropsiquiatr. 2002; 60(2-A):204-210.
5. Poulsen K, Simonsen J. Computed Tomography as Routine in Medico-Legal Autopsies. Forensic Sci Int. 2007; 171:190.
6. Pathak A, Singh D, Khandelwal N. Fallacies of Routine CT Scan in Identifying Lesions in Severe Head Injury. Indian J Neurotrauma. 2006; 3(1):37-42.
7. Lobato RD, Rivas JJ, Gomez PA, Castaneda M, Canizal JM,. Sarabia R. Head Injury Patients Who Talk and Deteriorate into Coma: Analysis of 211 Cases Studied with CT. Journal of Neurosurgery. 1991; 75:256-261.
8. Lobato RD, Gomez PA, Alday R, RivasJJ, Dominguez J, Cabrera A. Sequential Computerized Tomography Changes and Related Final Outcome in Severe Head Injury Patients. ActaNeurochir (Wein). 1997; 139: 385-91.
9. Menon A. Autopsy Findings and CT Scan Diagnosis in Fatal Head Injury: A Comparative Study. (MD Dissertation) Manipal: Manipal University; 2001.
10. Tsai FY, Teal JS, Itabashi HH, Huprich JE, Hieshima GB, Segall HD. Computed Tomography of Posterior Cranial Trauma. Journal of Computer Assisted Tomography.1980; 4: 291-305.
11. Yuzawa H, Higano S, Mugikura S, Umetsu A, Murata T, Nakagawa A. Pseudo-Subarachnoid Hemorrhage Found in Patients with Post-resuscitation Encephalopathy: Characteristics of CT Findings and Clinical Importance. American Journal of Neuroradiology. 2008; 29(8):1544-9.

12. Bederson JB, Connolly ES, Batjer HH, Dacey RG, Dion JE, DiringerMn, et al. Guidelines for the Management of Aneurismal Subarachnoid Hemorrhage: A Statement for Healthcare Professionals from a Special Writing Group of the Stroke Council, American Heart Association. Stroke.2009; 40: 994-1025.
13. Plaha P, Malhotra, Heuer, Peter. Management of Chronic Subdural Haematoma. Advances in Clinical Neuroscience and Rehabilitation. 2008; 8 (5): 12-15.
14. Zimmerman RA, Bilaniuk LT, Dolinskas C, Gennarelli T, Bruce D, Uzzell B. Computed Tomography of Acute Intracerebral Hemorrhagic Contusion. Computed Tomography. 1977; 1: 271-288.
15. Zimmerman AA, Bilaniuk LT, Hackney DB, Goldberg HI, Grossman RI. Head Injury: Early Results of Comparing CT and High Field MR. American Journal of Neuroradiology. 1986; 7:757-764.

Original Research Article

Study on Medico Legal Case Pattern at Tertiary Care Hospital Hyderabad Telangana

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Abstract

Medico-legal cases (MLCs) involve incidents of injury or illness that require law enforcement investigation, often due to suspected criminal activities. This study aims to analyze the types and patterns of MLCs reported at a tertiary care hospital in Hyderabad, Telangana, to gain insights into injury trends and inform preventive strategies.

A retrospective, observational study was conducted at Malla Reddy Institute of Medical Sciences, Hyderabad, analyzing MLCs reported between January 1, 2021, and June 30, 2021. Data were extracted from medico-legal records, including demographic information, types of injuries (e.g., assaults, RTAs, burns), and the manner of injury (accidental, suicidal, or homicidal). Statistical analysis was performed using Microsoft Excel.

A total of 2111 MLCs were reported, with 1471 (70%) male and 640 (30%) female patients. The age group 21-30 years found the highest frequency of cases (31.4%). The majority (78.25%) of cases were from urban areas. RTA accounted for the highest proportion of cases (44.19%) followed by assaults (16.76%) and poisoning (7.01%). Other cases such as falls from height, industrial accidents, and burns, were less common. RTAs were the most frequent type of MLC, indicating the need for enhanced road safety measures. Assaults and poisoning were also significant, underscoring the need for improved mental health support and violence prevention strategies. The findings suggest the need for targeted interventions to reduce the burden of MLCs in the region.

Key word: MLC cases; Pattern; Casualty.

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Introduction

Medico-legal cases (MLCs) refer to incidents involving injury or illness where the attending physician, after taking the patient's history and performing an examination, deems it necessary for law enforcement authorities to investigate[1,2] the cause of the condition. These cases often involve suspected criminal activities such as burn injuries, vehicular accidents, fall from heights, assaults, suspected homicides (including firearm injuries), poisoning and sexual assault.

Road traffic accidents (RTAs) are a significant contributor to the global burden of injury. According to World health organization[3] approximately 1.19 million people die each year as a result of road traffic crashes, between 20 and 50 million more people suffer non-fatal injuries, with many incurring a disability. The global mortality rate from RTAs was 20.8 per 100,000 population. According to a report by the United Nations[4], the crude death rate between 2015 and 2020 was 7.7, with developing nations predicted to account for 90% of global traffic fatalities. Furthermore, mortality from injuries is expected to surpass that from communicable diseases in the near future.

Despite the alarming statistics, injuries are often under recognized as a major public health issue in many countries. The collection of data on injury-related cases is vital for understanding the socioeconomic impact of injuries and for the formulation of effective preventive strategies.

The aim of this study is to investigate the various categories of medico-legal cases reported to the casualty department of a hospital. Specifically, the study seeks to analyze the types of MLCs presenting at the hospital and to identify patterns in the types of injuries and offenses involved.

Materials and Methods

A retrospective and observational study on pattern of medico-legal cases reported at the Casualty Department of Malla Reddy Institute of Medical Sciences, a tertiary care hospital in Hyderabad, Telangana. The study focused on medico-legal cases reported between 1st January 2021 and 30th June 2021, six months period. Data was collected from the medico-legal records maintained by the Medical record department after obtaining permission from hospital authority.

Inclusion and Exclusion Criteria: The study included all unnatural cases reported to the Casualty Department, encompassing accidental, suicidal, and homicidal cases. Natural disease-related cases were excluded from the study.

Data Collection: The data collected from the records included demographic information (age and sex), the month-wise distribution of various medico-legal cases, types of injuries like assault, fall from height, burns, human or animal bite, and injuries due to road traffic accidents (RTAs), Hanging and drowning. The manner of the incident (Suicide, accident and homicide) also collected. The collected data was analyzed using Microsoft Excel software to identify trends and patterns related to the reported medico-legal cases.

Statistical Analysis: Data was analyzed for frequency distribution, with the aim to assess the burden of medico-legal cases in the region. The analysis will help in understanding the prevalence of different types of medico-legal issues, which will, in turn, provide valuable insights for improving infrastructure and preventive strategies within the hospital. Additionally, the findings may support law enforcement agencies in identifying critical areas for intervention to reduce the occurrence of medico-legal issues.

Results

Study on medico legal case pattern was conducted in a tertiary care teaching hospital, Hyderabad. The total number of cases reported to casualty department is 2111, for a period of six months, MLC case details were collected from medical records. The data was analyzed statistically using Microsoft Excel 2019 version. The study results are as follows

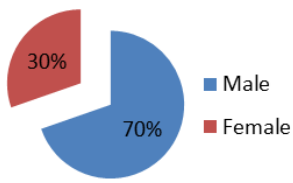

Figure 1: Showing the details of sex wise distribution of medico legal cases.

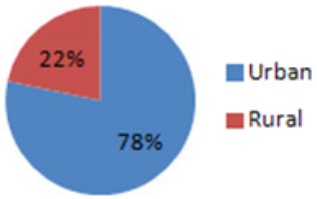

Figure 2: Medico legal case pattern distribution

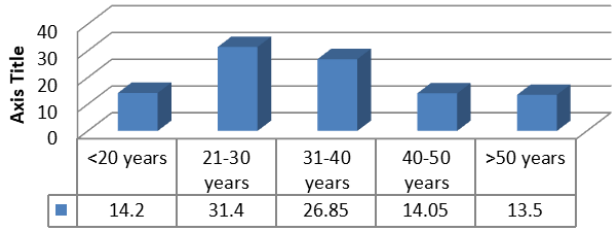

Figure 3: Age wise distribution of medico legal cases.

Urban and Rural wise.

Majority of medico legal cases are reported in the age group of 21-30 years are 31.4% Followed by, 26.85% of cases reported in age group of 31-40 years and the least number of cases were reported in above 50 years age group.

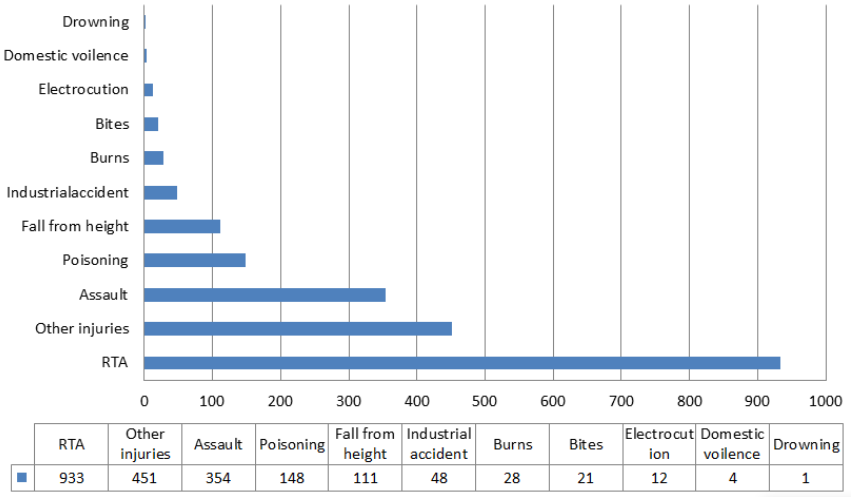

Figure 4: Pattern of distribution of medico legal cases

Maximum number of cases reported in the study is road traffic accidents 44.19%.

Discussion

This retrospective, record-based observational study was conducted at Malla Reddy Institute of Medical Sciences, Hyderabad, Telangana, to analyze the pattern of medico-legal cases (MLCs) reported to the casualty department over a period of six months. A total of 2111 case details were collected, consisting of 1471 (70%) male and 640 (30%) female patients. The study found a significant disparity in the locality of origin, with 78.25% of the cases coming from urban areas and 25.75% from rural areas.

The higher number of cases from urban localities is consistent with the hospital's location, situated in the northern part of the city, well-connected to suburban and district roads. This geographical advantage likely results in increased traffic contributing to the higher incidence of road traffic accidents. The dominance of urban areas in the study may also reflect population density, higher industrial activity, and the availability of medical facilities.

The most common pattern of MLC in this study was road traffic accidents (44.19%), followed by assaults (16.76%) and poisoning (7.01%). Other injuries (21.36%), remaining are falls from height (5.2%), industrial accidents (2.27%), and burns (1.32%), were also significant but occurred less frequently. The high incidence of RTAs aligns with the hospital's strategic location, where access to suburban and district roads contributes to traffic-related injuries. This finding is

consistent with similar studies conducted in other regions, where RTAs accounted for the majority of MLCs, highlighting the need for improved road safety measures and traffic management.

Assault-related injuries accounted for 16.76% of the cases in our study. The concentration of assault cases in urban and industrial areas mirrors the findings of other studies, such as those by Beejaysinh Rathod[5] at Govt. Medical College Vadodara. These areas often have higher socio-economic disparities and population density, which can contribute to a greater incidence of violent crimes. It is crucial to address social determinants of health and violence prevention in such settings.

Poisoning was the third most common pattern of MLC, with 7.01% of cases. The majority of poisoning cases in this study were suicidal, while accidental poisoning incidents were fewer. This pattern is consistent with national trends where suicide, particularly by poisoning, has become a significant cause of morbidity and mortality. Interestingly, no homicidal poisoning cases were reported, which may reflect the nature of poisoning being predominantly used in suicidal attempts rather than for homicidal purposes in this region.

Injuries, such as falls from height (5.2%), industrial accidents (2.27%), and burns (1.32%), contributed to the overall case load but were not as prevalent as RTAs and assaults. Industrial accidents although fewer in number, may reflect the hospital's proximity to industrial zones, which often increases the frequency of work place-related injuries. Falls from height, often resulting from construction accidents, are another area where preventive measures could significantly reduce incidents.

Injuries related to domestic violence (0.25%), electrocution (0.56%), and bites (0.99%) were reported to be relatively low in our study. Domestic violence, in particular, was under represented in comparison to studies in other urban areas, which may point to under reporting or lack of recognition of such injuries. Electrocution and bites were similarly infrequent, which may be attributed to regional differences in occupational hazards or animal-related injuries.

The pattern of medico-legal cases in our study shows similarities to findings from studies conducted in other regions of India. Several studies in India, by Dr. Manju[6] in South Kerala, Haridas SV[7], Yatoo GH[8], Dileep Kumar R[9] and Singh H[10] at Haryana revealed a similar distribution of pattern of MLC cases, with road traffic accidents and assaults being the most frequent pattern. Additionally, a study conducted by Santhosh Chadrappa Siddappa[11] at JJM Medical College Davangere in Karnataka also reported a comparable distribution of MLCs, indicating that these patterns are consistent across different geographic locations in India.

While the study provides valuable insights, there are a few limitations that should be considered. The study was conducted in a single tertiary care hospital, which may not be fully representative of all healthcare facilities in the region. The retrospective nature of the study also relies on the accuracy of records, and the possibility of under reporting or incomplete documentation exists. Furthermore, the study did not explore the socio-economic or psychological factors that may have contributed to the high incidence of suicides due to poisoning.

Conclusions

In conclusion, this study identifies road traffic accidents, assaults, and poisoning as the most common medico-legal cases in a tertiary care hospital in Hyderabad. The findings highlight the need for targeted interventions in urban and industrial settings, including road safety measures, violence prevention, and mental health support. Further studies are necessary to explore the underlying causes of these injuries and to develop strategies for prevention and intervention at both individual and societal levels. Additionally, improving data collection on domestic violence and other less-reported injuries could provide a more comprehensive understanding of medico-legal cases in the region.

Conflict of interest: Nil.

Ethical clearance: Yes, Institutional ethical clearance obtained with reference No: MRIMS-DHR-IEC-16/2022.

Source of funds: Self

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References

1. Sandeep KS, Ranjit TM, Deshpande VL, Dilip WR. Profile of medico-legal cases at a tertiary care hospital in Ahmednagar, Maharashtra. Indian J Forensic Med Pathol. 2015;8(4):113-5. doi: 10.21088/ijfmp.0974.3383.8415.1.
2. Malik R, Atif I, Rashid F, Abbas M. Analysis of 3105 medico-legal cases at a tertiary care hospital, Rawalpindi. Pak J Med Sci [Internet]. Available from: doi: 10.12669/pjms.334.11696.
3. World Health Organization. Road traffic injuries. WHO key facts [Internet]. 2023 Dec 13. Available from: https://www.who.int/news-room/ fact-sheets/ detail/road-traffic-injuries.
4. Wikipedia contributors. Mortality rate. Wikipedia, The Free Encyclopedia [Internet]. 2024 Dec 22. Available from: https://en.wikipedia.org/wiki/Mortality_rate.
5. Rathod B, B. SB. Evaluation of all medico-legal cases brought to casualty at GMC and SSG Hospital, Vadodara. Medico Legal Update. 2024;24(3):15-9.
6. Manju L, B. DN. A study on medico-legal cases attended in a tertiary care hospital in South Kerala. Int J Health Sci Res. 2018;8(4):257-60.
7. Haridas SV, Pawale DA. A retrospective study of the pattern of clinical medico-legal cases registered at a tertiary health care centre in Kolhapur district. J Forensic Med Sci Law. 2014;23(2):1-5.
8. Yatoo GH, Jalali S, Malik A, Khan A. Profile and pattern of medico-legal cases attending a tertiary care hospital in North India. Int J Med Pharm Sci. 2015;5(5):1-8.
9. Kumar RD, Siddaramanna TC, Parate SV, Hemanthraj MN. Retrospective study of the profile of medico-legal cases in Tumkur region, Karnataka. Int J Biomed Adv Res. 2015;6(4):339-40.
10. Singh H, Dhattarwal SK. Pattern and distribution of injuries in fatal road traffic accidents in Rohtak (Haryana). J Indian Acad Forensic Med. 2004;26(1):20-3.
11. Siddappa SC, D. A. A study pattern of medico-legal cases treated at a tertiary care hospital in Central Karnataka. Indian J Forensic Community Med. 2015;2(4):193-7.

Original Research Article

Sexual Dimorphism in Lip Prints

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Abstract

Background: Cheiloscopy, as a corroborative means of identification in Forensic Science gains more importance now-a-days. Both patent and latent lip prints are used as an evidentiary source in court of law in recent era.

Aim: A cross-sectional study of various lip prints was conducted here to determine the sexual dimorphism with a sample size of 345 (Male – 160, Female – 185) after obtaining proper consent and ethical committee clearance.

Methods: The prints were taken using the standard cellophane tape method after the application of red coloured lip stick which were classified according to the Tsuchihashi classification and analysed.

Results: The study results revealed that Type V and Type I were predominantly seen in males and females respectively. Also, the study concludes that the pattern of the lip prints differs among the individuals. In spite of the difference noted in the prints, due to the over lapping features, cheiloscopy can be used as substantial evidence rather than a definitive one.

Conclusion: Like fingerprints, the uniqueness of lip impressions between individuals is utilized by Forensic experts to utilize them as corroborative evidence in solving the crimes along with other primary evidences. Factors like the moisture or the oil and the type of the lip sticks may alter the visibility as well as the quality of the prints which reduces their evidentiary value. But the significant pattern of difference noted among the individuals in our study prove that lip prints can be used as a valid tool in identification.

Keywords: Cheiloscopy, lip prints, identification, corroborative evidence.

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Introduction

Anthropologists first noted the biological phenomenon of system of furrows on the red part of the human lips which served valuable evidence in Forensic Science [1]. The study of lip prints is termed as 'Cheiloscopy' or 'Quiloscopy' (derived from the greek word 'cheilos' meaning "lips" and 'skopein' meaning "see" [2]. It not only includes studying about the visible prints but also the latent ones made with moisture provided by minor salivary and sebaceous glands of the lips [3]. External surface of the lips has many elevations, depression, wrinkles and grooves developed on the sulci labiorum, present in the zone of transition between the inner labial mucosa and the outer skin which differs from person to person. Lip prints can be found on various surfaces where the lips come into contact like drinking glasses and cups, cigarette butts, utensils, paper and documents, mirror and glass surfaces while lipstick or lip gloss can leave lip prints on surfaces like tissue paper, napkin or clothing. It is important to note that the visibility and quality of lip prints on these surfaces can vary based on factors such as the amount of pressure applied, the type of cosmetics (lipstick, lip gloss) applied and nature of the surface material (e.g., porous or non-porous). The lip prints obtained from such sites readily give clues about various factors in the crime scene which can provide a direct link to suspect [4]. The lip print produced by traditional lipsticks (visible) are generally easy to identify and analyze whereas latent (invisible) lip prints may be highly prevalent and be present as hidden evidence making it difficult for the identification [5].

In criminal investigations, lip print analysis can aid in identifying missing persons or unidentified bodies, especially when other forms of identification, like fingerprints or dental records, are not available. Though lip grooves are permanent and unchangeable, any irresistible environmental factors such as minor/major trauma, inflammation, herpetic lesions may alter the morphology and pattern of wrinkles and cause flaw in the cheiloscopic studies. Thereby, lip print identification is not widely used or standardized as fingerprint identification. The accuracy and reliability of lip print analysis can vary depending on the quality of lip print impression, environmental condition and the expertise of a Forensic expert. As a result, lip print identification is typically used as a supplementary tool alongside other evidences and techniques in Forensic investigation. Hence, Forensic investigations involve combination of multiple methods, such as Deoxyribonucleic acid (DNA) analysis, skeletal examination, or other physical characteristics, to determine an individual's gender with a higher degree of accuracy [6]. However, the peculiar characteristics of lip print is considered as part of a comprehensive approach of using it as corroborative evidence in legal investigations.

Lip print identification

The process of lip print identification involves the comparing, matching and examining the characteristics of lip lines and grooves based on various classifications to determine if there is a match or exclusion. Lip prints consist of ridges and grooves created by the unique arrangement of skin on the lips as given in Figure 1.

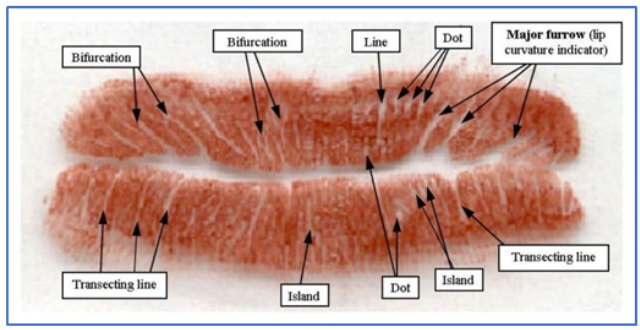

Figure 1. Lip print

The main types of lip print patterns include Vertical lip prints, followed branched lip prints, radial lip prints, rectangular prints, elliptical prints and diagonal prints according to the shape they present with. Also, the additional features such as wrinkles, scars, or other unique characteristics add up to their individuality. As fingerprints are unique to each individual, lip prints also have distinctive patterns and characteristics that can be used for identification [7].

In 1967, Clauco Martin Santos devised a simple system for classifying lip prints and lip grooves into simple types and composite types. Simple types include four groups viz straight line, curved line, angled line and sine shaped line. Likewise, Bifurcated, trifurcated and the irregular types are termed as

composite types.[9]. Two Japanese scientists namely, Yasuo Tsuchihashi and Kazuo Suzuki studied patterns of grooves on human lips and classified them into six types as shown in figure 3 which was also known as Tsuchihashi classification, one of the most widely used classification in literature. As given in figure 3, Type I - Clear cut vertical grooves run across the lips, Type I′ - Partial vertical grooves, that does not run across the lips, Type II - Branched groove, Type III - Intersected grooves, Type IV - Reticular grooves and Type V- Undetermined. Renaud, a French scientist studied 4000 prints of the lips and found that all were different except in case of uni-ovular twins and accordingly gave the classification as given in figure 4.

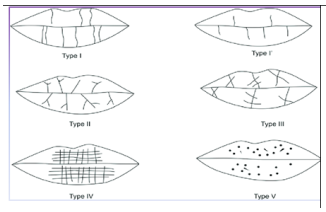

Figure 3: Tsuchihashi and Suzuki classification of lip prints

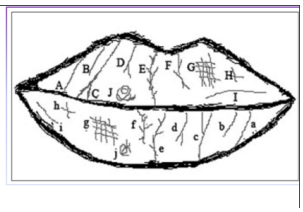

Figure 4: Renaud's classification of lip prints

In 1979, Afchar-Bayatclassified lip prints based on groove patterns in the front and lateral position of the lips[10]. Kasprazak Classified the lip prints using the pattern of lines in the lips. If the lines in the lips occur often, the pattern is described as linear, "L". If there is dominant bifurcation, it is called bifurcate, "R". If the lines cross then the pattern is dubbed reticular, "S". In the case where no superiority can be established, the pattern is named undetermined, "N".

Lip Prints from Crime Scene

Lip prints obtained from crime scene can be of 3 types viz patent, latent and plastic lip prints. A patent lip print, also known as a visible lip print, is the impression left by the markings created by the natural oils, saliva, or cosmetics on a person's lips onto a surface which are immediately apparent and can be seen through naked eye. Such lip prints can occur when a person's lips come in contact with objects such as drinking glasses, cups, or other smooth surfaces. Latent lip prints are not visible to the naked eye and has to be developed and analyzed for identification purposes. A plastic lip print, also known as an indented lip print, is a type of lip impression created through pressure and indentation of the lips on pliable surfaces such as plastic, wax, or other malleable substances. Such prints are not immediately apparent to the naked eye like the patent prints but can still be detected easily.

Collection and Development of Lip Prints

Various collection techniques include tape method, photography, dusting powder method, chemical method and casting. Patent lip print collection involves simple processes since they are readily visible without any enhancement techniques. A cellophane tape is usually used to remove the visible prints from the object which is then pasted onto a clean white sheet for visualizing the individual characteristics of the print. As the latent prints are invisible to naked eye dusting powder method is used. Suitable powders (e.g., black or white fingerprint powder) is gently dusted over the possible suspected surface, using a natural hair brush which helps in development of hidden lip print, if any, by adhering to the oils and residues from the lips, making the lip print visible. The developed lip print is then photographed and analyzed for further clues. High-resolution photography is used to capture all types of lip prints for analysis and comparison. Special lighting techniques may be employed to enhance the visibility of the prints.

Chemical methods make use of reagents that react with the components of the latent lip print to bring out its visibility. For example, ninhydrin, a chemical reagent commonly used for fingerprint development, can also be used to develop latent lip prints by spraying over the surface. In some cases, a casting material like dental stone or silicone rubber can be used to create a three-dimensional replica of the lip impression. This technique can provide a permanent record for further analysis. Analyzing plastic lip prints requires specialized training and expertise and the process can be more challenging compared to patent or latent lip prints. Factors such as the texture and elasticity of the material, environmental conditions, and age of the print can affect the quality and usability of the impression.

Rachna kaul et. al., conducted a study in 755 individuals to assess the efficacy of lip prints in sex

determination using Vahanwala method and found that Type I pattern of lip print was the most prevalent cheiloscopic pattern among the individuals. However, they concluded that lip prints do not serve a tool in sex determination [11]. Preeti Sharma et.al, studied particular pattern collected using tape lifting method on the basis of numerical superiority of types of lines and proved that lip prints are unique to one another and can be used in sex determination. Type I and Type I' patterns were found to be predominant in females while Type IV pattern was predominant in males [12]. According to a study by Sonal-Nayak et.al, Type I and Type I' patterns were found to be dominant in females, while Type III and Type IV patterns dominant in males. Another study conducted by Vahanwala-Parekh showed that all four quadrants having same type were predominantly seen in female subjects and male subjects showed presence of different patterns in a single individual [13].

Ghimire N et. al, conducted a study on analyzing and comparing the quadrant wise and sex wise predilection of lip print pattern by tape lifting method on applying lipstick. Based on Tsuchihashi classification, Type I pattern was found to be predominant in all the four quadrants among males with values of 62%, 56%, 54%, 57% in first, second, third and fourth quadrants respectively). Also in females, type I was predominant in 2nd, 3rd and 4th quadrant (40%, 45%, 51% respectively) whereas in 1st (right upper) quadrant type II pattern was predominant (37%) [14]. Neeti kapoor et.al determined the predominant pattern among central Indian population using Suzuki and Tsuchihashi classification by digital photography. Type I (30.63%) was found to be most predominant overall in the Marathi population. Type I (29.75%) and Type III (35.75%) was found to be most prevalent in males and females [15].

Mohamed Jaber et. al used a systematic review and meta-analysis where the predominant lip print present among males was type III (30.2%), followed by type II (29.9%), and type I comprised of 21.1%. While among females, almost 36.5% reported with type I lip print pattern, followed by type II (28.9%) [16]. Most of the studies revealed the uniqueness of lip print but further studies are required to assess the efficacy of lip prints in sex determination.

Forensic Significance of Lip Prints

As with any Forensic technique, proper training, validation, and adherence to scientific standards are crucial for its successful application in legal and investigative settings. Lip prints serve as evidence in the Court of Law with respect to various aspects, of which personal identification is the foremost crucial one in identifying suspects or victims in criminal cases when lip impressions are left at crime scenes or on objects recovered from the scene. Especially in personal identification like access control, biometric authentication, and electronic device security, lip prints play a crucial role. Being a non-invasive forensic technique, collecting lip prints from objects like drinking glasses or cigarette butts is less intrusive compared to some other methods, making it easier to obtain evidence without requiring physical samples from the person. Unlike other forms of identification such as facial features or voice, lip prints are less prone to alterations through aging, plastic surgery, or changes in appearance. Lip prints can also be used to reconstruct certain events in the crime scene. In addition, they assist in identifying missing persons or unknown deceased individuals when traditional methods, such as fingerprints or dental records, are not available or inconclusive. Some studies suggest that association between lip print patterns and certain personality traits or behaviors could favour psychological profiling too. Likewise, in anthropological research also lip prints provide insights into genetic and racial characteristics of populations.

Materials

Out of 500 individuals, 345 were taken up for the study with respect to inclusion and exclusion criteria. A cross-sectional study involving 345 healthy individuals was conducted at Sri Ramachandra Institute of Higher Education and Research (SRIHER), Porur, Chennai for a period of 2 months after ethical clearance. From SRIHER ethical committee. Based on the statistical significance with 95% confidence interval, the sample size was calculated to be 211. To round of the value, 250 male and 250 female participants were taken up for the study, with a total sample size of 500. The aim is to determine the sexual dimorphism from lip prints using the Tsuchihashi's

classification. Participants between the age group of 18-30 years were taken up for the study. Those with lip congenital anomalies, cleft palate, cheilitis, mouth sores, persons with lip scars, lip lesions and person with hypersensitivity to lipstick were excluded. Individuals allergic to cosmetics and who were not willing to apply lipstick were also excluded. The samples were collected from the participants by making them understand the procedure thoroughly and by obtaining an informed consent.

The materials used were shown in figure 5. The subjects were seated in a comfortable position. The lips were cleaned thoroughly with apollo wet-wipes by gentle wiping before taking the prints (Figure 6). A single stroke of bright shade of lipstick (non-glossy, oil-free lipstick: MARS LIPSTICK PENCIL 17) was applied using lipstick brush to the vermilion region of both upper and lower lips (Figure 7). After application, a 50mm of transparent cellophane tape was pressed against the lips from center to the corners (Figure 8). The participants were asked to refrain from moving their lips during the procedure to avoid any distortions on the print recordings. The cellophane tape was slowly removed from one end of the lips and pasted onto a proforma in order to provide a permanent record, which can be studied at any time (Figure 9). The recording procedure was repeated in case of observing any defects so as to ensure having a clear record of each participant. Attention was paid to hygiene while recording the lip prints. After confirming proper registration of all areas of the lips on proforma, the remaining lipstick on the lips was cleaned with wet-wipes. Also, the lipstick brush used was sterilized to avoid any future contamination. The obtained lip prints as in Figure10 were further examined for various lip characteristics using magnifying lens manually and categorized under different lip patterns based on Tsuchihashi's classification.

Figure 5. Materials used for collection of lip print

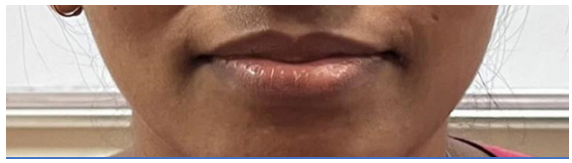

Figure 6. Cleaning of lips with wet-wipes

Figure 7. Application of lipstick using brush

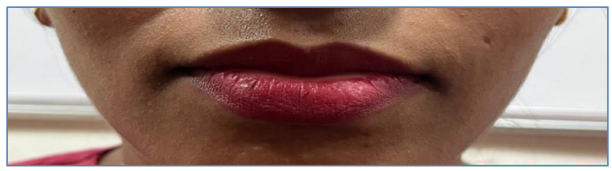

Figure 8. Lip print (after application of lipstick) ready for lifting

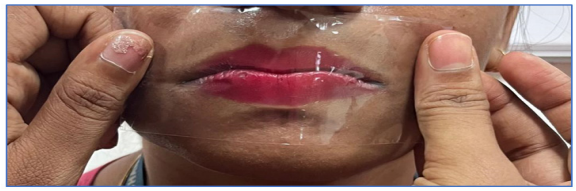

Figure 9. Taking impression of lip surface with cellophane tape.

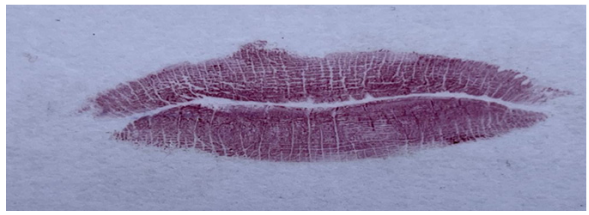

Figure 10. Resultant lip print obtained from the individual

Results

Table 1 shows the distribution among males and females of which total number of male participants was found to be 160 (46.4%) while the total number of female participants was found to be 185 (53.6%).

Table 1: Percentage calculation among males and females

Gender	Frequency	Percent
Male	160	46.4
Female	185	53.6
Total	345	100.0

Figure 11 shows the percentage calculation performed for both male and female populations separately. Among male population, Type V (24.4%) was the predominant type of lip pattern observed followed by Type I (22.5%), Type I'(21.2%), Type IV (12.5%), Type II (10.0%), Type III (9.4%) while among female population, Type I' (28.1%) was the predominant type observed followed by Type I (24.3%), Type V (16.2%), Type III (12.4%), Type IV (11.4%),Type II (7.6%). Type I' and Type I patterns were seen more common in the overall population.

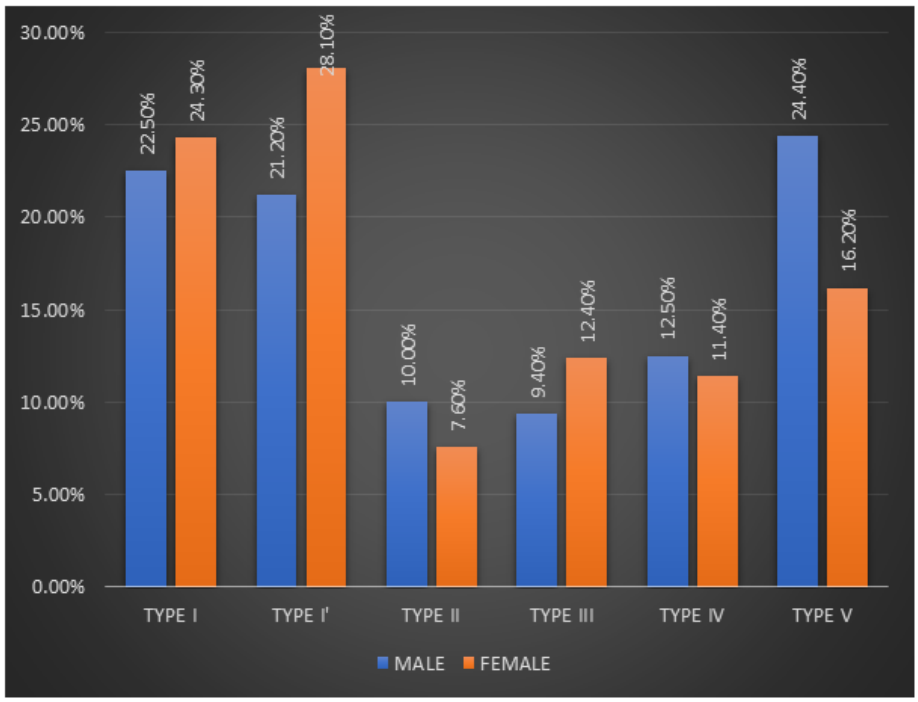

Figure 11. Percentage in male and female population based on lip print pattern.

Table 2 shows the Sample 'T' test performed for gender separately. Among the 160 (46.4%) male participants, mean and standard deviation were found to be 3.41 and 1.937 respectively. Among the 185(53.6%) female participants, mean and standard deviation were found to be 3.07 and 1.818 respectively. In Independent sample T test, two-tail method was performed to find out the significance between lip print pattern and gender. As a result, the 'p' value obtained in males and females were found to be 0.092 and 0.093 respectively. Since the obtained p value was found to be greater than 0.005, there was no significant difference observed between lip print pattern and gender.

Table 2: Sample 'T' test for different types of lip patterns.

Gender	N	Mean	Std. Deviation	T test	Pvalue
Male	160	3.41	1.937	1.691	0.092
Lip print					
Female	185	3.07	1.818	1.684	0.093

Discussion

Personal identification plays a crucial role in the field of Forensic Science. Many researches in cheiloscopy proved that even lip prints can serve as potential evidence in identification of its uniqueness. The present study assessed the association and correlation between gender and lip print pattern on the basis of numerical superiority of types of lines present. The current study showed no significant difference (P=0.093) between gender and lip patterns. However, in males, Type V lip pattern was found as the highest recorded lip print pattern followed by Type I, Type I', Type II, Type III and Type IV.

Similarly, in females, Type I' was found as the highest recorded lip print pattern followed by Type I, Type V, Type III, Type IV, Type II. The predominant pattern observed in the overall population including both males and females was Type I' followed by Type I, Type V, Type IV, Type III, Type II. The Type V pattern considered as the second predominant pattern in the present study similar to the study conducted by Prabhu *et al*. in 2012 where they studied 100 students from Goa, India [34]. In accordance with another study conducted by Sharma *et al* and Satyanarayana *et al*. it is found that complete (Type I) and incomplete vertical grooves (Type I') found to be predominant in females, undetermined pattern (Type V) to be the most common in males asthey had considered central part of lower lip for analysis unlike the current study where central part of both the lips were taken into account[17].

With reference to sex, non-significance could be due to low variance among the different lip print patterns in the overall population. In the current study, the participants included 160 males and 185 females. The highest prevalence of seen with type - I' of lip print pattern in overall study and the same pattern being highest in females can be attributed to higher number of female participants. The non significance between the gender could be attributed to lower sample size and unequal between male and female participants. However, the lip print pattern observed in each individual showed unique features making it an essential tool for identification in Forensic investigations. Based on the findings of the present study, it could be revealed that lip prints cannot behold the potential of determination of sex. Though the present study followed an infallible method, determining sex from lip prints showed no significance but certain differences were observed between males and females in terms of width, thickness, and shape of the lip grooves. Thereby, Type V and Type I' were the predominant lip print patterns observed in males and females respectively.

Conclusion

The current study concludes that there is difference between lip print patterns obtained among individuals and hence this method can serve as one of the identification methods in forensic scenarios where other forms of identification might be challenging. However, determination of sex from lip prints should be approached with caution and should be considered as supplementary evidence rather than definitive proof. The variations in lip print patterns among individuals of the same sex can be substantial and there can be significant overlap between male and female characteristics. Additionally, the quality of lip prints and the method of collection can affect the accuracy of sex determination. Lip prints should be captured and analyzed under controlled conditions by trained professionals to minimize errors and inconsistencies. A comprehensive approach that considers multiple studies are necessary to draw reliable conclusions in gender determination from lip prints. Similar studies with more sample size and equal distribution of gender are suggested in order to get a significant difference in lip patterns. Although, cheiloscopy is still considered as very reliable evidence in personal identification in crime investigations, attempts should be made to use the same as a group identity trait which can be very useful in situations like mass disasters.

Limitations

Lesser sample size and the unequal gender distribution led to the insignificant trend in lip prints among the study population.

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References

1. Łukasz smacki* , piotr porwik* krzysztof tomaszycki**, sylwia kwarcińska. the lip print recognition using hough transform. journal of medical informatics & technologies. 14/2010.
2. Dineshshankar J, Ganapathi N, Yoithapprabhunath TR, Maheswaran T, Kumar MS, Aravindhan R. Lip prints: Role in forensic odontology. J Pharm Bioallied Sci [Internet]. 2013;5(Suppl 1):S95-7. Available from: http://dx.doi.org/10.4103/0975-7406.113305.

3. Moshfeghi M, Beglou A, Mortazavi H, Bahrololumi N. Morphological patterns of lip prints in an Iranian population. J Clin Exp Dent [Internet]. 2016;8(5):e550–5. Available from: http://dx.doi.org/10.4317/jced.52921.
4. Karthikeyan Ramalingam S. Farzan Rehman2, Girish Lalawat2, Anil Pandey2Departments of Oral pathology and Microbiology. In: Cheiloscopy for Sex Determination: A StudyMonica Kinra. Jaipur, Rajasthan, India; Sebha, Libya.
5. Ramakrishnan P, Bahirwani S, Valambath S. Assessment of cheiloscopy in sex determination using lysochrome - A preliminary study. J Forensic Dent Sci [Internet](5). 2015;7(3):195–200. Available from: http://dx.doi.org/10.4103/0975-1475.172434.
6. Vezhavendhan N, Vendhan P, Kumar G. A study of lip prints among Pondicherry population. J Forensic Dent Sci [Internet]. 2012;4(2):84. Available from: http://dx.doi.org/10.4103/0975-1475.109894.
7. Malik R, Goel S. Cheiloscopy: A deterministic aid for forensic sex determination. J Indian Acad Oral Med Radiol [Internet]. 2011;23:17–9. Available from: http://dx.doi.org/10.5005/jp-journals-10011-1082.
8. Baxter K. Forensic analysis of lipstick trace. 2013 Aug 8.
9. Castelló A, Alvarez-Seguí M, Verdú F. Use of fluorescent dyes for developing latent lip prints. Color Technol [Internet]. 2004;120(4):184–7. Available from: http://dx.doi.org/10.1111/j.1478-4408.2004.tb00227.x.
10. Collection of lip prints as a forensic evidence at the crime scene--an insight Citation metadata Authors: Rachana V. Prabhu, Ajit D. Dinkar and Vishnudas Dinesh Prabhu Date: Dec. In: Consortium of Research Ardent Dentists. CORAD; 2010.
11. classification of lip print: forensic cheiloscopy classification. 2023.
12. Ludwig A, Page H. An investigation into the dynamics of lip-prints as a means of identification. Aust J Forensic Sci [Internet]. 2012;44(2):169–81. Available from: http://dx.doi.org/10.1080/00450618.2011.630413.
13. Castelló A, Alvarez-Seguí M, Verdú F. Luminous lip-prints as criminal evidence. Forensic Sci Int [Internet]. 2005;155(2–3):185–7.
14. Study of Lip Prints. 2009.
15. Ghimire N, Ghimire N, Nepal P, Upadhyay S, Budhathoki SS, Subba A, et al. Lip print pattern: an identification tool. Health Renaiss [Internet].
16. Kapoor N, Badiye A. A study of distribution, sex differences and stability of lip print patterns in an Indian population. Saudi J Biol Sci [Internet]. 2017;24(6):1149–54. Available from: http://dx.doi.org/10.1016/j.sjbs.2015.01.014.
17. Assessment of lip print (cheiloscopy) patterns and its use for personal identification and crime investigation: A systematic review and Meta-Analysis Mohamed Jaber1,3 *, Sudhir Rama Varma1,3 , Mawada Hassan1. Karrar Hadi1 , Amar Khamis2;
18. Suzuki K. Recent history of forensic odontology in Japan. Intern Microfilm J Leg Med. 1967;2:2.(18)
19. Tsuchihashi Y. Studies on personal identification by means of lip prints. Forensic Sci. 1974;3:233–48. (19)
20. Sivapathasundharam B, Prakash PA, Sivakumar G. Lip prints (cheiloscopy) Indian J Dent Res. 2001;12:234–7

Original Research Article

A Hospital Records-Based Study on the Profile of Accused in Sexual Assault Cases under the POCSO Act (2021–2023)

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Abstract

The Protection of Children from Sexual Offences (POCSO) Act, 2012, was enacted to safeguard children from sexual abuse. Over the years, India's rape laws, including those covering child rape, have evolved significantly, especially with the criminal law amendments in 2013 and 2018. With the broadening of the definitions of rape and sexual assault, routine potency testing in sexual assault cases is no longer necessary. This study aimed to analyze the profiles of accused individuals involved in sexual assault cases under the POCSO Act from 2021 to 2023 and reported for medical examination at Government Medical College, Nizamabad. In the 122 cases studied, it was found that a majority of the accused (118) were known to the victims, with a large chunk of them (76) of them being intimate partners. Most incidents occurred at the accused's home (88), and the majority of accused were unmarried males (97) aged 18-25 (67) employed as daily laborers (86). Of the 28 cases of non-penovaginal sexual assault, no potency test was required, yet the police requested it. The study emphasizes that routine potency tests should be abandoned, and instead, they should only be used judiciously in cases where necessary, as proposed by several high courts and the Supreme Court of India.

Keywords: Child abuse, Rape, Sexual assault, Potency test, Criminal procedure, Erectile dysfunction.

Introduction

Child abuse is an ever-growing social menace across the globe. In line with the United Nations Convention on the Rights of the Child, 1989, and the United Nations Optional Protocol on the Sale of Children, Child Prostitution, and Child Pornography, 2000[1]and considering its legal obligation towards the

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children of the country, India enacted the Protection of Children from Sexual Offences (POCSO) Act in 2012. This law provides a comprehensive legal framework for the protection of children from sexual abuse, sexual exploitation, and sexual harassment, and establishes procedures for the investigation and trial of such offenses in a fast-track way[2].

The Indian rape laws have undergone significant transformations over the years. The first phase of reform came after the '*Mathura case,*' following which the custodial rape was made a serious offense. The Section 114A of the Indian Evidence Act that allows for presumption of absence of consent in rape cases also came into existence. Subsequently, in a catena of judgements the supreme court remarked that even the slightest penetration of penis was sufficient to constitute rape. After the tragic Nirbhaya incident, the rape laws underwent a radical change with the introduction of the Criminal Law Amendment Act, 2013[3]. Following two other horrific cases, the Unnao and Kathua rapes, the Criminal Law (Amendment) Act, 2018 was enacted, providing for stricter punishments when rape is committed against minors. The new criminal law paradigm under the BNS, BNSS and BSA also has brought some more changes to the existing rape laws[4].

The definition of rape has been broadened in view of evolving patterns of sexual violence, now including penetration by fingers or objects, as well as non-penetrative acts, under the scope of rape or sexual assault. Even the slightest penetration of the penis into a woman's genitals constitutes rape, with no requirement for an erect penis or complete penetration[5].

When an accused of sexual assault is apprehended by the police, it is customary to seek a medical opinion on whether the individual is physically capable of performing an act of sexual intercourse. In proper medico-legal discourse, the individual is typically examined for impotency (more so erectile dysfunction which is a consistent or recurrent inability to attain/ maintain a penile erection sufficient for sexual intercourse), and if the medical opinion concludes otherwise, it is presumed that the individual is capable of doing a sexual act. The procedure mentioned herein is labelled '*potency test'* by the police for conversational convenience[6].

Several courts have consistently stated that a potency test is not required as a routine procedure. The Madras High Court[7], for instance, has directed courts across Tamil Nadu not to insist on conducting potency tests unless the accused voluntarily requests it to prove his innocence.

Conducting a potency test as a routine procedure in non-peno-vaginal cases can be problematic, leading to unnecessary expenditure of time and resources in proving a point that is not legally contested. Bringing an accused from judicial remand to a hospital for examination is a cumbersome and technically challenging process. Furthermore, the multidisciplinary evaluation required—often involves specialties such as urology or endocrinology—is difficult to facilitate, as many civil hospitals lack super-specialty departments. There have also been instances where accused individuals have escaped from custody during such examinations, emphasizing the security risks involved.

Furthermore, courts have emphasized that the timely examination of the victim is important for establishing the facts of the case and determining the role of the accused. While the examination of the accused for evidence collection is important, a potency test does not necessarily contribute to the criminal trial[8].

This study aims to analyze the profile of accused individuals examined at our hospital in sexual assault cases under the POCSO Act. The objectives are examining the socio-demographic profile of the accused, their relationship with the victim, and the details of the incident as per the information available in the police requisition. In addition, the study will evaluate the necessity of a potency certificate in these cases.

Methodology

The study was conducted in the Department of Forensic Medicine and Toxicology at Government Medical College, Nizamabad, reviewing sexual offense (SO) cases from the period 2021-2023. Out of a total of 185 SO cases registered during the study period, 122 POCSO act related cases were included in the present study. The following data was retrospectively extracted from the case files: the

accused's age, occupation, marital status, relationship to the victim, location and timing of the incident, time of reporting, the victim's sex, and the type of sexual assault.

Results

The majority of the accused in the POCSO cases were within the age range of 18-25 years, i.e., 67 individuals (Table 1).Among the accused, 86 were daily laborers, 23 were students, and 13 were engaged in business. In terms of marital status, 97 were single, while 25 were married. Out of the 122 cases, 109 involved penetrative sexual assault, while 13 involved non-penetrative sexual assault. The relationship between the accused and the victim is summarized in Table 2, with "lover" being the most common association, reported in 72 cases. Details of non-penovaginal assaults are provided in Table 3, with penetration using fingers observed in 15 cases. In most cases, the place of the offense was the accused's home, with 88 instances recorded, as detailed in Table 4. The most common time of reporting after the offense was between 1 week and 1 month, with 47 cases, as shown in Table 5.

The most common age group of victims in the study was 17 years old, with 49 cases, followed by 16 years old with 24 cases and 15 years old with 9 cases. There were 7 victims each in the 13, 11, and 8-year age groups, while 6 victims were 10 years old and 4 were 12 years old. Additionally, there were 3 victims aged 6 years, 2 each aged 14 and 7 years, and 1 victim each aged 9 and 5 years. In terms of sex, 119 victims were female, and 3 victims were male.

Table 1: Age distribution of accused individuals in POCSO cases

Age of the accused	No. of cases
Less than 18 years	27
18-25 years	67
26-30 years	15
31-40 years	10
41-60 years	2
61-80 years	1
Total	122

Table 2: Relationship of accused with the victim

Relationship with the victim		No. of cases
Intimate	Lover	72
	Father	2
	Husband (Child marriage)	1
	Stepfather	1
Friend	Neighbor	5
	Escort/Takes to school	1
	Friend (uncategorized)	12
Other relative	Uncle	3
Acquaintance		21
Stranger		4
Total		122

Table 3: Non penovaginal cases summary

Type of sexual assault	No. of cases
Penetrated with fingers	15
Undressed and kissed	2
Undressed and touched private parts	7
Undressed and laid upon victim	4
Total	28

Table 4: Place of sexual assault

Place	No. of cases
Accused home	88
Victim home	16
Outside	18
Total	122

Table 5: Time of reporting

Time	No. of cases
1 day	11
1 day – 1 week	30
1 week – 1 month	47
1month – 6months	11
>6 months	13
Pregnancy in	7
Delivered in	3
Total	122

Discussion

The present study aligns with NCRB statistics[9] and several other studies in the field[10-12]. Unmarried males between the ages of 18 and 25 constitute most of the accused involved in POCSO cases in our study. The incidents most commonly occurred at the accused's home, and in 118 cases, the accused was a known person to the victim, while in only 4 cases, the accused was a stranger. This highlights the prevalence of sexual violence within close circles.

In the study by Hugar BS et al.[10], 87 perpetrators were examined, with the majority falling within the age group of 18-24 years (40%). Similarly, in our study, most of the accused were in the 18–25-year age group (55%). In Hugar et al.'s study, most of the accused were either the victims' friends or acquaintances, comprising 74.6% of cases. In contrast, in our study, most of the accused were the victims' lovers (59%), followed by acquaintances (17%). In Hugar et al.'s study, most of the incidents took place in the perpetrator's home (20 cases), and similarly, in our study, most incidents occurred in the accused's home (88 cases). Hugar et al. reported 67 cases of alleged rape, 15 cases of molestation, and 5 cases of sodomy. In our study, penetrative sexual assault was present in 109 cases, and non-penetrative sexual assault was found in 13 cases.

Our results are consistent with those of Moses et al.[12], where intimate partners were identified as the primary perpetrators of sexual assault. In our study, 'lovers' was the most common relationship between the accused and the victim.

In cases where an allegation of penovaginal intercourse is made, a potency test may be relevant if the accused claims impotence as a defense, especially under rape or POCSO (Protection of Children from Sexual Offences) Act charges. Currently, various Indian textbooks suggest that the opinion of a potency test should be issued in a double negative format when an organic cause of impotence is absent, and this practice is followed in many institutions. Courts and investigative agencies would benefit from a clear, objective, and unequivocal opinion rather than a vague one. Potency testing requires a multidisciplinary approach, involving the expertise of forensic medicine specialists, psychiatrists, urologists, physicians, neurologists, endocrinologists, and other allied specialists[13]. It is not advisable to put a larger medical workforce in unnecessary trouble for each and every sexual assault case. Instead, an optimal use of human resources is the need of the hour.

The issue of preventing POCSO cases is complex and includes serious deliberations and discussions about the legal age for sexual intercourse, how teenage relationships can lead to litigation, and the importance of proper sexual education. It is also essential to recognize that in certain regions of the country, false POCSO cases are prevalent, sometimes used as a means to settle disputes or for revenue generation. Addressing these issues requires careful consideration of legal, socioeconomic, and educational factors to protect minors from sexual assaults or else their young adult phase of life will be marred by never-ending litigation.

Conclusion

In our study, out of the 122 SO cases registered under the POCSO act, 28 cases involved non-penovaginal offenses that did not require a potency certificate, yet one was still requested by the police. Moreover, 7 victims became pregnant, with 3 having delivered, and in these cases, DNA profiling could have been directly performed in solving the case and *potency test* serves no purpose.

We suggest that if an accused is apprehended for penetrative sexual assault not involving the penis or for non-penetrative sexual assault, they should be exempted from the potency test. As advocated by the courts, potency tests in males or the two-finger test in females in sexual offense cases are outdated, dehumanizing, and obsolete. The impotency of an individual may only be considered by the courts in civil matters, such as the nullity of a marriage, or if the accused wishes to prove their innocence in a criminal case. Furthermore, we recommend increasing awareness of the provisions of the POCSO Act among the public, children, and their parents, as well as providing periodic training to relevant personnel, including police officers, and judicial officers as stipulated by the law.

Limitations:

This retrospective, records-based study was conducted using data from only a single tertiary care institution. However, it did not include information on the legal outcomes of these cases, such as whether they resulted in successful prosecution. Furthermore, several critical details about the incidents were derived from police records, while the accused's version of events was not considered.

Recommendations:

Multi-center studies on large data sets are needed. Future research should explore the impact of pornography on sexual violence, migration from rural to urban areas as a risk factor, and the role of low socioeconomic conditions in promoting violent behavior. As we noticed in our study that a significant proportion of accused individuals in POCSO cases are daily laborers and likely migrants, understanding these factors also becomes crucial for developing targeted interventions to prevent sexual violence.

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References:

1. UNICEF, The Convention on the Rights of the Child: The children's version, Unicef.org. [cited 2025 Feb 28]. Available from: https://www.unicef.org/ child-rights-convention/ convention-text-childrens-version
2. The ProtectionofChildrenfrom Sexual Offences Act, 2012Last update- 28-02-2023, Nic.in. [cited 2025 Feb 28]. Available from: https://www.indiacode.nic.in/ bitstream/123456789/2079/ 1/AA2012-32.pdf
3. Nagpal H. The historical journey of rape laws in India [Internet]. Feminism in India. 2017 [cited 2025 Feb 28]. Available from: https://feminisminindia.com/ 2017/06/22/historical-journey-rape-laws-india/
4. Rai D. Criminal law amendment act, 2018 : Overview and analysis [Internet]. iPleaders. 2019 [cited 2025 Feb 28]. Available from: https://blog.ipleaders.in/ criminal-law-amendment-act-2018-2/
5. Jiloha RC. From rape to sexual assault: Legal provisions and mental health implications. Ind J Soc Psychiatr [Internet]. 2015;31(1):9. Available from: http://dx.doi.org/10.4103/ 0971-9962.161992
6. Express News Service. 'Potency test' for Prajwal Revanna: Is this even relevant for sexual assault cases? The Indian Express [Internet]. 2024 Jun 2 [cited 2025 Mar 12]; Available from: https://indianexpress.com/ article/explained/ potency-test-for-prajwal-is-this-even-relevant- for-sexual-assault-cases-9364564/
7. Times Of India. HC bars potency test of suspects [Internet]. Times Of India. 2025 [cited 2025 Feb 28]. Available from: https://timesofindia.indiatimes.com/ city/chennai/hc-bars-potency-test-of-suspects/ articleshow/118072542.cms
8. Ramana Dhara V. In India, 'potency tests' of those accused of rape Aren't very scientific [Internet]. Thewire.in. 2022 [cited 2025 Feb 28]. Available from: https://science.thewire.in/ law/jubilee-hills-sexual-assault-potency-test/
9. Roy E. NCRB data, Crime against kids: a third still under POCSO. The Indian Express [Internet]. 2022 Aug 30 [cited 2025 Feb 28]; Available from: https://indianexpress.com/article/india/ crime-against-kids-a-third- still-under-pocso-8119689/
10. Hugar BS, Jayanth SH, Praveen S, Chandra YPG, Harish S. Profile of perpetrators of alleged sexual assault. J Indian Acad Forensic Med [Internet]. 2019;41(4):253. Available from: http://dx.doi.org/10.5958/ 0974-0848.2019.00074.5
11. Raheel MS, Yadav A, Pooniya S, Kumar Gupta S, Jaiswal AK. Potency test of a rape accused in India – Rationale, problems and suggestions in light of the Criminal Law (Amendment) Act, 2013. Egypt J Forensic Sci [Internet]. 2016;6(4):333–6. Available from: http://dx.doi.org/10.1016/j.ejfs.2016.11.004
12. Moses TMK, Sravani Y, Rao PV, Reddy NS, Manasa M, Alekhya M. An analysis of demographics and attributing events in sexual offence cases reported at One Stop Centre – A retrospective study. J Indian Acad Forensic Med. 2024;46(1 Suppl):153-157.
13. Akhade SP, Kothari P, Sabale PR, Chavali KH. Comprehensive Review and Recommendations for Evaluation of Sexual Potency of Male in Context of Current Indian legal system. jiafm [Internet]. 2023;45(1):95–101. Available from: http://dx.doi.org/10.48165/ jiafm.2023.45.1.23'.

Original Research Article

Quasi-Experimental Study on Pesticide Usage among Farm Workers in Rural South India: A Methodology Paper

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Abstract

Synthetic pesticides are commonly used in agriculture to manage pests and protect crop yields. However, improper handling and use of these chemicals pose significant risks to farm workers, leading to health hazards and even fatalities. This methodology paper outlines a project aimed at assessing the awareness, attitude, and practices of farm workers regarding the safe usage of pesticides in rural south India and to evaluate the effectiveness of an educational intervention designed to improve safety. A quasi-experimental pre and post-test will be used to evaluate the knowledge, attitude of farm workers and their practice of handling pesticides in their daily life following an educational intervention for a period of 6 months. The study will involve a baseline assessment through questionnaires, followed by the development and implementation of an educational intervention through a targeted educational module tailored to the identified knowledge and practice gaps. The module will then be implemented in workshops, and its effectiveness will be measured through pre- and post-intervention assessments. The ultimate goal is to promote safer pesticide handling practices and improve farm workers' overall awareness and attitudes toward pesticide safety. This paper describes the methodology in detail and submits results of the pilot study conducted using the developed questionnaire.

Keywords: pesticide safety, educational intervention, farm workers, rural south India

Introduction

The extensive use of synthetic pesticides in agriculture has helped reduce crop losses and improve productivity; however, it also poses significant health and environmental risks, particularly for farm workers who handle these chemicals. Accidental pesticide poisoning is a major public health concern, especially in southern and southeastern Asia, where fatalities related to pesticide exposure remain alarmingly high[1,2]. In Tamil Nadu alone, 1,648 deaths due to accidental intake of pesticides were reported in 2021[3].

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The lack of knowledge about safe pesticide handling practices, improper storage, and incorrect disposal methods contribute to these health risks[4,5]. Therefore, increasing awareness and promoting safer handling practices among farm workers is critical. This study aims to assess the current levels of awareness and practices related to pesticide safety in rural Tamil Nadu and to evaluate the effectiveness of an educational intervention in improving these practices.

Synthetic pesticides play a crucial role in agricultural practices, helping to control pests and prevent crop damage. However, the unintentional acute pesticide poisoning among farm workers is a grave concern in southern and southeastern Asian countries[6,7]. Tamil Nadu has reported alarming statistics regarding pesticide-related fatalities, indicating the urgent need for improving the knowledge and practices surrounding pesticide usage among farmers[8]. Enhancing awareness and safe practices is essential to preventing such incidents.

Aim

To improve awareness, practices, and attitudes toward the safe usage of pesticides among farm workers in rural Tamil Nadu through an educational intervention.

Objectives

1. Assess the knowledge, attitudes, and practices (KAP) regarding the safe handling of pesticides among farm workers.
2. Create an educational module based on the identified knowledge gaps and unsafe handling practices.
3. Provide an educational intervention aimed at improving knowledge, attitudes, and practices related to safe pesticide handling and storage.
4. Measure the effectiveness of the educational intervention post-intervention, particularly changes in knowledge, attitudes, and practices after six months.

Methodology

Study Design: This is a community-based, quasi-experimental study which wasconducted to assess the knowledge, attitude, and practice (KAP) regarding the safe use of pesticides among farm workers in rural Tamil Nadu. The study is divided into two phases: a pre-intervention baseline assessment followed by an educational intervention, with subsequent evaluations to measure the impact of the intervention.

Study Setting: The study was conducted in the K.V. Kuppam block under the Rural Unit for Health and Social Affairs (RUHSA). The K.V. Kuppam block is a 100% rural block, selected for its predominantly agrarian population, who are regularly exposed to chemical pesticides in their work. The K V Kuppam block is divided into 18 peripheral service units (PSUs) for provision of primary health services to the community. Each PSU caters to a population of about 7000 and helps in reaching out to the people in the entire block. There are about 108 villages and hamlets in the entire block and the study was conducted in 10 randomly selected villages from the block.

Participant Recruitment

Sampling Frame: A list of farm workers and aides who use pesticides was generated from 10 randomly selected villages in the K.V. Kuppam block. Participants were selected through a stratified random sampling technique. A preliminary meeting was scheduled with the Block Development Officer and Agricultural Extension Officer (AEO) to discuss the project objectives and ensure their support for community engagement. A list of farmers and farm workers was generated from the pesticide procurement records of local pesticide shops, as well as community informants. Eligible participants are those who spray, mix, or store pesticides in their farming activities. From each of the 10 selected villages, 20 participants were randomly selected, leading to a total of 200 participants.

Inclusion Criteria:

Adults (18+ years) who are farm workers and use chemical pesticides.

Permanent residents of the K.V. Kuppam block.

Those who have lived in the area for at least one year.

Consent to participate in the study.

Exclusion Criteria:

Adults with mental disabilities that impair comprehension.

Sample Size Calculation:

For the pretest evaluating baseline knowledge, attitude and practice – Based on previous studies reporting a 42% awareness level of pesticide safety among Indian farmers, a sample size of 147 participants was calculated assuming 8% margin of error. Considering a 25% non-response rate, a minimum of 183 participants were needed for the study. It was decided to recruit 200 participants (20 from each village from the 10 randomly selected villages) for this study. The formula used for calculation of the sample size using the above prevalence (or proportion of people with awareness of use pesticide use) was:

$n=p(1-p)(Z/E)^2$,

where n = sample size required, p = proportion of the event in the population, Z = values from standard normal distribution reflecting the confidence level that were used (usually Z value for 95% confidence interval is 1.96) and E is the desired margin of margin of error.

For the post-test evaluation of effectiveness of educational intervention – For the assessment of the effectiveness of the educational intervention aimed at improving knowledge regarding safe pesticide usage, a sample size calculation was performed to determine the number of participants needed to achieve sufficient statistical power. The primary outcome measure is the improvement in knowledge level, which we anticipate was reflected as a 20% increase from the baseline knowledge level of 48.3% as determined by pretest results. The sample size required for showing the effectiveness of the educational intervention was 210 assuming a 20% improvement of baseline knowledge. It was calculated as follows -

Sample Size

$$n = \left(\frac{Z_{1-\alpha/2} + Z_{1-\beta}}{ES} \right)^2$$

The sample size required for the study can be calculated using the formula:

Where:

$Z1-\alpha/2$ is the z-value for the desired confidence level (for a 95% confidence level, this is typically 1.96).

$Z1-\beta$ is the z-value for the desired power (for 80% power, this is typically 0.84).

$$ES = \frac{|p_1 - p_2|}{\sqrt{p(1-p)}}$$

ES is the effect size, calculated as:

Where:

p1 is the proportion of participants with adequate knowledge before the intervention (baseline level).

p2 is the proportion of participants with adequate knowledge after the intervention (baseline level + 20% increase).

p is the average of p and p2.

Calculating Parameters

Baseline Knowledge Level: p=0.483 (from the pretest study results)

Expected Post-Intervention Knowledge Level: p2 =20% of p1 = 1.2*0.483 = 0.5796

Average Proportion p: (p1+p2)/2 = (0.483+0.5796/2= 0.5313

Effect Size Calculation: using the formula for effect size and substituting the values, ES = 0.097/0.499 = 0.194

Sample size : The required sample size using the above formula with a 20% improvement in outcomes is calculated as follows -

For a 95% confidence level $Z1-\alpha/2=1.96$

For an 80% power $Z1-\beta=0.84$

Sample Size = $(2.8/0.194)^2$ = 208.3. We took 210 as the final sample size to have enough power to show the effectiveness of the educational intervention by at least 20% from baseline.

Data Collection Tools

Questionnaire: The questionnaire was modified from standardized KAP instruments in the literature was adapted from a study done by Rostami F et al[9]

among Iranian farm workers. The questionnaire had a content validity ratio (CVR) and content validity index (CVI) as 75% and 79% in the study. The Cronbach alpha for the knowledge attitude and practice questions were found to be 0.70, 0.71, and 0.79 respectively. The English questionnaire was translated into Tamil and back translated into English by two independent members to verify for the meaning and context and was discussed among the community health workers to check for the correctness of colloquial language to make it comprehensible among the local population. Few modifications were made after the pilot study based on the farmer's suggestions.

Questionnaire had 5 sections –

Section 1 Sociodemographic details

Section 2 Questions on farming practices of the community

Section 3 Knowledge of the farmers on safe pesticide usage

Section 4 Attitude of the farmers on safe pesticide usage

Section 5 Practice of the farmers on safe pesticide usage

The questionnaire will assess:

- Knowledge of pesticide safety
- Attitudes toward safe pesticide handling
- Practices related to pesticide usage

The questionnaire was administered by trained research assistants. Depending on literacy levels, it was either be self-administered or delivered through an interview.

Educational Intervention

Based on the findings of the baseline KAP assessment, an educational intervention module was designed. The intervention consist of:

A 20-minute video on the safe handling, storage, and use of pesticides.

A 30-minute demonstration of best practices.

A 20-minute participatory advocacy session to encourage safe pesticide use.

A 30-minute hands-on training at five stations (purchasing, storage, mixing and disposal, spraying, and post-use hygiene).

Pamphlets were also distributed, summarizing key messages from the educational sessions.

Post-Intervention Evaluation

Immediate Post-Test: A post-test was conducted at the end of the educational sessions to assess changes in knowledge and attitudes.

Follow-Up After Six Months: A follow-up assessment will measure changes in pesticide handling practices to evaluate the long-term impact of the intervention.

Methods to Minimize Bias

To ensure consistency, all questionnaires were administered by the same trained research assistants. The educational intervention was delivered to participants from the same community where the pretest was conducted, thus minimizing interviewer bias.

Data Analysis

Descriptive Statistics: The baseline KAP data was analyzed using descriptive statistics, including means, medians, and standard deviations for continuous variables and proportions for categorical variables.

Bivariate Analysis: Chi-square tests were used to assess the association between demographic variables and knowledge, attitudes, and practices. Odds ratios and p-values were calculated to identify significant relationships.

Pre-Post Comparison: Paired t-tests were used to compare mean knowledge and attitude scores before and after the intervention. Changes in practices will be analyzed using proportions.

Timeline of the Study

Participant Recruitment and Baseline Survey: 8 months

Data Analysis of Baseline KAP: 2 months

Development of Educational Module: 2 months

Educational Intervention (Workshops): 8 months

Post-Test and Long-Term Follow-Up: 6 months

Final Data Analysis and Reporting: 2 months

Status of the study and results

The baseline questionnaire was administered to 200 participants , who will be recruited after getting their informed written consent from selected 10 villages in the local community. The results of the baseline data was analysed to model the intervention content and delivered using the methods described earlier. This was followed by an endline intervention among 210 participants from the same local community but selected randomly from those who attend the educational intervention sessions.

The results of the pilot study conducted among 50 farm workers including farm hands, farmers, and persons associated with purchase, storage, handling and disposal of pesticides are presented in this paper. Participants were recruited into the study between Nov 2023 to June 2024. The results are as follows –

The mean age of the participants was 56.72±14.56 years; the median age was 60 years with the minimum age being 30 years and the oldest being 83 years of age. 64% of the participants were males and 28% has no or primary level education.

Table 1: Knowledge of the farmers on safe pesticide usage:

		Yes	No
Knowledge on PPE usage:	Gloves	26 (52%)	24 (48%)
	Workwear	29 (58%)	21 (42%)
	Boots	11 (22%)	39 (78%)
	Face shield	20 (40%)	30 (60%)
	Respiratory protection	7 (14%)	43 (86%)
Knowledge on ways of entry of pesticides into the body:	Hand	21 (42%)	29 (58%)
	Skin	20 (40%)	30 (60%)
	Inhalation	27 (54%)	23 (46%)
	Eyes	28 (56%)	22 (44%)
Correct Knowledge on safe disposal of pesticides		20 (40%)	30 (60%)
Correct Knowledge on storage of pesticides:		18 (36%)	32 (64%)

Table 2: Attitudes of the farmers regarding safe pesticide use

Attitude	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
PPE not required when used in little amount	10(20%)	4(8%)	6(12%)	17(34%)	13(26%)
Pesticide mixing should be done outdoors is important	18(36%)	17(34%)	1(2%)	2(4%)	12(24%)
High quality pesticide are not dangerous	2(4%)	3(6%)	6(12%)	22(44%)	17(34%)
Using pesticide is essential and necessary	17(34%)	18(36%)	3(6%)	9(18%)	3(6%)
Exposurebathing is not required, and changing clothes is enough	18(36%)	7(14%)	2(4%)	18(36%)	5(10%)
Personal protective equipment is important to prevent the body from pesticide	4(8%)	7(14%)	6(12%)	20(40%)	13(26%)
Bathing immediately after using pesticide, decrease poisoning	22(44%)	22(44%)	0(0)	3(6%)	2(4%)
Smoking during pesticide increase pesticide entrance to the body	20(40%)	16(32%)	7(14%)	6(12%)	1(2%)
During use of pesticide drinking and eating is not a problem	8(16%)	2(4%)	5(10%)	18(36%)	17(34%)
Using personal protective equipment is not easy when using pesticide	2(4%)	28(56%)	6(12%)	7(14%)	7(14%)
The sprayer tanks can be washed in a river or waterway without damage	10(20%)	11(22%)	0	19(38%)	10(20%)
Pesticides only have lethal effect on pest	6(12%)	8(16%)	10(20%)	21(42%)	5(10%)

Table 3 Practice regarding safe pesticide use

Practice with regard to PPE	Always	Almost	Sometimes	Never
I wear mask when I am using pesticides	24(48%)	10(20%)	9(18%)	7(14%)
I wear gloves when spraying pesticides	19(38%)	7(14%)	10(20%)	14(28%)
I wear glasses when spraying pesticides	6(12%)	2(4%)	9(18%)	33(66%)
I always wear long sleeved shirt when spraying	26(52%)	8(16%)	9(18%)	7(14%)
I always wear foot cover/foot wear	6(12%)	7(14%)	9(18%)	28(56%)

Discussion

Conducting the pilot study and analysing the results provided us with insights and understanding of process of pesticide usage and the reasons for unsafe use, inadequate knowledge and indifferent attitudes at multiple levels which helped us in designing the intervention using methods to target all levels and groups.

We identified the workflow that occurs during the process of pesticide spraying in different settings and scenarios. We found participants were mostly unaware with safe handling and usage of pesticides, specifically use of personal Protective equipment (PPE) like glasses, gloves and footwear. We found that women in the household are also involved in the process of mixing the pesticides, though they don't know the name or the nature of the pesticides and are not involved in purchasing. We also found there were separate farm labourers who were designated for this job. Though all the farm labourers were exposed to pesticides at point in time of spraying not all of them are involved in spraying. So, we could clearly identify four levels involved in safe handling for targeting the contents of the health intervention, i.e., at the level of buying, level of storage and mixing, level of spraying and usage and after use and safe disposal. Each of these levels or steps are manned by different individuals in a family or a community. For example, buying is done by the landowners/farmers who are usually men while mixing and storage are done at the household level which involves women of the household and spraying is done by a separate group for farm labourers each with different levels of exposure, knowledge and understanding. The intervention will be designed keeping all these facts in mind specifically targeting these different stations and levels. We will thus design the intervention which specifically demonstrates the safe use of pesticides at different levels and use techniques like video shows, demonstrations, participatory advocacy and a hands-on training at five stations for reinforcing the safe use of pesticides and reach all types of farm workers and handlers of pesticides.

Conclusion

This study seeks to address the critical gaps in awareness and practice regarding pesticide safety among farm workers in rural Tamil Nadu. This methodology paper outlines a comprehensive plan to assess and improve the awareness and practices of safe pesticide usage among farm workers in rural Tamil Nadu. By implementing a structured educational intervention, this study aims to enhance the knowledge and attitudes of participants, thereby potentially reducing the incidence of pesticide-related health hazards. This paper provides insights to new researchers in this field to help design and implement an effective intervention program for improving awareness and practice of pesticide usage in the community.

Limitations and Strengths

Being a quasi-experimental pre-post study, the individual participants have not been randomised and therefore there may be some inherent biases in gender, age group and socio-economic status. The participants of pretest and post-test are randomly selected at both time points, so this study may not be able to state that the knowledge, attitude and practice (KAP) of the same individuals have changed/ improved; however it reflects a general change in the KAP of the community. Since this a methodology study, it does not provide results from the study but a snapshot of the findings from the pilot study to reveal the trends. This may be helpful for researchers to implement the same in a different setting but they may have difficulty comparing outcomes as this is not

stated within this paper. This study describes in detail about the methods of how the study was conducted and this can be used for successful implementation of an educational intervention program.

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Ethical Clearance: The research study has been approved by the Institutional Review Board (IRB) which includes the scientific and the ethics committees, IRB Mo. 15493 [OTHER] dated 28.06.2023 and further amended to include the interventional module developed after the analysis of pre-test results, dated July 30, 2024.

Conflicts of interest: The authors declare no conflict of interests

References

1. Konradsen F, van der Hoek W, Cole DC, Hutchinson G, Daisley H, Singh S, Eddleston M. Reducing acute poisoning in developing countries: options for restricting the availability of pesticides. Toxicology. 2003 Nov 5;192(2-3):249-61. doi: 10.1016/s0300-483x(03)00339-1. PMID: 14580791.
2. Kumar P, Nanda R. Assessing the impact of pesticide exposure on farm workers' health in southern India. Environ Health Perspect. 2020;128(3):340-5. doi: 10.1289/EHP5847.
3. National Crime Records Bureau, Ministry of Home Affairs, Government of India. Accidental deaths and suicides in India: 2021. Accessed 2025 Feb 6. Available from: https://www.ncrb.gov.in/accidental-deaths-suicides-in-india-year-wise.html?year=2021&keyword=
4. Yadav IC, Devi NL. Pesticide usage pattern and awareness among farmers in India: a case study from 12 states. J Environ Sci Health B. 2017;52(8):775-87. doi: 10.1080/03601234.2017.1341004.
5. World Health Organization. Pesticide residues in food and the environment: impacts on public health. Geneva: WHO; 2018.
6. Eddleston M, Karalliedde L, Buckley N, Fernando R, Hutchinson G, Isbister G, Smit L. Pesticide poisoning in the developing world: a minimum pesticides list. Lancet. 2002;360(9340):1163-7. doi: 10.1016/S0140-6736(02)11204-9.
7. Gupta PK. Pesticide exposure: Indian scene. Toxicology. 2004;198(1-3):83-90. doi: 10.1016/j.tox.2004.01.021.
8. Sharma R, Patel V, Kumar P, Singh A. Pesticide-related fatalities and the urgent need for improved pesticide management practices in Tamil Nadu. J Agric Environ Health. 2021;45(3):245-60. doi: 10.1234/jaeh.2021.0453.
9. Rostami F, Afshari M, Rostami-Moez M, Assari MJ, Soltanian AR. Knowledge, attitude, and practice of pesticides use among agricultural workers. Indian J Occup Environ Med. 2019;23(1):42-7. doi: 10.4103/ijoem.IJOEM_153_18. PMID: 31040589; PMCID: PMC6477942.

Original Research Article

Analysis of Geriatric Deaths: An Autopsy Study

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Abstract

Introduction: With the increase in medical advances and technology, people are living longer, and the percentage of the geriatric population is on the rise. However, this subset of population of their own set of problems and cannot be treated as others.

Material and Methods: An autopsy based retrospective study on deaths of geriatric population was conducted for the period of 1 year (January 2023- December 2023) in a medical college hospital.

Results: Out of all autopsies done during the period, geriatric cases were 17% (n= 34), with male predominance (n= 29). Among the deceased, the highest was in the age group 60-70 years (n= 23), next being 70-80 years (n= 9) and least was in 80-90 years (n= 2).Natural death was most common among them (n= 15), followed by accidental deaths (n= 13), suicidal death being third (n= 5) and homicide being least (n=1). Among natural deaths, death due to cardiovascular causes was the highest (n= 12), followed by deaths due to respiratory system (n= 3). Among unnatural deaths, Road traffic accidents were the highest (n=12), suicide by poisoning and drowning were 2 cases each.

Conclusion: The study shows natural death is more common among geriatric population, with most dying due to cardiovascular causes. The study also shows that road traffic accidents are of significant importance when it comes to geriatric deaths, amounting to the same number of deaths due to cardiovascular causes. These types of deaths can be prevented.

Keywords: Geriatric, Autopsy, Natural Death, Unnatural Death

Introduction:

With increase in medical advances, medical technology and improvements in socio-economic conditions, the life expectancy is increasing. This means people will get older and older and yet survive for long periods.

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Geriatrics is the term used in the medical field to denote elderly people. The term geriatrics originates from the Greek "geron" meaning "old man", and "iatros" meaning "healer". It aims to promote health by preventing, diagnosing and treating disease in older adults.[1]

The number of elderly people or the older population is on the rise. According to WHO, all countries face major challenges to ensure that their health and social systems are ready to make the most of this demographic shift. It is estimated that by 2050, 80% of older people will be living in low- and middle-income countries. By 2030, 1 in 6 people in the world will be aged 60 years or over. Between 2015 and 2050, the proportion of the world's population over 60 years will nearly double from 12% to 22%.[2] The rise in number of these elderly people is more pronounced in highly populated countries like India where it is estimated that by 2050, nearly 20% of their billion plus population will be elderly. Infact, the population of people aged80+ years is expected to have a phenomenal increase by around 279% between 2022 and 2050.[3]

The elderly people or the senior citizens as they are colloquially called in India are a new subset of vulnerable population. They do not have fixed income, they are not generally covered under medical insurances, and they often suffer from multiple diseases needing long term multiple medications. The complications due to non-communicable diseases will keep on increasing with duration of disease, thus elderly people will have more and more complications as they age further.

The problems faced by geriatric population are different than other subsets of population, thus needing further studies. They pose a major public health challenge, especially in developing countries where their health care system is already very constrained. The mortality profile among this population might shed some light into implementing programmes catered specifically for the elderly. However, most of these studies done are for natural death where the statistics are collected from death certificates issued by the treating doctors. There is a dearth of literature on elderly mortality based on medico-legal autopsies. Not many studies have been conducted on this subject, especially in India. Thus, the present study was carried out to investigate the mortality profile of elderly population, subjected to medicolegal autopsies in a tertiary care center in South India.

Despite its importance, there is a significant research gap in geriatric autopsies in Rural Bengaluru. The current literature highlights the need for improved understanding of the disease patterns and causes of death, enhanced health care policies and clinical practices. Raising awareness about the importance of geriatric autopsies and its benefits can provide valuable data for further research and quality improvement.

Materials and Methods

This descriptive study was conducted in the Department of Forensic Medicine and Toxicology, Akash Institute of Medical Sciences and Research center, Devanahalli, Bengaluru rural after obtaining due clearance from the institution ethics committee. The retrospective study was for the period of one year from January 2023 to December 2023.Inclusioncriteria (all autopsies done on people aged 60 years and above) and exclusion criteria (autopsies on people aged less than 60 years and mutilated dead body) were applied. Postmortem reports, Inquests and ancillary reports were taken, the data was collected and analyzed.

Results

A total of 200 autopsies were conducted in this time period. Among them, autopsies conducted over deceased aged 60 years, or more were 17% (n =34).

Among them, majority were male, amounting to 85.29% out of autopsies done on elderly population (n=29). Females amounted for 14.7% (n= 5).

The age group among the elderly was diverse as well. The highest was in the age group of 60-70 years, with 67.6% (n=23), followed by 71-80 years with 26.47 % (n= 9) and 81 years and more amounted to 5.88% (n= 2). Mean age was 68.47years and standard deviation was7.33 years.

Table 1: Sex and age group distribution.

Sl No	Age group in years	Male (%)	Female (%)	Number (%)
1	60-70	19(55.88)	4(11.76)	23(67.6)
2	71-80	8(23.52)	1(2.94)	9(26.47)
3	81 and above	2(5.88)	0 (0)	2(5.88)
	TOTAL	29(85.29)	5(14.7)	34

Regarding manner of death, natural deaths were more common, amounting to 44.11% (n= 15) but accidental deaths came in very close with 38.23%(n=13). Third most common was by suicides, amounting to 14.7%(n=5) and least was homicide with a single case amounting to 2.94%.

Table 2: Manner of death

Sl No	Manner of death	Number	%
1	Natural	15	44.11
2	Unnatural- accidents	13	38.23
3	Unnatural- suicides	5	14.7
4	Unnatural- homicides	1	2.94
	TOTAL	34	100

In natural deaths, death due to Coronary artery disease was seen in 12 cases (35.29%) and disease of lungs was seen in 3 cases (8.82%).

Among all the accidents, 12 were due to road traffic accidents (35.29%) and one was due to unknown animal bite (2.94%). In suicides, 2 had taken poison (5.88%), 2 had drowned (5.88%) and one had cutthroat injury (2.94%). Only a single homicide case was noted in the study population during the study period (2.94%).

Table 3: Cause of death

Sl No	Cause of death	Number	%
1	Coronary artery disease	12	35.29
2	Disease of lungs	3	8.82
3	Road traffic accidents	12	35.29
4	Unknown animal bite	1	2.94
5	Poisoning	2	5.88
6	Drowning	2	5.88
7	Suicidal cutthroat	1	2.94
8	Stab injury to Neck	1	2.94
	TOTAL	34	100

Discussion

In 2019, the global population aged 60 years and over (older adults) was just over 1 billion people, representing 13.2% of the world's total population of 7.7 billion. That number is 2.5 times greater than in 1980 (382 million) and is projected to reach nearly 2.1 billion by 2050.[2] This shows how as we progress in medicine and related fields and increase socio-economic reforms, the number of elderly population will keep on increasing, perhaps even exponentially. India's elderly population is growing rapidly, with a decadal growth rate of 41%and by 2046, the elderly population in India will surpass the population of children (0 to 15 years old).[3] It is high time we started caring about this vulnerable population. Mortality statistics are one of the methods of collecting data for public health issues. Though many have conducted studies into death in geriatric population, most concentrate on natural deaths and not consider medico-legal autopsies for the data collection. And such studies are even rarer in India where there is much need to gather such data.

This descriptive retrospective study was done on medico-legal autopsies done ongeriatric population in a medical college hospital in South India to know the burden and the demographic profile.

Geriatric medicolegal autopsies in our study amounted to 17% of all medicolegal autopsies conducted during the period. This is consistent with other studies conducted like Cetin S et al[4] in Turkey where percentage was 16.8%. The percentage is higher than other studies like Kumar RP et al[5]in Tumkur, southern India where geriatric deaths undergoing medicolegal autopsies was 7.56% or the study done in Adana, Turkey by Hilal A et al[6] where the percentage was 8.1% or Bhuyan BR et al[7]in Eastern India where percentage was 12.6%.

The predominance for male is evident in the study, with males accounting to 85.29%. Higher percentage is attributed to males travelling more than females and proximity of the center to airport and highways. Male predominance was seen in study done in eastern India by Bhuyan BR et al[7]where 72.2% of geriatric autopsies were conducted on males. Male predominance is seen in studies done in other countries too. For example, in study by Hilal A et al[6] in Adana, Turkey, male predominance was around 73.8% or in study by Turkoglu A et al[8]in Elazig, Turkey, where males amounted to 73.6% or in the study done in Sivas by Beyaztas FY et al[9] where males amounted to 73.2%.

Most of the cases in the current study were in the age group of 60-70 years (67.64%). This is higher than other studies like Bhuyan BR et al[7]where 60-69 years constituted 58.8%.

This study shows that nearly half of the cases coming to the medico-legal autopsy were due to natural causes. The proximity to aninternational airport and any deaths there, though it looks like due to natural causes, needing an autopsy might be the cause of such high numbers. This is still consistent with study done in Turkey by Cetin S et al[4] where natural deaths amounted to 49%.However, it is not consistent with study done by Bhuyan BR et al[7] where natural deaths amounted to just 9% and accidental deaths were more common amounting to 64.1% or study done by Akhiwu WO et al[10] in Nigeria where natural deaths were just 27.3% or study done by Kumar RP et al[5] where natural deaths formed just 26.58% or in study done in Ankara by Akar T et al[11] where natural deaths amounted to 42.37% of geriatric case autopsied or the study by Hilal Aet al[6] where natural causes amounted to 42.7%

Among natural deaths, death due to coronary artery disease was highest, with 35.39% and next was respiratory system (8.82%). This is consistent with other studies like Akar T et al[11]where diseases due to cardiovascular system were major causes in the natural deaths. In study by Berlzanovich AM et al[12] in Vienna, the major cause of death was due to cardiovascular system and next was respiratory illness. Even the study done by ShokraniB et al[13] shows the common causes were cardiovascular diseases and infectious diseases. However, in study by Turkoglu A et al[8], causes of natural deaths were myocardial infarctions and cerebrovascular diseases.

Accidents were most common among unnatural causes, with road traffic accidents taking up the majority. The presence of highways might account for the high number of accidents. The elderly often suffer from vision problems and have slowed reflexes, thus the probability of them suffering an accident is more. This is similar to the study done in SriLanka by Vadysinghe AN et al[14,] where accidents amounted to 62.1% of unnatural deaths. In a study by Turkoglu A et al[8], accidents were commonest with road traffic accidents and falls claiming the majority. In study done by Akhiwu WO et al[10] in Nigeria, road traffic accidents were 50.9% of autopsied geriatric cases.

Old age is reported as a predictor of completed suicide. Moreover, late-life suicides account for nearly 18% of all suicidal deaths. Major depression and physical illnesses were reported to play an important role among older suicide completers[11]. Suicides are comparably lower in this study amounting to 14.7% of all cases. This is considerably lower than in other studies like Bhuyan BR et al[7] (25%) or Kumar RP et al[5] (32.28%) but higher than few studies like Cetin S et al[4] (11.9%) Turkoglu A et al[8] (9.8%) or Akhiwu WO et al[10](1.8%). Poisoning and drowning were preferred equally and only one attempted suicidal cutthroat in the current study. In a study done by Beyaztas FY et al[9] in Sivas, hanging and poisoning were common methods of committing suicides. But in study by Kumar RP et al[5], hanging and drowning were more preferred methods to commit suicides.

Homicides in the current study are very less, amounting to 2.94% of all geriatric cases autopsied. This is still lower than few studies done before like Cetin S et al[4] (6%),

Conclusion

In the present study, autopsies on geriatric population constituted 17% of all autopsies performed. Out of which, nearly half of them were due to natural causes and more than one third of total geriatric deaths were due to road traffic accidents.

The proportion of geriatric population will increase with time. The elderly population will survive longer yet suffer longer too, thus imposing

an even higher burden on the medical system. A systematic study into the death of this subset of population might give us an idea of where to concentrate our focus on to ensure these people will live longer and yet not suffer much.

Death is inevitable but we can find ways to prevent deaths like suicides or accidents or to delay them as in natural deaths. Proper care at home, frequent health checkups and free or cheaper medications, ensuring old people do not feela burden themselves, might help a lot.

Limitations:

The sample size in the current study is less. Moreover, the study was conducted in a single center. These factors might lead to the formation of some bias. Thus, a multicentric study for a longer period might be of greater help.

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IEC Clearance: IEC approval taken, reference number- AIMSRC/IEC/48/2024 dated 27/12/24

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References

1. https://en.wikipedia.org/wiki/Geriatrics Accessed on 1/3/2025
2. https://www.who.int/news-room/ fact-sheets/ detail/ ageing-and-healthAccessedon 1/3/2025
3. https://www.drishtiias.com/ daily-updates/daily-news- analysis/india-ageing-report-2023Accessed on 1/3/25
4. Çetin S, Baduroğlu E, Gök E, Fedakar R, Öner BS. Medicolegal evaluation of geriatric deaths in Bursa, Turkey. Journal of Health Sciences and Medicine. 2023;6(1):152-7.
5. Kumar RP, Reddy SP, Rudramurthy S. Death profile in elderly-A study in district hospital Tumkur, South India. Indian Journal of Forensic Medicine & Toxicology. 2013 Jul 1;7(2):144.
6. Hilal A, Akçan R, Eren A, Turhan A, Arslan M. Forensic geriatric deaths in Adana, Turkey. Archives of gerontology and geriatrics. 2010 May 1;50(3):e9-12.
7. Bhuyan BR, Hansda MK, Swain R, Sahu G. Mortality Profile of Autopsied Geriatric Population: A Retrospective Study from Eastern India. Journal of Indian Academy of Forensic Medicine. 2024 Jun;46(2):238-41.
8. Turkoglu A, Tokdemir M, Bork T, Tuncez FT. FORENSIC AUTOPSIES OF GERIATRIC DEATHS CONDUCTED IN ELAZIG. Turkish Journal of Geriatrics/Türk GeriatriDergisi. 2014 Dec 1;17(4).
9. BEYAZTAŞ FY, BÜTÜN C, ÖZER E, Celik M. EVALUATION OF FORENSIC AUTOPSIES OF THE ELDERLY PEOPLE IN SIVAS. Turkish Journal of Geriatrics/Türk GeriatriDergisi. 2013 Dec 1;16(4).
10. Akhiwu WO, Igbe AP. Deaths with medicolegal implications in the elderly: experience from Benin City, Nigeria. Asian J GerontolGeriatr. 2011 Jun;6:35-7.
11. Akar T, Karapirli M, Akçan R, Demirel B, Akduman B, Dursun AZ, Sari S, Özkök A. Elderly deaths in Ankara, Turkey. Archives of gerontology and geriatrics. 2014 Sep 1;59(2):398-402.
12. Berzlanovich AM, Missliwetz J, Sim E, Fazeny-Dörner B, Fasching P, Marosi C, Waldhoer T, Muhm M. Unexpected out-of-hospital deaths in persons aged 85 years or older: an autopsy study of 1886 patients. The American journal of medicine. 2003 Apr 1;114(5):365-9.
13. Shokrani B, Fidelia-Lambert MN. Geriatric autopsy findings in the last 10 years: an urban teaching hospital experience. Journal of the National Medical Association. 2005 Mar;97(3):390.
14. Vadysinghe AN, Senasinghe P, Sivasubramanium M, Jayasooriya P, Premarathna BG, Rathnayake RM, Wickramasinghe WM. Unnatural deaths of the elderly population of Sri Lanka: A descriptive analysis. The American Journal of Forensic Medicine and Pathology. 2018 Jun 1;39(2):148-51.

Original Research Article

A Morphometric Study of Distal Humeral Parameters of Telugu Population and Estimation of Humeral Length by Regression Analysis

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Abstract

Background: Long bones of human skeletal remains are useful for Forensic analysis, stature estimation and determination of sex. Aim of the study is to use morphometric data of distal Humerus for estimation humeral length by regression analysis and for aiding orthopaedic Surgeons in preparation of pre-contoured and locked anatomical plates for rehabilitation of distal Humerus fractures.

Material and Methods: Study was conducted on 211 unpaired dry humeri (107 right and 104 left) from the collection of Department of Anatomy of a Medical college in Andhra Pradesh, Using slide calliper and Osteometric board.

Results: The mean of maximum length of humeri of right/ left side were 307.83 + 20.74/ 305.58 + 22.93. A strong positive correlation was observed between Humeral length and Distance between medial and lateral epicondyle (0.67 / 0.69), Distance between medial margin of Trochlea to Capitulum (0.68 / 0.65),Distance between Medial epicondyle to Capitulum (0.65 / 0.60) , length of medial flange of Trochlea (0.64 / 0.69) and length of the Lateral Flange of the Trochlea (0.52/0.63) of right and left Humeri.

Conclusion: The morphometric parameters of Distal end of right humeri were generally found to be greater than that of left humeri. There is a strong correlation between the Distal morphological parameters and the humeral length, except for anterior posterior diameter of Trochlea (D6). In absence of intact bones, the Distal Humeral landmark distances can also be used for Humeral length estimation and subsequent stature estimation.

Key word: Distal, Humerus, Regression, Correlations, Morphometric

Introduction

Genetic factors like race, environment and lifestyle influence the morphometric measurements of Humeral parameters. Anthropometric techniques are used in Study of dry bones for Stature estimation, Determination of sex and racial traits of a person. Anthropometric measurements of Long bones have

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provided reliable correlations with stature and exhibit sexual dimorphism but vary across various populations.

In archaeological studies stature estimated from human skeletal remains is an essential step in assessing health, sexual dimorphism, and general body size trends among past populations[1]. Estimation of living stature and humeral length can be done from fragmented Humeral remains, in the absence of more appropriated long bones, as femur or tibia [2,3].Stature and general body size estimation from skeletal remains help in identification of unidentified war victims and missing persons in medico legal cases. So it has got enormous potential for use in Medical fields, Forensic science and state of Law.

Estimation of stature from a single extremity bone is a common forensic practice [4] and many regression equations are given by various workers. Since 1996, the Trotter formulae, developed on American Whites and Negroes, have been used almost without exception. To determine the stature of the population in Bosnia and Herzegovina. In 2002 using bones from unidentified Bosnian and Croatian males victims of war, Ross and Konigsberg[5] presented new formulae for stature estimation for Balkans. The same year, 2002, in his master thesis, Sarajlić also presented formulae for stature estimation of Bosnian population. The research was undertaken on male cadavers. The cadaver length was measured directly and the length of the long bones was obtained from radiographs.

The Femur is generally considered the best long bone for estimating stature. Pelvic bones and post cranial elements are used for determination of sex from archeological remains and are more accurate than Skull, but skull is frequently used as it is better preserved (Novotny et al,1993) but inter observer discordance affects the Reliability of assessment Sex from Cranial Traits[6].

Humerus, Radius & Ulna are the bones used for stature estimation in absence of Femur and Tibia. Stature estimation can be done by measurement of the Humerus according to the study of Munoz et al [7]. For this purpose Humerus can be used alone or collectively with other bones of upper limbs for the determination of sex and the estimation of stature of an individual [8]. In the absence of a complete Humerus, the Humeral fragments are used for determination of the full humeral length [9] .

The anthropometric parameters of the Humerus e.g. its head diameter and epicondyle width can be used to determine sex [10]. Some studies show that maximum length of Humerus and the vertical diameter of the head of the Humerus are useful to determine the gender of skeletal remains [11]

Fractures of the humeral shaft in individuals over 65 years of age are becoming increasingly common, correlating with the rise in life expectancy and the prevalence of osteoporosis[12] Correlations between different measurements between the anatomical landmarks of the Distal Humerus will help the orthopedic surgeon in reconstructive surgery.

This study will provide morphometric data of the Distal humerus of Telugu population, which can be used in reconstructive surgeries by Orthopaedic surgeons for complex fractures involving damage to the distal end of arm bone. This study will provide data for improved prosthesis and precontoured implants development, as Total elbow arthroplasty (TEA) is increasingly becoming a popular option for non-reconstructable Distal Humeral fractures in osteoporotic patients. Limited study has been done in India and abroad towards collection of Distal Humeral Morphometric data, they show variances across race & sex and they can vary due to change in the mode of living. Thus the Prosthetic design will be population and sex specific and studies are needed to provide such data for appropriate prosthetic manufacture.

Material and methods

Materials:

211 dry unpaired adult Humerus bone of unknown age and sex, from the bone banks of Department of Anatomy of private medical college in Andhra Pradesh were considered for the current study. They were segregated to determine whether they belonged to the right or the left side 107 bones were right sided Humerus & 104 were left sided Humerus. Ethical committee clearance was obtained.

Whole bones without any deformities or fracture lines and broken ends were included. Bones with

deformities due to malignant lesions were excluded from the study. Every measurement was taken three times by different persons to eliminate bias.

Methods:

Sample size selection: The sample size depends on the Population size, Confidence level which corresponds to a Z-score, Margin of error (E) and Standard deviation. Cochran's Formula can be used for sample size (N) s shown below

$N = Z^2 * p(1-p)/E^2$

p = Population proportion

The Z-score for 95% confidence level is 1.96 and assuming a margin for error of 5% (0.05) the maximum sample size is ~384. As we have a sample size of 211 data the margin of error comes to around ~7%.

Sampling Technique: There are two type of sampling techniques, Probability Sampling & Non-Probability Sampling. As the bone samples used for this study are from the bone bank of a medical college, which were segregated based on some inclusion and exclusion criteria, the sampling method qualifies for Non-Probability Sampling type namely Purposive Sampling and Convenience Sampling without bias.

The maximum length of Humerus was measured using a Osteometric board and morphological Parameters of the Humerus was measured using Vernier calipers. The standard Morphological parameters listed below measurements were recorded **Ref Fig:1**

D1 : The length of Humerus bone measured from the tip of the head of the Humerus to the transverse line passing at the apex of the Trochlea.

D2 : transverse distance between the medial and lateral Epicondyles.

D3 : transverse distance from the Medial Margin of Trochlea to Capitulum.

D4 : horizontal distance from the medial Epicondyle to the Capitulum,

D5 : the maximal Transverse diameter of the Trochlea.

D6 : Anteroposterior diameter of the Trochlea at the mid part of the Trochlea.

D7 : Maximal length of the Medial Flange of the Trochlea.

D8 : Maximal length of the Lateral Flange of the Trochlea.

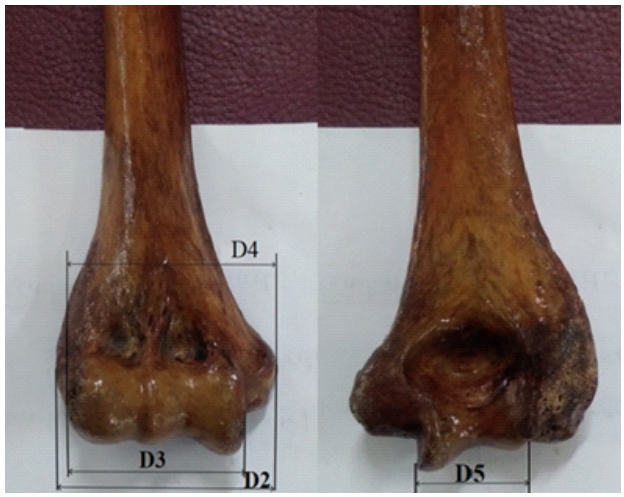

FIG 1: Distal humeral parameters

Results

Data was collected separately for Right and left humeri and was captured into MS Excel sheets Data was checked for outlier data. Thereafter, Microsoft Excel Data analysis package was used to obtain descriptive statistics separately for Right and left humeri samples for computing Mean, minimum & maximum length and Standard deviations ref **Table-1**

Regression analyses were subsequently performed. Firstly humeral length was regressed on various morphometric parameters of the distal end. Pearson's Correlations coeff (r), Coefficient of Determination (r^2) and SEE (Standard error of Estimate) was computed. The linear regression equations were derived for the estimation of Humeral length using individual distal humeral parameters. Humeral length was noted to be having a strong correlation with the distal morphometric parameters a shown in **Table: 2**. All the correlations have highly significant F values ($p < 0.001$).

The SEE for all the equations ranged between 16.57 to 18.65mm / 15.49 to 19.29 mm for Left / Right Humeri.

Table 1: Statistical analysis of the humeral dimensions for left & right Humerus (mm)

Parameters	Mean + SD (mm)		Minimum(mm)		Maximum(mm)	
	Right Humerus	Left Humerus	right	Left	right	Left
D1	307.83 ± 20.74	305.58 ± 22.93	265.00	255.00	381.00	376.00
D2	57.44 ± 4.68	56.50 ± 5.0	47.80	45.50	72.00	69.40
D3	39.69 ± 3.51	39.87± 4.41	32.00	31.90	49.00	57.80
D4	54.53 ± 4.78	53.24 ± 5.03	42.00	42.80	70.50	65.50
D5	24.23 ± 2.7	23.63± 2.53	18.80	18.50	29.60	34.00
D6	15.24 ± 2.39	14.92 ± 2.10	10.50	10.00	22.50	21.00
D7	23.48 ± 2.54	23.34 ± 2.44	17.50	17.20	32.00	31.00
D8	17.66 ± 2.24	17.56 ± 2.10	13.00	11.20	25.00	26.00

Table 2: Regression equations, Pearson's Correlation, Coeff of Determination and Standard error of Estimate.

Parameter (X)	Regression equations (Humeral length= A * X + B)		Pearson's Correlation coeff		R2 (Index of determination)		SEE(mm)	
	Right Humerus	Left Humerus	Right	Left	left	Rights	left	Right
D2	y = 2.9657x + 137.49	y = 3.1647x + 126.76	0.67	0.69	0.48	0.45	16.69	15.49
D3	y = 4.0319x + 147.82	y = 3.3757x + 170.97	0.68	0.65	0.42	0.46	17.59	15.52
D4	y = 2.8098x + 154.62	y = 2.7264x + 160.43	0.65	0.60	0.36	0.42	18.46	15.87
D5	y = 4.1796x + 206.58	y = 5.3594x + 178.94	0.54	0.59	0.35	0.30	18.59	17.48
D6	y = 3.2807x + 257.84	y = 6.4146x + 209.84	0.38	0.59	0.34	0.14	18.65	19.29
D7	y = 5.2157x + 185.38	y = 6.522x + 153.36	0.64	0.69	0.48	0.41	16.57	16.02
D8	y = 4.8483x + 222.22	y = 6.9295x + 183.88	0.52	0.63	0.40	0.28	17.81	17.74

Discussion

It is a common practice to estimate Humeral length and Human stature from Regression equations developed using human long bone and their fragments[13].The statistical method of regression analysis has been used in the estimation of stature from intact long bones of the upper and lower limbs for different populations like Americans whites and negroes by Trotter and Gleser, 1952 [14], data from Americans after Korean war was used to re-evaluate the previous regression equations by Trotter and Gleser in1958[15], for South Africans by Bidmos et al [16]and Turkish by Celbis and Agritmis, 2006[8]. Whole length of Humerus can be estimated from measurement of proximal or distal fragments.

But from the data analysis result we found that all the parameters of lower end of Humerus are having statistically significant correlation with the whole length of the Humerus. This information may be useful for the cosmetic surgery in fracture of lower end of Humerus as well as for preparing prosthesis. But for a growing bone this may not be useful.

With advances in osteosynthesis, anatomically pre-molded locked plates, reinforced Y-plates, and Lecestre plates are used for stabilization & rehabilitation of complex distal humeral fractures[17]. Cobb and Morrey's 1997 study on 20 elderly patients (21 elbows) of mean age of 72 years, who had underwent TEA for acute distal Humerus fractures, reported excellent results

An Anthropometric study of paired humeri by Colin P. McDonald et al concluded that the anthropometric features of the distal Humerus of both sides that are used during elbow surgery are similar. Hence Preoperative imaging of the contralateral normal elbow should be considered in patients with periarticular bone loss where referencing anatomical landmarks of the injured side is not possible. This

information can be used as part of a preoperative plan to determine the ideal position of the implant, for ligament reconstruction or external fixator during surgery in combination with computer-assisted elbow surgery[18].

Table 3: Comparison with other studies

Parameters	Group	Siva Narayana and Himabindu [19] (100 humerus)	Salles et. al[1] (40 humerus)	Ashiyani et al [20] (100 humerus)	Shivani Azhagiri [21]et al (100 humerus)	Present study 211 humerus
D1	Right	-	313±23	303.9±16.6	309.98±26.58	307.83 + 20.74
	Left	-	305±16	303.2±15.8	303.40±18.41	305.58 + 22.93
D2	Right	58.0±4.0	58.0±6	56.6±3.6	57.55±4.39	57.44 ± 4.68
	Left	57.0±4.6	57.0±4	55.8±4.2	56.91±4.07	56.50 ± 5.0
D3	Right	40.7±6.3	40.0±4	38.7±2.5	-	39.69 ± 3.51
	Left	41.0±6.8	39.0±4	39.0±3.0	-	39.87 ± 4.41
D4	Right	56.3±3.7	58.0±5	54.2±3.3	55.18±4.19	54.53 ± 4.78
	Left	56.0±4.5	56.0±4	53.9±4.1	54.07±3.92	53.24 ± 5.03
D5	Right	22.4±2.2	24.0±3	22.6±1.8	24.76±2.34	24.23 ± 2.7
	Left	22.4±2.2	24.0±2	22.4±2.0	24.76±2.46	23.63 ± 2.53
D6	Right	15.6±1.8	16.0±2	14.5±1.5	17.16±1.89	15.24 ± 2.39
	Left	15.6±1.8	16.0±1	14.5±1.7	16.13±2.05 `	14.92 ± 2.10

Conclusion

Knowledge of the morphometric parameters of Humerus segments are important in forensic studies and in archeological investigations for determining the racial traits like stature. It can be used by Surgeons for treatment of the distal humeral fractures towards early rehabilitation of the patients.

Attempt was made to in the present study, to use Morphometric parameters of Telegu population for estimating Humeral Length by regression analysis, as no such study was found available. Estimation of Humeral length from Distal humeral parameters using Regression analysis can be done for other Indian Population with different genetic and racial traits for comparison. As Regression analysis is an accepted method for estimation of length of long bones and living height of individuals, from measurements of long bones fragments and their maximum length. Regression equations were generated to estimate Humeral length (for both left and right) using morphometric parameters D2, D3, D4, D5, D7 and D8 are shown in **Table-2**. They have a Pearson's correlation ranging from 0.52 to 0.68 and SEE ranging from 16.57 to 18.65mm / 15.49 to 19.29 mm (Right/ Left Humerus) indicating a moderately strong positive correlation between Humeral length and the mentioned morphometric parameters.

Any regression analysis is based on a representative quality data. Limitation of this study lies in the fact that the data obtained were not segregated based on Sex and age. Future research using CT based methods can provide segregated Distal humeral data. The equations and correlations would have been better if the data available had been paired and could have been segregated based on sex & age.

Conflict of Interest: None

Source of Funding: None

Ethical Clearance:

Permission for the study was taken from the Institutional Ethics Committee of GITAM institute

of medical sciences and Research, Visakhapatnam, Andhra Pradesh. The bones used in the study are from the collection of the Department of Anatomy, GITAM institute of medical sciences and Research.

References

1. Salles, Carvalho, Silva, Santana. Reconstruction of humeral length from measurements of its proximal and distal fragments. Brazilian Journal of Morphological Sciences. 2009.; 26((2)): p. 55-61.
2. Hoppa RD, Gruspier KL. Estimating diaphyseal length from fragmentary subadult skeletal remains: implications for palaeodemographic reconstructions of a southern Ontario ossuary. American Journal of Physical Anthropology. 1996 july; 100(3): p. 341-354.
3. Steele DG, McKern TW. A method for assessment of maximum long bone length and living stature from fragmentary long bones. American Journal of Physical Anthropology. 1969 September; 31(2): p. 215-227.
4. B R, Mujumdar RD. Stature estimation from femur and humerus by regression and autometry. Acta Anatomica. 1976 July; 94(2): p. 311-20.
5. Ross AH, Konigsberg LW. New formulae for estimating stature in the Balkans. Journal of Forensic Sciences. 2002;(47(1)): p. 165-7.
6. Walrath DE, Turner P, Bruzek J. Reliability test of the visual assessment of cranial traits for sex determination. AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 125. 2004 October; 125(2): p. 132–137.
7. Munoz JI, Linares-Iglesias M, Suarez-Penaranda JM, Mayo M, Miguens X, Rodriguez-Calvo MS, et al. Stature estimation from radiographically determined long bone length in a Spanish population sample. Journal of Forensic Sciences. 2001 March; Volume: 46(Issue: 2): p. 363-366.
8. Celbis O, Agritmis. Estimation of stature and determination of sex from radial and ulnar bone lengths in a Turkish corpse sample. Forensic Science International. 2006 May 10; Volume 158(Issues 2–3).
9. Wright LE, Vásquez A. Estimating the length of incomplete long bones: Forensic standards from Guatemala. AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY. 2003; 120(3): p. 233–251.
10. Albanese, F.V. Cardoso, R Saunders. Universal methodology for developing univariate sample-specific sex determination methods: an example using the epicondylar breadth of the humerus. Journal of Archaeological Science. 2005 January; Volume 32(Issue 1): p. 143-152.
11. Khan MA, Humara G, Mansor Nizami S. Determination of Gender from Various Measurements of the Humerus. Cureus. 2020 Jan; 12(1).
12. Abaydi, Bouziani T, Tbatou A, Radi. Distal humerus fractures in subjects over 65 years old: about 62 cases in Moroccan population. Pan African Medical Journal. 2024 June; 48(1).
13. Yasar İscan M, Steyn M. Human Skeleton in Forensic Medicine: CHARLES C THOMAS, Springfield,; 2013.
14. Trotter M, C. Gleser G. Estimation of stature from long bones of American Whites and Negroes. American Journal of Biological Anthropology. 1952 December; 10(4): p. 463-514.
15. Trotter, C. Gleser. A re-evaluation of estimation of stature based on measurements of stature taken during life and of long bones after death. American Journal of Biological Anthropology. 1958 March; Vol 16(1): p. 79-123.
16. A. Bidmos, Brits. Updated lower limb stature estimation equations for a South African population group. South African Journal Science. 2020 May; Vol 116(5/6).
17. Lecestre, Dupont, Lortat Jacob A, Ramadier. Severe fractures of the lower end of the humerus in adults. Rev Chir Orthop Reparatrice Appar Mot. 1979 Jan-Feb; 17(5): p. 11-23.
18. McDonald C, King, Peters T, Johnson. An anthropometric study of the distal humerus with implications towards contralateral registration. In Orthopaedic Proceedings; 1 March 2010. p. 14.
19. Himabindu DA, Amudalapalli Siva N. The Morphometric Study of Distal end of Humerus. PARIPEX - INDIAN JOURNAL OF RESEARCH. 2018 April; Volume-7(4): p. 136-137.
20. A. Ashiyani Z, Solanki S, Mehta CD. The Morphometric Measurement of Segments of Humerus. Journal of Research in Medical and Dental Science. 2016 January – March; 4(1): p. 38-40.
21. Azhagiri, Venkatesh, Ramasamy, Ramachandran K. Study on morphometry of distal humerus and its clinical correlations. BIOINFORMATION. 2024 August; 20(8): p. 859-861.

Original Research Article

Knowledge, Attitude, Preparedness and Perception of Pocso Act Among Third Year Medical Undergraduate Students at Tertiary Care Teaching Hospital, North Karnataka

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Abstract

Background: The tragedy of child sexual abuse is a worldwide problem that exists among both developed and developing countries. The most vulnerable groups in society for sexual abuse are children. Though the child is the most important asset of society, the child sexual abuse has become an emerging issue and national sensation day by day. In regards to this problem, a special law has been enacted named as Protection of Children from Sexual Offences Act (POCSO), 2012. This law amended in order to protect the rights of children.

Objectives: 1. To assess the knowledge, attitude and preparedness/perception among undergraduates about the POCSO Act 2012.

Materials and Methods: This was an observational, cross-sectional, and questionnaire-based study. Data was collected from willing participants among the undergraduates of Bidar Institute of Medical Sciences, Bidar using google forms. Data was entered into the Microsoft Excel sheet. The statistical analysis was carried out using Microsoft Excel 2021.Categorical data was presented as numbers and percentages, while continuous data was presented as mean ± standard deviation.

Results: In this study 130 undergraduate students have participated. The questionnaire consisted of 17 questions about the POCSO. In the knowledge aspect 42 have scored <80% and 88 have scored > 80% about POCSO. 94.6% participants think that medical students need to be trained to handle a POCSO case. 63.8 % believes that fear of social stigma is the biggest barrier preventing people from reporting CSA.

Conclusion: From this study we observe that the upcoming young doctors had adequate knowledge and positive attitude towards the POCSO cases. Although teaching young children about appropriate and inappropriate touch

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starts in the primary grades, CSA can be reduced by increasing the awareness among the local community to make the healthier environment for the children.

Key words: POCSO Act, Child abuse, sexual offence, knowledge, attitude, preparedness

Introduction

Child sexual abuse (CSA) has been recognized as a major public health problem impairing the health and welfare of children worldwide.[1] The tragedy of child sexual abuse problem that exists among both developed as well as developing countries. Though the child is the most important asset of society and the future of tomorrow, the child sexual abuse has become an emerging issue and national sensation day by day. In regards to this problem, a special law has been enacted named as Protection of Children from Sexual Offences Act (POCSO), 2012. This law amended in order to protect the rights of children. Passing this Act has been a major step in securing children's right.

The World Health Organization (WHO) defines Child Sexual Abuse as "the involvement of a child in sexual activity that he or she does not fully comprehend, is unable to give informed consent to, or for which the child is not developmentally prepared and cannot give consent, or that violates the laws or social taboos of society."[2]

According to the NCRB report of 2022, there are a total of 1,62,449 cases of crime against children registered during 2022, showing an increase of 8.7% over 2021(1,49,404 cases).Major crime heads under 'Crime Against Children' during 2021were Kidnapping & Abduction (45.6%) and Protection of Children from Sexual Offences Act, 2012(39.7%) including child rape. The crime rate registered per lakh children population was 36.6 in 2022 in comparison with 33.6 in 2021.[3]

The basic need for the study was to assess the knowledge about the POCSO Act and creating an awareness among young doctors and their approach towards the cases in the future.

Methods and Materials

This was an observational, cross-sectional, questionnaire-based study conducted in Department of Forensic Medicine & Toxicology in a Bidar Institute of Medical Sciences, Bidar. The study was conducted for three months from August 2024 to October 2024. The study was initiated after getting approval from Institutional Ethics committee.280/BRIMS/IEC/2024, Dated: 22.02.2024.

Participation in the study were from 3rd year M.B.B.S students from BRIMS, Bidar. The participants were voluntary. The study participants were briefed about the rationale of the study and participants were assured of the privacy and confidentiality of data. The informed consent to take part in the study was also taken before enrolling them in the study. Out of 152 students 130 students have participated in the study.

Inclusion criteria: consented 3rd year students.

Exclusion criteria: Students who didn't give consent and other year students. Other health care workers were excluded from the study.

A structured self-administered Google form-based questionnaire in the English language was prepared to collect the relevant data of the study variables. The questionnaire contained a total of 17 questions related to Knowledge, Attitude, Preparedness/ perception aspects of the POCSO in three sections. The questionnaire was validated with content validity index (17). For this, a panel of four peer experts (Head of the Department, Associate professor and two assistant professor of Department of Forensic Medicine) reviewed each question individually and CVI was calculated, which obtained a score of 0.83. The questionnaire was then distributed to the study participants through a digital web link using Google forms.

Link was provided to the participants and responses received within 30 minutes was considered for analysis. For logistics reasons, if the participant is not equipped to fill in the digital form, a physical form containing the same set of questions was given to the participants and the written response was collected within 30 minutes. There was a total of six multiple-choice questions related to the knowledge aspect of POCSO. Knowledge of the study participants was assessed using a scoring system, where we gave a score of "1" for each correct

answer and a score of "0" for each incorrect answer. Moreover, there was a total of 11 questions related to attitude, and Preparedness/ perception aspect of POCSO (six questions on attitude and five questions on Preparedness/ perception domain).

Dataanalysis:

Data was entered into the Microsoft Excel sheet. The statistical analysis was carried out using Microsoft Excel 2021. Categorical data were presented as numbers and percentages, while continuous data were presented as mean ± standard deviation.

Results

We got a total of 130 responses during the study period. The majority of participants belonged to the age group of 21-22 years (n=87, 66.9%) and >22 years (n= 35, 26.9%). Out of 130 participants 68(52.3%) participants were male, 58 (44.6%) participants were female and 4(3.07%) preferred not to reveal their gender.[Table no. 1, Figure no. 1 & 2]

Table 1: Demographic characteristics of study participants (n=130)

Demographic characteristics	Categories	Frequency
Age	18-20 years	8(6.1%)
	21-22 years	35(26.9%)
	>22 years	87(66.9%)
Gender	Male	68 (52.3%)
	Female	58 (44.6%)
	Prefer not to say	4 (3.1%)

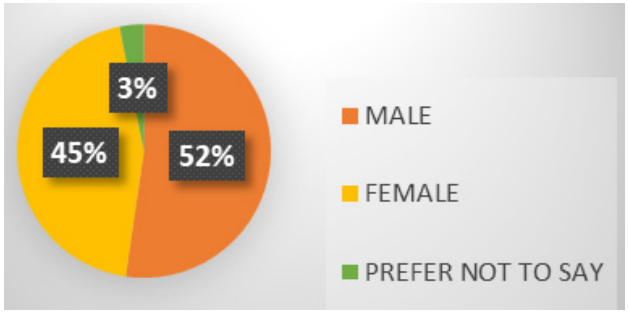

Fig. 1: Gender Distribution

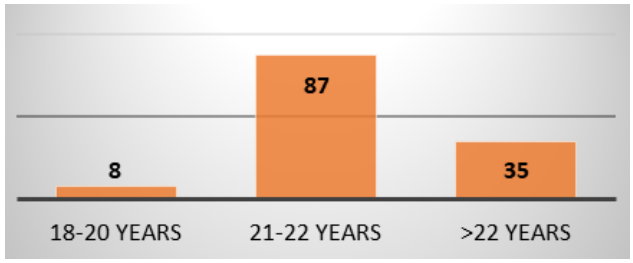

Fig 2:Age Distribution

Assessment of Knowledge:

There were total of seven questions in the questionnaire to assess the knowledge aspect of POCSO The mean score of each participant is 4.8± 1.42. Out of 130 participants, 88 have scored >80% and 42 have scored < 80% (Fig no. 3). It was observed that 75.4% (98) of the participants knew the acronym POCSO Act means. The age of child under POCSO Act was known to 79.2% (103). 71.5% (93) participants were aware that POCSO Act is gender neutral act. 82.3% (107) of participants was aware about the child helpline number in India. 93.1% (121) participants were responded correctly about the punishment awarded under POCSO Act. Only 67.7% (88) of the participants were aware about the punishment if the doctor fails to report the POCSO case. (Fig No. 4)

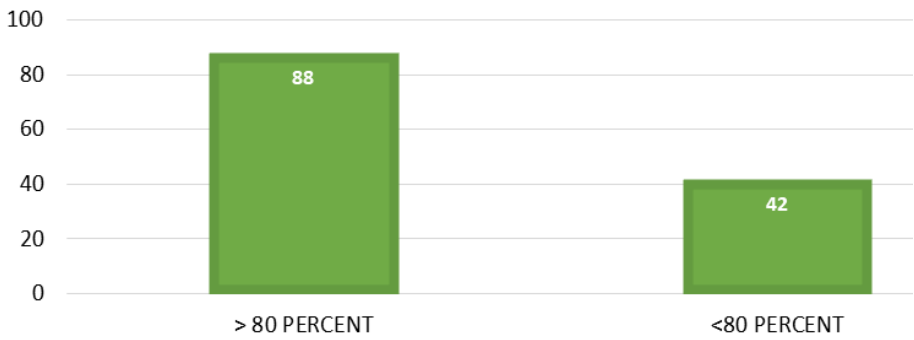

Figure 3: knowledge scores

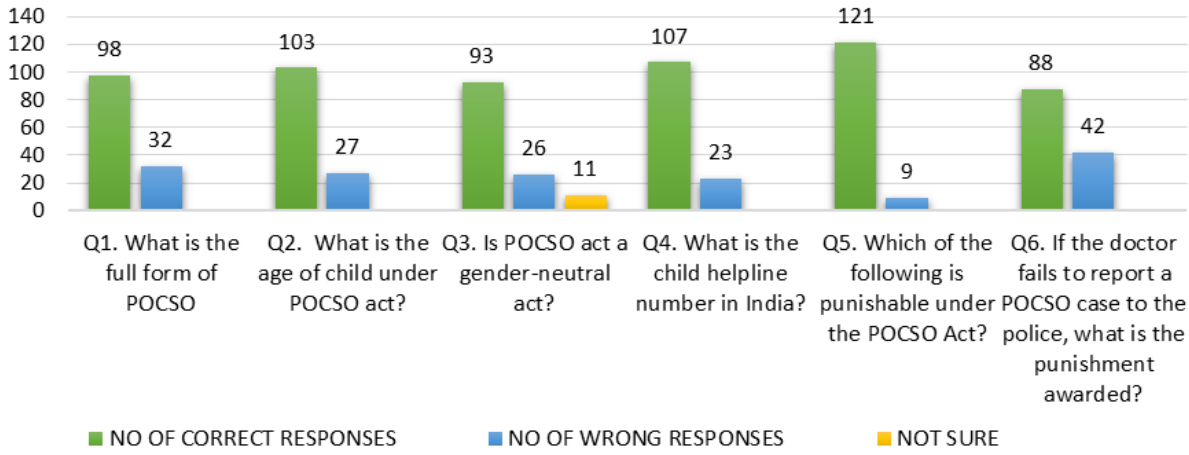

Figure 4: Knowledge Assessment

Assessment of Attitude:

There were six questions to assess attitude of participants towards POCSO Act. Only 63.8% (83) of the participants were aware about that male accused can be examined by the female doctor. Among the 130 participants 76.2% (99) knew that the duty of the doctor is to rule out the life-threatening condition is their first responsibility when the POCSO case approaches for medical care. 56.2% (73) of them believes that when it comes to the legal trail child's testimony alone serves as the evidence in the court of law and 24.6% (32) thinks that it depends on the circumstances and 11.5% (15) believes that more evidence is required to take sufficient action under the POCSO Act. 37.7% (49) thinks that POCSO Act is moderately enforced in the community and 33.1% (43) thinks it is poorly enforced. 84.6% (110) responded that POCSO Act training programs should be mandatory in schools and colleges for the better understanding and awareness. (Figure No. 5)

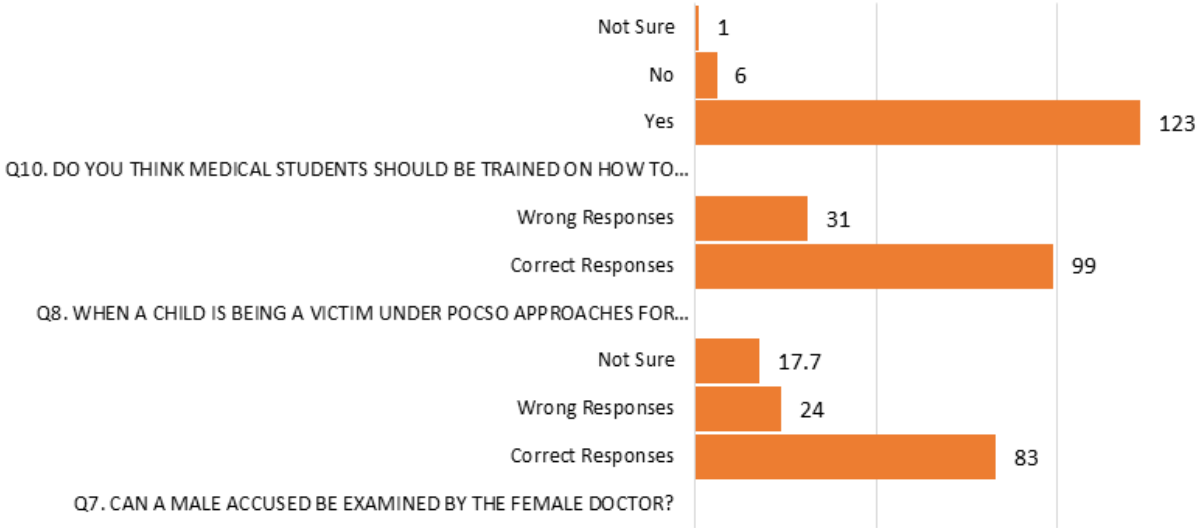

Figure 5: Attitude Assessment

Assessment of Preparedness/perception

There was a total of five questions in the questionnaire to assess the Preparedness/perception of study participants regarding POCSO Act. Among the 130 participants only 18.5% (24) participants are fully prepared to handle situations involving child sexual offences, 32.3% (42) participants are not at all prepared to encounter the situation and 49.2% (64) participants are somewhat prepared to handle

the situation. 55.4% (72) responded that they are somewhat confident but may need more guidance when they are intervening or helping a child who may be a victim of sexual abuse, 16.9% (22) participants are very confident in knowing what steps to take, 15.4% (20) participants would like to refer the case to a professional than intervene directly, 12.3% (16) participants responded that they are not confident and wouldn't know how to respond. 86.2% (112) participants very strongly think that awareness among young children about the good touch, bad touch, awareness among local community will help to reduce these types of crimes, 7.7% (10) thinks it is important, 5.4% (7) thinks it is moderately important and 0.8% (1) thinks it is not important. When asked about what is the biggest barrier preventing people from reporting child sexual offenses, 63.8% (83) believes that fear of social stigma is the main reason, 15.4% (20) thinks that there won't be any actions taken, 11.5% (15) thinks there is a lack of awareness about the POCSO Act in the society and 9.2% (12) thinks there is a fear of the legal process aftermath. 76.2% (99) participants agree that educational institutions should play in preventing child sexual abuse and they should be actively educating students about the POCSO Act and abuse prevention, 13.1% (17) believes strict policies to handle cases of child sexual abuse, 9.2% (12) participants think they should work with law enforcement to ensure child safety.

Table 2: Knowledge, attitude, preparedness/ perception about POCSO among 3rd year medical students

SECTION I- KNOWLEDGE BASED ASSESSMENT	**n**	**%**
Q1. What is the full form of POCSO?		
Correct response	98	75.4
Wrong response	32	24.6
Q2. What is the age of child under POCSO act?		
Correct response	103	79.2
Wrong response	27	20.8
Q3. Is POCSO act a gender-neutral act?		
Correct response	93	71.5
Wrong response	26	20
Not sure	11	8.5
Q4. What is the child helpline number in India?		
Correct response	107	82.3
Wrong response	23	17.7
Q5. Which of the following is punishable under the POCSO Act?		
Correct response	121	93.1
Wrong response	9	6.9
Q6. If the doctor fails to report a POCSO case to the police, what is the punishment awarded?		
Correct response	88	67.7
Wrong response	42	32.3
SECTION II- ATTITUDE BASED ASSESSMENT		
Q7. Can a male accused be examined by the female doctor?		
Correct response	83	63.8
Wrong response	24	18.5
Not sure	23	17.7
Q8. When a child is being a victim under POCSO approaches for medical care, what will be the first step to be taken, if you are on the duty?		
Correct response	99	76.2
Wrong response	31	23.8
Q9. If a child's testimony is the only evidence in a sexual abuse case, do you believe it is sufficient for legal action under the POCSO Act?		
Yes, it is sufficient	73	56.2
No, more evidence is needed	15	11.5
It depends on the circumstances	32	24.6
I don't know	10	7.47
Q10. Do you think medical students should be trained on how to handle a POCSO case?		
Correct response	123	94.6
Wrong response	6	4.6
Not sure	1	0.8
Q11. Do you believe the POCSO Act is well enforced in your community?		
Yes, very well enforced	27	20.8

Moderately enforced	49	37.7
Poorly enforced	43	33.1
Not enforced at all	11	8.5
Q12. Do you think POCSO Act training programs should be made mandatory in schools and colleges?		
Yes, it should be mandatory for students and staff.	110	84.6
Yes, but only for professionals directly working with children (e.g., teachers, counsellors).	16	12.3
No, it should be optional.	2	1.5
No, awareness about POCSO can be raised through other means.	2	1.5
SECTION III- PREPAREDNESS/ PERCEPTION BASED ASSESSMENT		
Q13. Do you feel you are adequately prepared to handle situations involving child sexual offenses?		
Yes, fully prepared	24	18.5
Somewhat prepared	64	49.2
Not prepared	42	32.3
Q14. How confident are you in intervening or helping a child who may be a victim of sexual abuse?		
I am somewhat confident but may need more guidance.	72	55.4
I am very confident in knowing what steps to take.	22	16.9
I would rather refer the case to a professional than intervene directly.	20	15.4
I am not confident and wouldn't know how to respond.	16	12.3
Q15. How important do you think awareness among young children about the good touch, bad touch, awareness among local community will help to reduce these types of crimes?		
very important	112	86.2
Important	10	7.7
moderately important	7	5.4
Not important	1	0.8
Q16. What do you think is the biggest barrier preventing people from reporting child sexual offenses?		
Fear of social stigma	83	63.8
Belief that no action will be taken	20	15.4
Lack of awareness	15	11.5
Fear of the legal process	12	9.2
Q17. What role do you believe educational institutions should play in preventing child sexual abuse?		
They should actively educate students about the POCSO Act and abuse prevention.	99	76.2
They should have strict policies to handle cases of child sexual abuse.	17	13.1
They should work with law enforcement to ensure child safety.	12	9.2
Educational institutions are not the primary place for dealing with such issues	2	1.5

Discussion

Protection of children from sexual offences Act, 2012 mainly deals with the child abuse cases. It is divided into 46 sections and was published in official gazette on 20th June 2012 but the enactment came into force on 14th November 2012. Child sexual abuse has gone largely unrecognized and unreported in India for a number of reasons, including fear of embarrassment, guilt, community denial, associated sociocultural stigma, lack of confidence in government agencies and a communication gap between parents and children about the issue.

In this present study, 75.4% of the participants knows the acronym of POCSO and 79.2% knows the age of children under POCSO Act which is similar to the study conducted by Afzal Haroon et al[4]. 93% of the participants knew the offence under the POCSO Act which is similar to study conducted by Kaduet al.[5]In our study 88 respondents had > 80 % of knowledge regarding the POCSO Act which is similar to the results conducted by Singh R et al.[6] About 71.5% disagree that girls are the only victims of sexual assault which is a correct and the study results are similar to Afzal et al.[4] According to new UNICEF published on 9th October 2024.[7] estimates revealed that more than 370 million girls and women alive today- or 1 in 8 experienced rape or sexual assault before the age of 18. An estimated 240 to 310 million

boys and men or around 1 in 11 have experienced rape or sexual assault during childhood.

The offences and punishments listed under POCSO Act of 2012 in August 2019 are as follows:

1. Sexual Assault: imprisonment of three to five years and fine.
2. Penetrative Sexual Assault on child below 16 years of age- minimum imprisonment of 20 years which may extend to remainder of natural life and fine.
3. Penetrative Sexual Assault on child of 16 to 18 years of age- minimum imprisonment of 10 years which may extend to imprisonment for life and fine.
4. The Aggravated Penetrative Sexual Assault- minimum rigorous imprisonment of 20 years which may extend to imprisonment for life and fine or with capital punishment.
5. Aggravated Sexual Assault- imprisonment of five to seven years and fine.
6. Sexual Harassment- imprisonment which can extend up to 3 years and fine.
7. Use of child for pornographic purposes- five years and fine and in the event of subsequent conviction, seven years and fine.

According to the POCSO Act, it is mandatory to report cases of sexual abuse against children and in India who has provided 24-hour toll-free number 1098 as emergency child helpline.[8] In this present study 82.3% of the participants are aware of the helpline number.

Not reporting a case of child abuse case is punishable and can result in 6 months of imprisonment with or without fine and 88% of the participants are aware about the same. This was an encouraging finding from the future doctors. The knowledge regarding the POCSO Act is satisfactory among the undergraduates.

Assessment of attitude is positive regarding the POCSO Act since 63.8% of the participants are aware regarding the examination of male accused by the female doctor which is a correct response. 76.2% participants will rule out the life-threatening complications in case of child abuse case and inform to RMO, 94.6% participants believe and welcoming the idea that medical students should be trained how to handle a POCSO case.

Assessment of Perception/ Preparedness is not adequate since only 18.5%(24) out of 130 participants are ready to handle a situations involving sexual offences, 55.4% (72) participants are not confident and need more guidance from the professionals. Choudhary V et al, conducted a qualitative study on Perspectives of Children, Caregivers and Professionals on the impact of child sexual abuse and recommended multidimensional impact assessment, culturally sensitive assessment and intervention protocols, incorporation of family focused approach and,multidisciplinary team approach to ensure the holistic wellbeing of children.[10]

Conclusion

Although safety begins from home, child sexual abuse can be reduced by increasing the knowledge and awareness in the local community. To handle the cases of sexual abuse for a better structural approach and improved outcome, a multidisciplinary approach involving primary health care professionals, police officers, lawyers, child welfare committee workers, paediatrician, Gynaecologists, Forensic experts, Psychiatrists and NGO is essential[9]. India had no legislation until 2012 to address the evil offences committed against male and female children. POCSO Act being a gender-neutral legislation aims to provide safety to children and punish the offenders based on gravity of offences committed against children and addresses all aspects of child abuse. More research will help in finding the barriers to the successful implementation of the POCSO Act at the grassroot level and makes us understand the challenges faced by rural or marginalised communities in accessing justice and support services.

Limitations: only the 3rd M.B.B.S students were taken into for the present study.

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Institutional Ethical Committee: 280/BRIMS/IEC/2024 Dated: 22-02-2024

Conflict of interest: None

References

1. Paul V, Rathaur VK, Bhat NK, Sananganba R, Ittoop AL, Pathania M. Child abuse. Journal of Family Medicine and Primary Care. 2021 Jan;10(1):110–5. doi:10.4103/jfmpc.jfmpc_1862_20
2. World health organisation. Global status report on alcohol, 2004 [Internet]. United Nations; [cited 2024 Dec 21]. Available from: https://digitallibrary.un.org/record/556210?ln=en
3. Afzal Haroon, Kashif Ali. Assessment of knowledge and attitude about POCSO Act among medical interns: A questionnaire based study. Indian Journal of Forensic Medicine & Toxicology. 2024 Apr 27;18(2):5–8. doi:10.37506/hvpzys06
4. https://www.ncrb.gov.in/National Crime records Bureau (NCRB) 2022 report.
5. Kadu S, Shinde A, Mhaske SN, Assessment of Knowledge and Attitude about POCSO Act amongst Medical Practitioners. Indian Journal of Forensic Medicine and Pathology 2021; 12(4): 407-412.
6. Singh R, Koushal V, Bharti B. A Descriptive Study on Child Sexual Abuse Act in India. Journal of Family Medicine and Primary Care. 2022 Jun;11(6):2923–32. doi:10.4103/jfmpc.jfmpc_1071_21
7. https://www.unicef.org/indis/ what-we-do/child-protection.
8. Seth R, Srivastava RN. Child sexual abuse: Management and prevention, and protection of children from sexual offences (POCSO) act. Indian Pediatrics. 2017 Nov;54(11):949–53. doi:10.1007/s13312-017-1189-9
9. Maul KM, Naeem R, Rahim Khan U, Mian AI, Yousafzai AK, Brown N. Child abuse in Pakistan: A qualitative study of knowledge, attitudes and practice amongst health professionals. Child Abuse & Neglect. 2019 Feb;88:51–7. doi:10.1016/j.chiabu.2018.10.008
10. Choudhary V, Satapathy S, Sagar R. Qualitative study on the impact of Child sexual abuse: Perspectives of children, Caregivers, and professionals in Indian context. Journal of Child Sexual Abuse. 2019 Jan 25;28(4):489–510. doi:10.1080/10538712.2018.1563262.

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