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EDITORIAL

Should all the crimes reported to a medical officer be mandatorily informed to law enforcement authorities in Sri Lanka? An ethico-legal interpretation

Sarathchandra Kodikara

"All crimes should be informed to the law enforcement authorities" is the currently widespread and accepted belief among the majority of the medical fraternity within Sri Lanka. This credence has been implemented in the teaching protocol of medical undergraduates and postgraduates for decades. Therefore currently, nearly the entirety of the medical officers would report all the alleged crimes they come across in the hospital to the Police, regardless of the patient's wishes. There were incidents in which the patient specifically requested not to inform the crime he/she was involved in, but the medical officer nevertheless had proceeded to inform the Police.

Here, the medical officer firmly believes that a crime should mandatorily be informed, and if not he/she is statutorily responsible and punishable for not informing to the relevant authorities according to the certified procedure.

However, in certain noted cases, the after-effects of such a reporting could potentially be socially and psychologically unpleasant, particularly for the victim involved. For example, in an alleged case of domestic violence, the wife solicits from the according medical officer to refrain from informing this incident to Police. Ignoring the personal autonomy of the patient, the medical officer informs this and the Police would start investigations. Studious interrogation from the husband, children, and other inhabitants, police visits to the home, filing a court case against the husband who lives in the same house and the breadwinner of the family, husband, and wife appearing and arguing in the court house as the respondent and the complainant while being living in the same house may create unnecessary outcries within the family and society.

However, this is not the reality, and correct interpretation of the current law. The section 21 of the Criminal Procedure Code of Sri Lanka states that:

Every person aware-
(a) of the commission of or the intention of any other person to commit any offence punishable under the following sections of the Penal Code namely, 114, 115, 116, 117, 118, 119, 120, 121, 122, 126, 296, 297, 371, 380, 381, 382, 383, 384, 418, 419, 435, 436, 442, 443, 444, 445 and 446 ;
shall in the absence of reasonable excuse-the burden of proving which shall lie upon the person so aware-forthwith give information to the nearest Magistrate's Court or to the officer in charge of the nearest police station or to a peace officer or to the Grama Seva Niladhari of the nearest village of such commission or intention.

Accordingly, within the "Offences against the human body" listed in Chapter XVI of the Penal Code of Sri Lanka only murder (Section 296) and culpable homicide not amounting to murder (Section 297) should be informed. Other crimes listed in the same chapter such as simple hurt (Section 310), grievous hurt (Section 311) sexual harassment (Section 345), rape (Section 363), incest (Section 364 A), unnatural offences (Section 365), acts of gross indecency between persons (Section 365A), grave sexual abuse (Section 365 B) are not listed in section 21 of the Criminal Procedure Code of Sri Lanka and therefore need not be informed mandatorily.

Though listed under “Offences against the property” in Chapter XVII of the Penal Code of Sri Lanka, voluntarily causing hurt during a robbery, (Section 382), voluntarily causing grievous hurt, or attempts to cause death during a robbery (Section 383) should be mandatorily informed as per the Section 21 of the Criminal Procedure Code of Sri Lanka.

Therefore, in summary, all the crimes reported to a medical officer should not mandatorily be informed. The mandatorily informed crimes include murder (Section 296), culpable homicide not amounting to murder (Section 297), voluntarily causing hurt during a robbery, (Section 382), and voluntarily causing grievous hurt, or attempts to cause death during a robbery (Section 383).

In all other reported cases, the medical officer has virtually no legal binding to inform a crime reported to him/her, and must respect the autonomy of the patient, and should not go against the patient's wishes. Anything contrary to this rule is a violation of the ethical principle of ‘autonomy’.

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RESEARCH ARTICLE

AN ASSOCIATION BETWEEN LANDSTEINER-RHESUS TYPING OF BLOOD AND CHEILOSCOPY AMONG FEMALE STUDENTS IN BENGALURU RURAL: FORENSIC MEDICINE PERSPECTIVE

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ABSTRACT

Introduction: Cheiloscopy is the term used for the study and analysis of lip impressions. In the field of forensics, identification is of utmost importance.
Objective: To study the relationship between lip prints and blood groups in female students in rural Bengaluru, Karnataka, India.
Materials: Lip prints and blood groups were obtained and recorded using cotton swabs, lipstick, antisera for slide agglutination test, slides, lancelets, sanitizer, and hand towels.
Methods: 189 students from the MVJ Medical College and Research Hospital participated after giving informed written consent. By applying cello tape to lips that had been painted with lipstick and then affixing the tape to the proforma sheet, the lip prints were collected. Suzuki and Tsuchihashi classification was used to categorize the same. The slide agglutination method was used to determine the blood group. Statistical analysis was done using the chi-square test. P value of 0.05 was considered of statistical significance.
Results: Type II or branching type was the most common lip print in our study. Most individuals (181 out of 189 participants) belonged to the Rh-positive blood group. The study participants with blood type O were the most commonly seen. Association between type II lip print and blood group O were found to be the most common.
Conclusions: This research shows the relationship between cheiloscopy and blood groups. These are frequently discovered evidence at a scene of the crime and are crucial for identification.

Keywords: *ABO typing; Blood grouping; cheiloscopy; Landsteiner grouping; Rhesus typing*

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INTRODUCTION

Cheiloscopy is the term used for the study and analysis of lip impressions. In the field of forensics, identification is of utmost importance. Residual and noticeable lip impressions may be found at scenes of crime, from homicides to larceny. Lip imprints are the distinctive patterning made by fissures (*sulci labiorum*) on the mucosa of the lips that are found at the area of transition between the skin and the labial mucosa[1]. Even though R. Fischer first characterized these patterns created by grooves on the lips back in 1902, two scientists from Japan, Tsuchihashi, and Suzuki, later provided more thorough investigations on the distinctiveness of cheiloscopy in 1970[2]. As early as the sixth week of foetal development, these lip patterns can be identified. Despite climate changes, diseases, mild trauma, inflammatory reactions, and infectious diseases, the lip prints remain unchanged[3]. For personnel identification, cheiloscopy is just as dependable as dactylography. Interestingly, homozygous twins' lip prints resemble each other a great deal more than their fingerprints[4]. According to numerous studies, the architecture of lip prints does not alter with advancement in the age of the individual[5].

Landois initiated the investigation on blood types in the late 1800s[6]. Karl Landsteiner's discovery of the ABO grouping of blood in the early 1900s, followed by the Rhesus typing, marked a major turning point in the development of blood transfusion[8].

ABO or Landsteiner blood grouping is determined by a solitary gene with alleles that are situated on chromosome 9. Rhesus blood group inheritance is determined by the existence of either the R or r alleles[7]. All red blood cells (RBCs) contain a crucial "H" antigen that is home to a specific antigen type and sugar. These antigens may be antigens A or B, and the sugar they contain could either be galactose or N-acetyl galactosamine (NAG) (G). Almost all RBCs share the "H" antigen, and the presence of both antigen "A" and N-acetyl galactosamine identifies it as belonging to the A blood group. It is blood group B if antigen "H" is present together with antigen "B" and galactose; blood group 'O' does not contain sugar and can only contain antigen "H". There are several incredibly rare circumstances where all three "H," "A," and "B" antigens are absent. These are referred to as Bombay blood types. Additionally, other antigens on RBCs include C, D, and E, with D being the most crucial in clinical settings. Blood types are classified as Rh negative or Rh positive depending on whether the D antigen is present. This method of classification of blood-based on D antigen is known as rhesus typing[9].

Any possible correlation between these three parameters (gender, blood group, and lip prints) must be explored and examined as they are of prime importance in a crime scene[25]. Since using other complicated methods for identification, such as analysing DNA, is sophisticated and inconvenient in rural and impoverished nations, the utilization of these parameters is of exceptional relevance[26].

OBJECTIVE

To analyse the relationship between Landsteiner-Rhesus typing of blood and cheiloscopy among female students in rural Bengaluru Rural district in India.

MATERIALS AND METHODS

The target demographic for this study were female students from Bengaluru Rural between the ages of 18 and 25 years. Students were informed in detail about the study in their classrooms and those willing to participate in the study were selected if they satisfied the criteria mentioned below. The research participants provided their written informed consent.

1. Inclusion Criteria
   a. Pupils over 18 years of age who consented to take part in the research.
2. Exclusion Criteria
   a. Pupils with lip injuries, ulceration, wounds, or smoking habits.
   b. Pupils who have cleft lips or any sort of anatomical abnormalities of the lips.

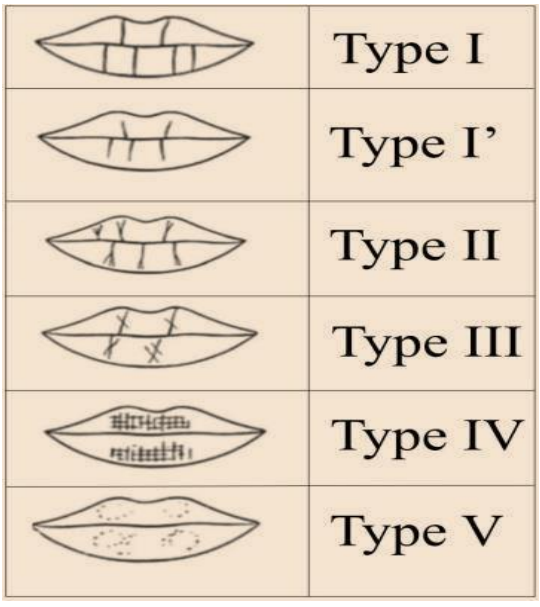
Proforma papers with questions on the study participants' age, sex, and blood type were provided. The proforma had slots for collecting the lip print.

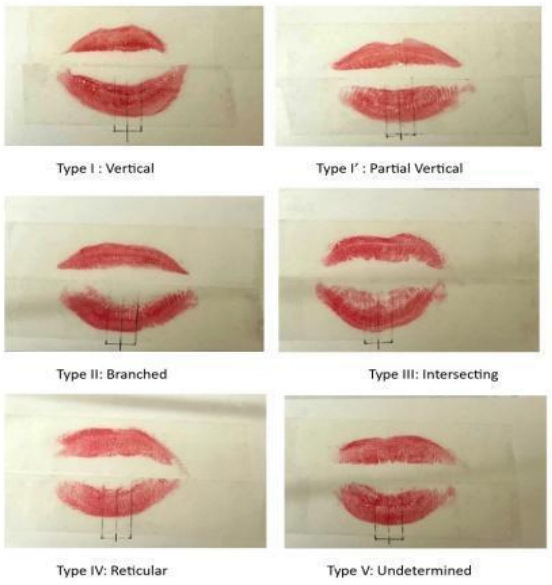
Collection and examination of lip prints

Under the supervision of the staff, the subjects were asked to thoroughly clean their lips using soap and water. Lip impressions were taken by using a cotton swab to apply lipstick over the labial mucosa. Using clear cellophane tape, these imprints were then transferred onto the proforma sheet by taping the cello tape to the lips and then attaching the tape to the proforma. After scanning, this data was then digitally evaluated. It was categorized using the system used by Suzuki and Tsuchihashi.

Type I - Vertical
Type I' - Incomplete vertical
Type II - Branched
Type III - Intersecting
Type IV - Reticular
Type V - Undetermined

Suzuki and Tsuchihashi Classification[10]





Identification of blood group

Slides, the appropriate antisera, and a sterile lancelet were used in the slide agglutination procedure to determine blood groups. Using a microscope, agglutination was examined to identify the blood group. Using antisera A and antisera B, a drop of blood from the participant was used to determine the blood type. An agglutination reaction to antisera A implied that the blood sample belonged to Landsteiner group A. Similarly, an agglutination reaction to antisera B implied that the blood sample belonged to Landsteiner group B. The sample was grouped under Landsteiner group O when neither A nor B antisera showed agglutination. When agglutination was achieved with both the antisera, it was coined as blood group AB. Similarly, the Rh status was determined based on the ability or inability of the Rh antigen to agglutinate the blood sample[27].

This procedure was carried out by designated health officers in the institution and was performed under the guidance of a medical laboratory technician (MLT) and medical officers of the haematology laboratory of MVJ Medical College and Research Hospital, Bengaluru, India.

Statistical analysis

The two assessors looked through the data gathered and entered the findings into Excel sheets. A Cohen kappa value of 0.8 was used to confirm the research's inter-examiner reliability. The chi-square test and Monte Carlo approach were done through Python for statistical analysis. For the Monte Carlo test, the cut-off p-value was 0.4, and for the chi-square test, it was 0.05.

RESULTS

Table 1: Age distribution among the study population

Age (in years)	No. of study participants
18-29	50 (26.4%)
20-21	86 (45.4%)
22-23	24 (12.6%)
24-25	21 (11%)
26-27	8 (4.1%)
-	Total: 189

Study subjects were selected from students from MVJ Medical College and Research Hospital, Bengaluru. Students were informed in detail about the study in their classrooms. Numbers were allotted to students who showed interest and fulfilled the above-mentioned criteria. Out of which 189 female students were selected using a random number generator. Ages of the subjects ranged from 18 to 27 (Table 1).

Table 2: Distribution of lip prints among the study population

Type I (Vertical)	**28 (14.8%)**
Type I' (Partial Vertical)	47 (24.8%)
Type II (Branched)	52 (27.5%)
Type III (Intersecting)	19 (10%)
Type IV (Reticular)	38 (20%)
Type V (Undetermined)	5 (2.6%)

The analysis of the cheiloscopy data revealed that Type II or branched type lip prints were the most frequent, followed by Type I (Partial Vertical). The undetermined type of lip pattern was the least prevalent in the current study (Type V). Rhesus typing revealed that, of the 189 individuals, 95.7% had the Rh-positive blood type (181 participants) and 4% had Rh-negative blood (Table IV). The O blood group, which included 85 out of the study population, was the most frequently observed in the study (44.9%). Blood group O was trailed by blood group B (25.9%) and blood group A (22.7%). blood group AB was least prevalent in the current study amounting to 6.3% of the total population (Table 3).

Table 3: Distribution of Landsteiner blood grouping among the study population

A	B	AB	O
43 (22.7%)	49 (25.9%)	12 (6.3%)	85 (44.9%)

Table 4: Distribution of Rhesus blood grouping among the study population

Rh – Positive	Rh-Negative
181 (95.7%)	8(4%)

Blood type O and Type II lip prints were most frequently associated with one another in the current study amounting to 13.2% of the total study population. The most common lip print seen in blood group A and AB was type I' (7.4% and 2.6% respectively), whereas most individuals of blood group B had type II lip print (5.8%).

Table 5: Blood group and lip print

	A	B	AB	O
Type I (Vertical)	6 (3.1%)	9 (4.7%)	1 (0.5%)	12 (6.3%)
Type I' (Partial Vertical)	14 (7.4%)	10 (5.2%)	5 (2.6%)	18 (9.5%)
Type II (Branched)	12 (6.3%)	11 (5.8%)	4 (2.1%)	25 (13.2%)
Type III (Intersecting)	1 (0.5%)	8 (4.2%)	0 (0%)	10 (5.2%)
Type IV (Reticular)	9 (4.7%)	9 (4.7%)	2 (1%)	18 (9.5%)
Type V (Undetermined)	1 (0.5%)	2 (1%)	0 (0%)	2 (1%)

Approximated p-value (Monte Carlo): 0.9822

Table 6: Rhesus typing and lip print

	Rh-Positive	Rh-Negative
Type I (Vertical)	28 (14.8%)	0 (0%)
Type I' (Partial Vertical)	44 (23.2%)	3 (1.5%)
Type II (Branched)	48 (25.3%)	4 (2.1%)
Type III (Intersecting)	18 (9.5%)	1 (0.5%)
Type IV (Reticular)	38 (20.1%)	0 (0%)
Type V (Undetermined)	5 (2.6%)	0 (0%)

Approximated p-value (Monte Carlo): 0.9438

Type II and type I' lip prints were the most prevalent in both Rh+ and Rh-blood groups. Type II lip print accounted for 27.4% of the total study population among which 25.3% was seen among Rh-positive individuals and 2.1% among Rh-negative individuals. Similarly, type I' lip prints made up 24.7% of the study's overall population, of which 23.2% were found in Rh-positive people and 1.5% in Rh-negative people. Type I, IV, and V were seen exclusively among Rh-positive individuals in the current study. (Table 6)

DISCUSSION

Sharma et al. found that Type I and Type I' lip prints were the most common among women in their study of dentistry students in Mathura, Uttar Pradesh[11]. Type I lip prints were common among Nigerian women, according to a study by Chukwumeka et al[12]. Another research by Obosi N et al. revealed that Type I' was the most prevalent among Nigerian women[13]. In the current study conducted among a female-only population in India, it was found that the most common lip print observed was Type II followed by Type I'.

According to research by Sandhu H et al among people of Srinagar, a district in Rajasthan, B positive was the most common blood type among women, whereas AB- was the least common[14]. Similar findings were found in a study undertaken by Kukadiya U et al, with B positive blood group being most common in female participants[15]. However, a study by Lakshmi Narayana B et al. showed the highest frequency of O-positive blood groups among women[16]. In the current study, the most observed blood group was O followed by B.

A study conducted by Nazli R et al. on pregnant women revealed that 92.5% of the study population belonged to Rh-positive blood group[17]. Similarly, in a study conducted in Pakistan among 8327 women from Faisalabad and 6652 women from Safdarabad, it was found that Rh-positive blood groups were seen most frequently (81. 09% in Faisalabad and 89.9% in Safdarabad)[18]. The current research study population consisted of women from rural Bengaluru, of which 95.8% were Rh-positive.

Blood type O was shown to be most frequently associated with Type II lip prints according to the present study. The same was found to be the case among females in the study conducted by Kesarwani P et al. and Verma P et al. with blood type O showing the most association with Type II

lip print[19,20]. However study conducted by Kaul N et al. shows the prevalence of type B blood group among individuals with type II lip print. Here, the O blood group was most associated with type I lip print, and vertical lip print- blood group B association was most frequently identified[21].

Karim B. et al. state that due to their distinctiveness, lip prints are extremely important for identification, and such a study is significant because it shows that, like fingerprints, lip impressions might be very helpful in criminal investigations[23]. In their research, Khanapure S et al. mention that the examination of unidentified bodies in mass disasters or identification of criminal suspects, as well as missing persons, depends heavily on personnel identification. These biological records, which remain unaltered throughout a person's lifespan, are of utmost significance. Blood is a vital component of medicolegal practice that, either by itself or in conjunction with lip prints, may help to reveal various criminal issues[24].

The current study was conducted in a gender-specific manner to achieve a more concentrated approach to the matter. While various studies are available on this topic, the number of gender-specific studies was limited. Even though the current investigation has several shortcomings including limited sample size, low number of Rh-negative individuals, and limited age groups, the findings nevertheless provide an opening for further extensive research on this topic.

CONCLUSION

In the current study, the commonest lip print observed among women is the branched type followed by partial vertical. The most frequent blood group among the study participants is O. However, the correlation between blood group and cheiloscopy established here was not of statistical significance. Therefore, studies conducted on a more diverse ethnic group and larger population may help establish a correlation between blood group and lip prints.

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None

CONFLICTS OF INTEREST

The author declared no conflicts of interest.

ETHICAL ISSUES

Ethical approval was obtained from the Institutional Ethics Committee, MVJ Medical College & Research Hospital, Bengaluru, India.

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AUTHOR CONTRIBUTIONS

AS: Conception or design of the work; acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; and final approval of the version to be published.

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RESEARCH ARTICLE

A RETROSPECTIVE DESCRIPTIVE STUDY ON DEATHS DUE TO FIREARM INJURIES IN WESTERN PROVINCE, SRI LANKA

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ABSTRACT

Introduction: The use of firearms is a well-recognized method of committing a homicide. In Sri Lanka, the use of firearms was prominent among terrorists and underworld criminals. The analysis of the injury pattern will help to find the trends related to firearm injuries. Deaths that deviate from the routine pattern of injuries will be highlighted.
Objectives: The objective of the study was to identify injury patterns in firearm-related deaths and the methods used to identify the range.
Methods: The data from 40 firearm-related autopsies conducted at Offices of the Judicial Medical Officer at Colombo North Teaching Hospital, Colombo South Teaching Hospital, and Office of the Judicial Medical Officer, Colombo from 2000 to 2019 were collected from the post-mortem reports using pre-formed questionnaires and entered into the SPSS statistical package for analysis.
Results: The majority were between 21 and 40 years of age (75%) and male (97.5%). Head alone was involved in 25% of deaths and head in combination with other regions was involved in 45% of the deaths. Cause of death (COD) in 50% of cases was head injuries alone and in 12.5% of cases, COD was from head injuries in combination with other injuries. The commonest circumstance was homicide in 72.5% of cases. Rifled firearm was the most common weapon used (90%). Range or the distance of fire was in the distant range in 65% of cases followed by close range in 17.5% of cases. Distance of fire was decided by the history, if available, the appearance of the entry wound, and other observations.
Conclusions: Scientific evaluation of deaths following firearm injuries demands proper assessment of the range or the distance of fire based on modern technology. This becomes more relevant if there is an incompatibility with the history and the appearance of the wound, especially when deciding the circumstance of death.

Keywords: *Autopsy; Cause of death; Gunshot wounds; Homicide; Suicide*

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INTRODUCTION

Gun violence and gun control are topics of great contention among the national and international community. Guns, to a certain demographic, signify safety against violence, whereas to another demographic, are a threat to the most basic of human rights, "the right to life"[1]. In Sri Lanka, 464 cases of homicides were recorded in the year 2020[2]. Information regarding the involvement of firearms in these deaths was not available in official sources. However, it was observed that 22 (3.72%) out of the 590 cases of suicides reported in the year 2020, had employed firearms as a method[3].

A retrospective analysis done on post-mortem reports of alleged homicidal deaths reported to

Judicial Medical offices of Colombo and Ragama, from July 2005 to June 2006 found that out of 256 alleged homicides 83 (31%) were due to gun violence[4]. A similar retrospective analysis conducted at Karapitiya Teaching Hospital from the 1st of January 2011 to the 31st of December 2011 observed that 30% of the homicidal deaths reported were due to firearm injuries[5].

The National Centre for Health Statistics, United States of America (USA) reported 19,141 homicides in the year 2019 of which 14,414 (75.30%) were classified as firearm homicides[6]. The USA being the country with the most firearms per capita in the world has a high homicide rate compared to other high-income countries[7]. In England and Wales, the homicides reported to police in 2019 and 2020 were 809[8]. Only a minority (4%) of the reported cases were due to firearm injuries, while the majority (40%) were due to sharp force injuries[8]. Out of the reported 45,878 homicides in India during the year 2014, 3,655 (7.96%) were due to firearm injuries[9].

The dead must be spoken for to protect the rights of the living. One crucial part of speaking for the dead is the post-mortem examination conducted by a qualified professional. Analysis of fatal firearm injuries regarding their type, direction, dating, range, etc., is of utmost importance to come to conclusions about the cause of death, circumstance, and details regarding the perpetrators. Determining the range or distance of a firearm injury observed at the post-mortem in the process of opinion formation is one of the areas that may have not received much attention in studies done in the region, if not worldwide.

Sri Lanka even though is one of the many lower middle-income countries in the South East Asian region, has the highest Human Development Index value[10]. Thus, Sri Lanka is in a unique position to seek innovative but cost-effective methods of analysing fatal firearm injuries. Integrating analysis of the type and range of firearm injuries with information technology will be the obvious step forward. The objectivity associated with deep learning of artificial intelligence backed by the knowledge and experience of subject experts will enhance the objective interpretation of injuries. However, relying solely on technology is not advocated in matters that deal with inherently subjective humans. The authors would like to put forth the idea of combining photogrammetry: with the use of ubiquitously present smartphones and their high-definition cameras and deep learning with modern software to analyse fatal firearm injuries.

OBJECTIVE

The objective of the study was to identify the injury patterns in firearm-related deaths and patterns in methods that were used to identify the range.

METHODS

The data from 40 firearm-related autopsy reports belonging to the investigators from the Offices of the Judicial Medical Officer at Colombo North Teaching Hospital, Colombo South Teaching Hospital, and Office of the Judicial Medical Officer, Colombo from 2000 to 2019 were collected using a pre-formed questionnaire and entered into the SPSS statistical package for analysis. Microsoft Word and Microsoft Paint software were used for the generation of pictograms that are illustrated in this article.

Sampling was done using the convenience sampling method and all the reports belonging to the investigators meeting the inclusion criteria were selected. Deaths involving multiple types of trauma such as sharp or blunt force trauma, deaths with no eyewitness statements, and deaths following complications of firearm injuries where there was a difficulty with interpreting initial injuries were excluded from the study.

The number of shots fired, the region of the body injured and the wound characteristics important for the estimation of range of fire were given prominence when gathering data from the autopsy reports.

RESULTS

Epidemiology

The study sample included 40 deaths with the majority being between 21 and 40 years of age (75%). Out of the study cohort, the majority were male (97.5%) except for one female (2.5%) who was a housewife. The majority were Sri Lankan nationals, except for one foreign national skilled worker. Available details on the occupations of the deceased are summarized in Table 1.

Table 1: Occupations of the deceased

Occupation details	Frequency	Percent (%)
Professional	13	32.5
Details not available	10	25.0
Skilled worker	7	17.5
Non-skilled	7	17.5
Unemployed	3	7.5
Total	40	100

Body Regions involved

When considering body regions involved in the path of the gunfire, the head alone was involved in 25% of the cases. Chest alone was involved in one case (2.5%). Multiple region involvement (head, chest, abdomen, etc.) was noted to be more common (65%, n=26) compared to solitary region involvement (35%, n=14) (Table 2).

Table 2: Body Regions involved in the path of the gunfire

Region	Frequency	Percentage (%)
Head	10	25.0
Head in combination with other regions (excluding chest)	5	12.5
Chest	1	2.5
Chest in combination with other regions (excluding head)	9	22.5
Head and chest	3	7.5
Head and chest in combination with other regions	8	20.0
Abdomen	1	2.5
Abdomen and upper extremities	1	2.5
Neck	1	2.5
Pelvis	1	2.5
Total	40	100.0

The total number of shots fired according to the post-mortem findings in these 40 cases amounts to 158. The head and chest have been the target of most entry wounds in the examined dead bodies. This is illustrated in Figure 1. Most victims had sustained either one (22.5%, n=9/40) or two (22.5%) entry wounds. Further details are elaborated on in Figure 2.

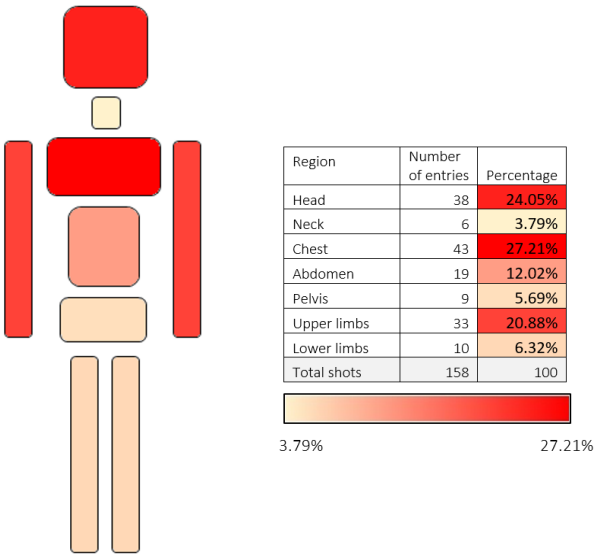

Figure 1: Distribution of entry wounds of firearm injuries.

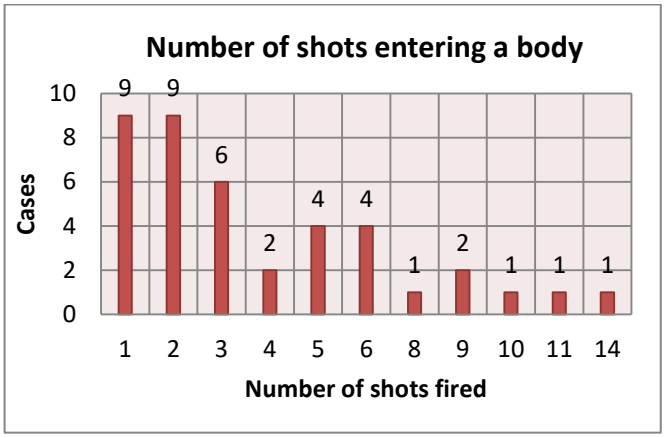

Figure 2: Frequency of number shots entering a body.

The cause of death (COD) in 50% of cases was head injuries alone and in 12.5% of cases, the COD was due to head injuries in combination with other injuries. The chest injuries, by itself, were the COD in 5% of the cases. The chest in combination with other injuries was documented as the COD in 35% of the cases. Out of those, 12.5% are a combination of head, and chest injuries or in combination with an injury to another region.

The manner of death was homicide in 35 (72.5%) cases. There were three suicides, of which two were committed using a smooth-bore weapon. These were single shots aimed at the head which resulted in their deaths. Another case of suicide was done by service personnel using an automatic assault rifle. The injuries were to the head and neck region with a single entry wound in the neck. The manner of death was not known in two cases; an expatriate

who went fishing and later found dead and a drug dealer.

Determining the range of fire

Range or the distance of fire can be divided into contact, near contact, close, intermediate, and distant ranges depending on the characteristics of the entry wound. The wound characteristics that are inferred from analysis of products of firing, i.e., soot, and powder residue, can vary depending on clothing and other intervening objects in the path of fire. This was given consideration when handling autopsies. The contact wounds and near-contact wounds are self-explanatory. Close range is defined as less than six inches, intermediate between six inches to six feet, and distant range as beyond six feet distance of fire from the victim[11].

In the 40 cases analysed, five (12.5%) cases were presumed to be contact or near-contact wounds. Two cases with contact wounds were due to smooth-bore weapons while the others were due to rifled weapons. One case with the rifled weapon injuries appeared to be of distant range as there was no burning, blackening, or tattooing. Only an abrasion collar was documented. In this particular case, two shots were fired at the head and both shots had exited. The injury pattern was incompatible with the history given by eyewitnesses. A naked eye observation of a contusion collar may have been documented as an abrasion collar.

One victim suffered both a distant range rifled firearm injury and a contact range smooth bore firearm injury. In this case, there was no burning, blackening, or tattooing found surrounding the injuries caused by both weapons. The latter was decided as contact due to the presence of a wad and cork inside the brain and other wound features supportive of the burst effect. One rifled weapon injury was concluded as a contact injury due to the presence of a contusion collar which was located in the occipital region.

There were eight (20%) close-range injuries. One of them was caused by a smooth bore weapon, which had a local large bursting effect which helped to determine the range as contact. Others were all from rifled weapons. One rifled weapon entry wound had all three features of burning, blackening, and tattooing observed. Four wounds had a combination of two of the three different features of burning, blackening, and tattooing. The most consistent feature observed was blackening, which was observed in six out of eight cases, with two cases reporting blackening alone as the reason for determining range. Only one (2.5%) intermediate-range injury was observed, which didn't have any burning or blackening, but had tattooing and an abrasion collar.

There were 27 (67%) distant range injuries. All of the 27 were from rifled weapons except one case where the weapon could not be identified. The absence of burning, blackening, and tattooing alone was used to state the range as distant in 18 cases, with two cases having eyewitness accounts in addition to the above evidence to support the range as distant. Seven cases had only an abrasion collar. In the case of one rifled injury found in a decomposed skeletonized body, the range was indeterminate. A detailed infographic analysis of reasons for determining the range is given in Figure 3.

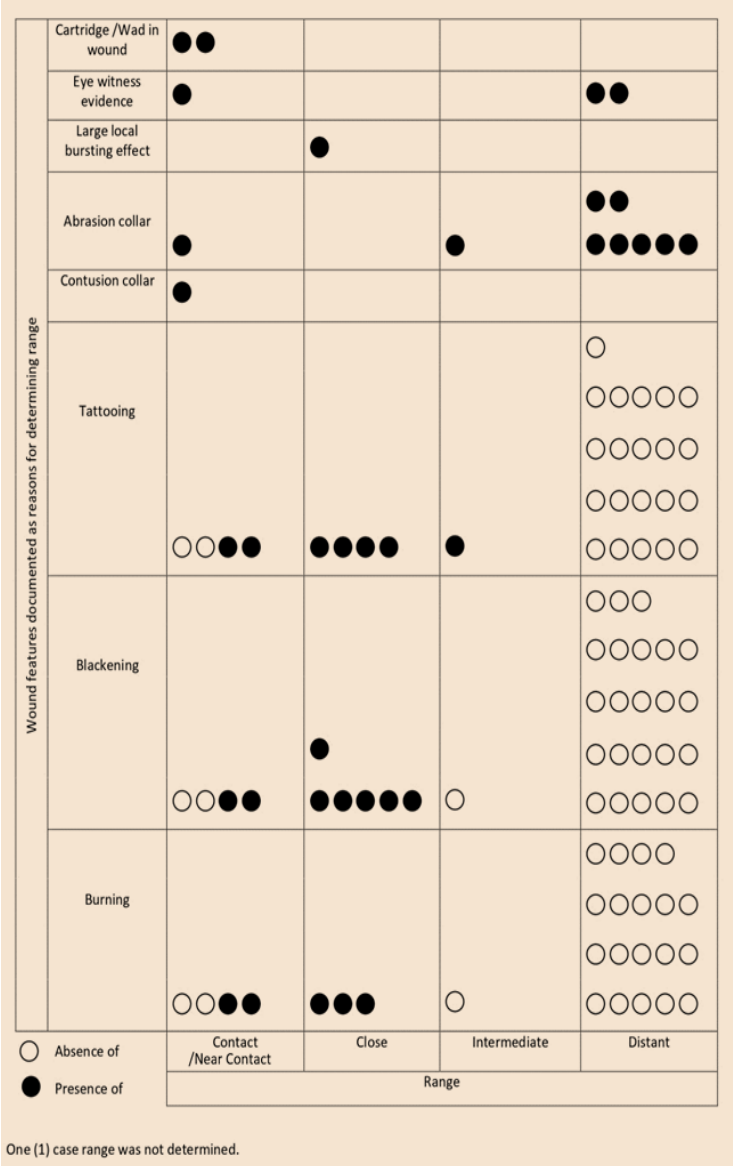

Figure 3: Range with the reason/s stated in the post-mortem report to determine the range.

Firearm and bullet trajectory

The rifled firearm was the sole weapon used in 90% of the cases (n=36/40). The smooth-bore weapon was the sole weapon used in 5% (n=2/40) cases. Both rifled and smooth-bore weapons were used in one case (2.5%). In one case, where an individual in a factory was shot multiple times, the weapon used was not identified. Among the 37 cases which involved rifled weapons, 16 were cases that involved automatic assault rifles, 8 cases involved either a handgun or a pistol, and further details were not available in another 13 of the cases. Bullet ricochet was identified in two of the cases where rifled weapons were used.

DISCUSSION

The dominance of male victims is noted in this study is compatible with another study from Sri Lanka which showed a 41:1 male: female ratio[4]. A study from India had 92.48% male victims[12] and a study from Bangkok had 91.3% male victims[13]. Both studies had a greater proportion of female victims compared to studies from Sri Lanka. This increase in female victims is also observed in European countries. Sweden had 35%[14], Denmark had 29.43%[15], and Italy had 7.6%[16] female gun violence victims. America with its controversial gun violence policies had 13.56%[17] female deaths.

Considering the total 158 shots fired at the victims of the current study, the chest (27.21%, n=47) had been the most targeted body region, with the head (24.05%, n=38) being the second. This pattern is inversed in another study conducted in Sri Lanka where the head was the most preferred target (36%, n=30) followed by the chest (30%, n=25)[4]. This is in direct contrast with one study conducted in India from 2008 to 2010 which noted the abdomen (48.49%, n=32) as the most targeted region[18]. This study considered victims who died due to complications of gunshot wounds. However, two other studies from India[19,20] showed the chest as the most targeted and the head as the second, which is consistent with the pattern observed in the current study. Studies from Thailand[21] and Denmark[15] had a similar pattern of having the head being the most targeted followed by the thorax. A Polish study has demonstrated that the head was the most common target in suicides, whereas, in homicides and accidental firearm fatalities, the chest region was the most common target[22]. The USA study noted that the head was the most common target despite the motive but, suicides had the head as the target in 89.1% of cases, whereas homicides had the head as a target in 38.3%, followed by chest (22.2%) at a close second. (The USA study only considered single gunshot wound fatalities in the study.) The head and neck region being the targets of the three cases of suicides in this study is compatible with the above findings. The head and chest being the most common target depict human understanding of the vitality of the head and chest to life. The chest is the most common or prominent target in most homicidal deaths involving firearms and in our study with only two cases of suicidal deaths by firearms, probably because the chest is the widest part of the human body.

However, case-by-case consideration of regions involved in the path of the gunfire, rather than the individual shots fired. The head alone was involved in 25% of cases (n=10) with the head region alone or in combination with other regions including the chest being involved in 65% of cases (n=26). Chest alone was involved in 2.5% of cases (n=1) with chest region alone or in combination with other regions including the head was involved in 52.5% of cases (n=21). The head is the most common region involved by itself or in combination with other regions despite the lesser number of shots fired at it signifies the fatality of a gunshot wound to the head. The chest region by itself was only involved in one case even though it was the most common region that had entry wounds. Chest in combination with other regions was less involved when considering cases individually, which probably points towards the reduced fatality of chest wounds. This is confirmed when considering the causes of death of individual cases where in 50% of cases head injuries alone and in 12.5% of the cases head injuries in combination with other injuries were responsible.

The manner was a homicide in the majority of cases, with only three cases of suicides. This is compatible with other studies from developing countries where guns are used for homicides rather than suicides[18,19,23]. The inverse is true for developed countries[14, 23,24].

There are no articles published analysing the reasons for determining range. Figure 3 is a graphical representation of the reasons that could be considered in the decision-making process when considering the range retrospectively by perusing the reports. This graph includes both shotgun and rifled weapon injuries with varied reasons useful in determining the range that are both unique and common to both types of weapons. This effort was made by the authors to look for any strong objective evidence knowing the subjective variations that may occur in determining the range and to propose better scientific analysis. A similar analysis could not be found in other articles published despite

extensive searches in 'Google Scholar' and 'PubMed' search engines.

As represented by Figure 3 interpreting distance and the type of weapon is not an exact science. It needs expert knowledge and experience to determine the above. As the world is moving forward, information technology is playing an increasingly important role in scientific investigations. Photogrammetry as defined by the American Society of Photogrammetry and Remote Sensing is the "art, science and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring and interpreting imagery and digital representations of energy patterns derived from noncontact sensor system"[24]. The idea of using photogrammetry for assistance in forensic autopsy is not novel. In 1994, Brueschweiler et al. evaluated the photogrammetric method for the documentation of patterned wounds in forensic medicine[26]. During the past two decades, research has established that regions with body hair and reflective moist areas are poorly documented in photogrammetry despite the use of different scanning methods[27]. The authors hold hope that these barriers are not permanent in the face of constantly advancing technology. The idea of using smartphones to create an original database with the 3D reconstruction of the body and interpreted data at autopsies with regards to the type of weapon and range of fire, to be fed to deep learning software, is novel. Deep learning is a type of machine learning that simulates one of the basic human learning methods: learning by example[28]. More examples provided to the deep learning software will lead to more intelligent output of processed data. Ultimately, this deep learning software could give suggestions about the type of weapon and range. Understandably this need not be limited to injuries caused by firearms. This could be used as a recording tool and an assisting tool that adds validation to medico-legal autopsies in the future.

CONCLUSION

The chest and head were the regions involved most in fatal firearm injuries with upper limb injuries occurring in combination may suggest defence injuries. Blackening is the most observed feature used in determining close-range injury. Scientific evaluation of deaths following firearm injuries demands proper assessment of range. Analysis of wound appearance with modern technology will enhance accuracy.

The chest and head were the regions involved most in fatal firearm injuries with upper limb injuries occurring in combination may suggest defence injuries. Blackening is the most observed feature used in determining close-range injury. Scientific evaluation of deaths following firearm injuries demands proper assessment of range. Analysis of wound appearance with modern technology will enhance accuracy.

LIMITATIONS AND RECOMMENDATIONS

The study is limited by the number of autopsy reports analysed and by the convenient sampling method. When further studies are undertaken, the survey method of collecting data, even for a small duration might be more suited for the actual construction of the database suggested.

Another limitation in the analysis process is the subjective analysis used to represent range and reason for determining range. Adding an annexure containing a questionnaire with standard questions to the post-mortem reports of victims of firearm injuries might lead to standardization of reporting of firearm injuries. It will easily provide data needed for the construction of a database with sophisticated analysis. The whole endeavour can be enhanced with the widely available information communication (IT) network and IT literacy in professionals involved in the whole post-mortem process. This is a realistically far-set goal. However, the distance to the goal could be shortened by small steps taken by academics in pioneering change.

ACKNOWLEDGEMENTS

None

CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL ISSUES

The post-mortem reports that were selected for analysis belonged to the investigators and were kept in safe custody. The victim's identity is protected as investigators have not used any personal information that would lead to an identity and only the collective data is used for analysis Thus the study was conducted adhering to fundamental ethical principles including confidentiality.

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None

AUTHOR CONTRIBUTIONS

DNA: Analysis of work; interpretation of data for the work; drafting the work or revising it critically for important intellectual content; final approval of the version to be published. **DPSG:** Analysis of work; interpretation of data for the work; drafting the work or revising it critically for important intellectual

content; final approval of the version to be published. **DLK:** Acquisition and analysis of work; interpretation of data for the work; final approval of the version to be published. **WNSP:** Conception or designing of the work; acquisition of work; interpretation of data for the work; final approval of the version to be published. **PP:** Conception or designing of the work, acquisition of work, interpretation of data for the work; drafting the work or revising it critically for important intellectual content; final approval of the version to be published.

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CASE REPORT

DEATHS DUE TO RABIES IN SHIVAMOGGA, INDIA: CASE SERIES AND REVIEW

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ABSTRACT

Rabies is a fatal disease and deaths due to this have been on the increase. This is due to a lack of awareness leading to failure to obtain proper treatment. We report five cases confirmed to be rabies virus positive, with Negri bodies in their neuronal tissues. Due to a lack of awareness, the individuals are failing to take proper postexposure prophylaxis. The people are avoiding going to health care hospitals as a result of which, after varying incubatory periods the individuals eventually are succumbing to the illness. They are exhibiting characteristic encephalitic symptoms, as a result of this deadly disease. Proper prevention and management, along with awareness among the people can decrease the fatality. Effective programs and continuous surveillance of rabid dogs, to effectively control their population and vaccinate them on a consecutive basis, can combat the virus and stop its spread.

Keywords: *Canine species; Negri bodies; Post-exposure prophylaxis; Rabies encephalitis; India*

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INTRODUCTION

Rabies is a vaccine-preventable viral disease that is occurring worldwide in huge numbers. It affects more than 150 countries in almost all continents except Antarctica, and it is an almost 100% fatal disease once the clinical symptoms appear[1,2]. It is estimated that around 59,000 deaths every year due to this fatal disease have occurred. Children between the age group 5 and 14 years are frequent victims[1]. It is estimated that 90% of human rabies exposure and 99% of human rabies death is due to exposure to rabid dogs[3]. In India, the burden of rabies is not fully known, but it is reported that around 18,000 to 20,000 deaths occur every year, constituting 36% of world rabies deaths[4]. The main objective of this report is to discuss five rabies-confirmed cases in the district and aims to find out the reasons for the sudden increase in rabies deaths.

METHODS

A total of 12,616 cases were subjected to autopsy from the year 2008 to 2023, out of which 5046 cases were subjected to microscopic examination. They were subjected to complete autopsy under special precautionary measures, and specimens of brain preserved in formalin and trigeminal ganglion preserved in viral transport medium (VTM) were sent for neuropathological and neuro-virological examination to the National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore, Karnataka, India. The histopathology of the specimens was done by staining them with haematoxylin-eosin. The autopsy findings were documented along with the detailed history of the cases from the police and relatives of the deceased.

OBSERVATIONS

Case 1
A 71-year-old male with a previous history of dog bite 14 days back, came with symptoms of hydrophobia and aerophobia, after which he expired

within a day of treatment (Table 1). At autopsy, he had multiple old healed scars over his left leg and all the internal organs showed congestion. The brain showed no gross abnormalities except for mild cerebral oedema and tonsillar herniation. Microscopically, there were numerous neuronal intracytoplasmic inclusion bodies (Negri bodies) in the cerebral cortex, cerebellum (Fig 1, 2, 3), and brainstem.

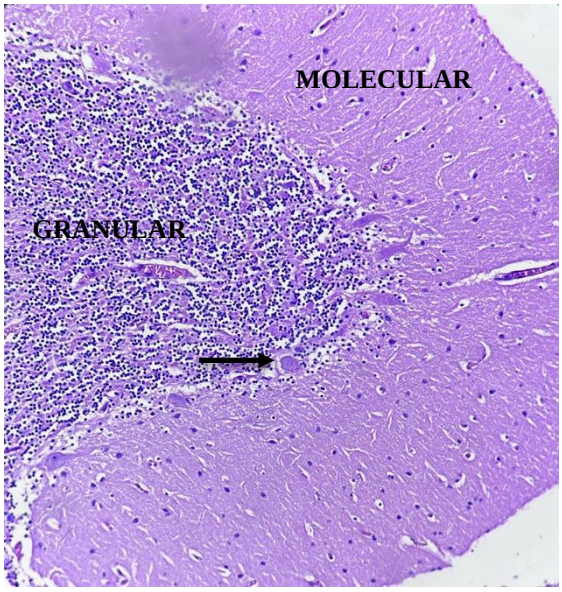

Fig. 1: Negri bodies in the cytoplasm of Purkinje cells of the cerebellum (black arrow) (H&E x10).

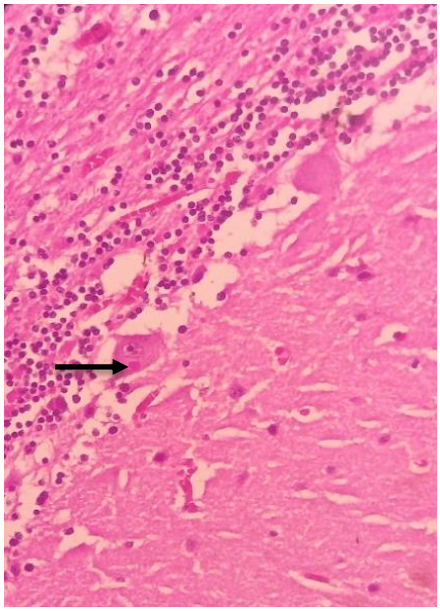

Fig. 2: Negri body inside Purkinje cell (black arrow) (H&E x40).

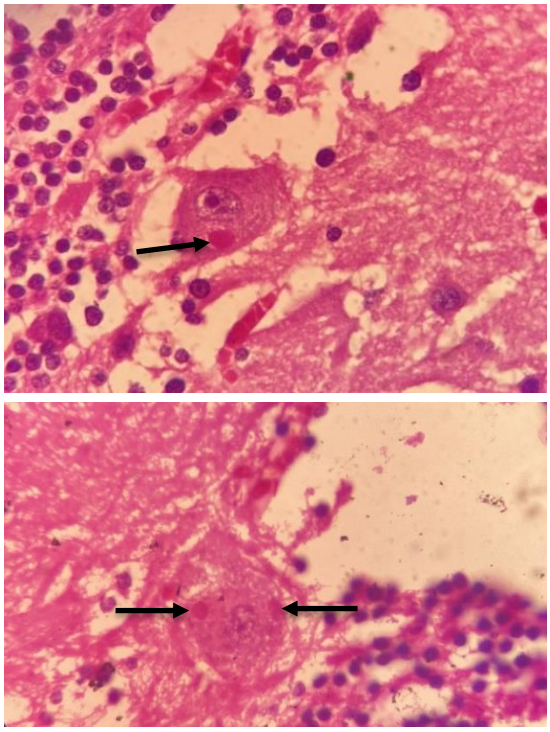

Fig. 3: Negri bodies inside Purkinje cells (black arrow) (H&E x100)

Case 2

A 16-year-old male with a history of dog bite 23 days back succumbed to his illness within one day after developing hydrophobia and aerophobia (Table 1). The brain was intensely congested and oedematous and other organs also showed congestion.

Case 3

A 40-year-old male with complaints of hydrophobia and aerophobia gave a history of dog bite several months back. At autopsy, the brain was deeply congested along with the other organs. Microscopically, there was diffuse cerebral oedema with ischemic changes (Table 1).

Case 4

A 30-year-old male came with complaints of aerophobia and hydrophobia after an alleged history of dog bite to his leg three months back. At autopsy, all the organs were congested (Table 1).

Case 5

A 43-year-old female, alleged to have been bitten by a cat four months back, for which she had taken a tetanus toxoid injection, expired after developing aerophobia. At autopsy, the brain was pale and showed petechial hemorrhages (Table 1).

Table 1: Demographic, clinical details, neuropathology, and neurovirology findings of the patients.

No.	Age in years/ sex	Type of rabies variant/ type of animal	Postexposure prophylaxis given/not given.	Incubation period	Period of survival after clinical symptoms (days)	Neuro-histopathology findings	Neuro-virology findings
1	71/M	En/Dog	Not given	14 days	1 day	Rabies encephalitis with neuronal viral inclusion bodies in the cerebral cortex, cerebellum, and brainstem.	Positive for rabies viral RNA.
2	16/M	En/Dog	Not given	23 days	1 day	Rabies encephalitis with neuronal viral inclusion bodies in the cerebral cortex, cerebellum, and brainstem.	Positive for rabies viral RNA.
3	40/M	En/Dog	Not given	Several months	1 day	Viral inclusions representing Negri bodies of rabies in multiple neuronal zones.	Positive for rabies viral RNA.
4	30/M	En/Dog	Not given	Three months	2 days	Rabies encephalitis with neuronal viral inclusion bodies in the cerebellum.	Positive for rabies viral RNA.
5	43/F	En/Cat	TT alone given	Four months	2 days	Purkinje cells show round to oval eosinophilic intracytoplasmic inclusions (Negri bodies).	Positive for rabies viral RNA.

M: Male; F: Female; En: Encephalitic; RNA: Ribonucleic acid.

DISCUSSION

The age group affected due to this virus was of a wide range in our cases. The animals causing the disease were dogs, and a cat in one of the cases. All the individuals experienced the characteristic symptoms of rabies and had varying incubation periods. The neuropathological and neurovirological findings were suggestive of rabies virus. The varying incubation periods, the causative animals, and the reasons for the sudden increase in this disease will be discussed further. The Rabies virus belongs to the Rhabdovirus family and it has a unique morphology of having a bullet shape. It is an enveloped virus and its nucleocapsid has a helical symmetry. It has two major antigens- Glycoprotein-G and Nucleocapsid[5].The incubation period of this deadly virus is one to three months. In our cases, the incubation period ranged from fourteen days to four months. But rare cases such as less than two weeks or more than one year also have been reported[6]. The virus has two variants- Encephalitic or Furious, which accounts for 80% of Rabies cases, and Paralytic variant, which accounts for 20% of cases. The Encephalitic variant shows characteristic features of autonomic dysfunction and episodes of agitation and aggressive behaviour. The patient develops aerophobia and hydrophobia, as seen commonly in our cases, further substantiating that the rabies virus causes early brainstem dysfunction. The Paralytic variant usually lacks these characteristic symptoms, but they pose challenges for physicians in differentiating them from Guillain-Barre Syndrome, as they show the same pattern of ascending paralysis[6,7,8]. The average survival is five days for the Encephalitic variant and thirteen days for the Paralytic variant[8].

There is even a case known to have an incubation period of 25 years in India, further raising the concern about the virus' erratic incubatory intervals[9]. All cases conducted by us showed a similar pattern of history, wherein none of the individuals took immediate recommended treatment such as post-exposure prophylaxis. Four out of five cases were caused due to dog bites and one case was due to a cat bite. This further concludes that; dogs are not the only reservoirs of this fatal virus and any mammal including foxes serve as carriers/ reservoirs[10].

At autopsy, not many changes were noted grossly except for brain oedema and congestion of all the organs. Microscopically, the characteristic eosinophilic intracytoplasmic inclusion bodies (Negri bodies) were found in the neurons. All the cases showed positivity for rabies viral RNA.

Studies of these Negri bodies have shown that they are most commonly predominant or can be easily found in Purkinje cells, hippocampal pyramidal cells, and brainstem nuclei[8]. They are bodies varying from 2 to 10 µm, and they consist of a mass of nucleocapsids surrounded by viral particles budding from intracytoplasmic membranes[11]. It is further studied that these bodies are usually found in areas devoid of inflammation[12].

The positive diagnosis of rabies seems to pose challenges for physicians, as there are difficulties in diagnosing it antemortem. Post-mortem samples seem to be promising. An audit from a clinical laboratory was taken regarding rabies in India, wherein 128 patients were followed up[7]. Antemortem samples such as cerebrospinal fluid (CSF), serum, saliva, and nuchal skin biopsy were taken. Postmortem brain tissue was taken into the study. Laboratory tests could confirm rabies in 40.6% of suspected cases and postmortem samples gave almost 100% sensitivity and specificity[7].

CT and MRI have shown to be of some importance in the antemortem diagnosis, by looking into the hypodense and ill-defined hyperintensity lesions in various neuronal zones[13]. There are various antemortem laboratory tests available for the diagnosis, however, their limitations are to be taken into consideration, with a focus on their sensitivity and specificity. The tests done are Direct Fluorescent Antibody Test (DFA) on corneal smear (Antigen), DFA on skin biopsy, RT-PCR on saliva for viral nucleic acid, Real-time PCR on saliva for viral nucleic acid, Virus isolation from saliva by Rabies Tissue Culture Infection Test (RTCIT), Antibody detection in serum/CSF by Rapid Fluorescent Focus Inhibition Test (RFFIT)[13]. The postmortem samples subjected to histopathology can be stained with haematoxylin and eosin, Sellers stain, Eosin Methylene Blue stain, or stains based on Methylene Blue along with immune-histochemistry for easier visualization of the Negri bodies[14,15].

The management and prevention of rabies is important to face the fatality of this virus. The Government of India has launched the National Rabies Control Programme (NRCP) for the prevention and control of rabies. The Ministry of Fisheries Animal Husbandry & Dairying and the Ministry of Health & Family Welfare jointly launched 'The National Action Plan For Dog Mediated Rabies Elimination (NAPRE) from India by 2030. The main objectives of the NRCP are to provide rabies vaccine and immunoglobin, training on animal bite management, prevention, and control, strengthen the reporting of animal bite events, and create awareness about rabies prevention. The NAPRE has framed the Animal Birth Control Rules, 2023, to combat the population of stray dogs[16]. The NAPRE has also proposed strategies for the human health component, which includes encouragement of pre-exposure prophylaxis for High-Risk Groups, to formulate protocols for the safety of health workers/professionals exposed to an environment conducive to rabies virus transmission[17].

It has been noted that before the COVID lockdown, cases of rabies reported were nil from our centre. However, we could see a rapid rise in its number which could be due to the COVID-19 lockdown allowing free movement of canines and an increase in the number of cases. A study stated that human rabies cases had resurfaced in countries like Brazil, Bhutan, Lebanon, Afghanistan, Jordan, Philippines, South Africa, Sri Lanka, USA, and India after the lockdown, and it could be due to pet dog abandonment, decreased human–dog contact, and starvation of street dogs during lockdown which further added to the stray dog menace[18].

Compulsory post-exposure prophylaxis and awareness among the public are lacking, especially in rural areas, where they tend to go for home remedies or succumb to superstitious beliefs. The current medicine era is developing at a faster rate, wherein many new treatment methods are being implemented. There is even a case where a 15-year-old girl who was bitten by a bat, was induced into a coma for almost a month as a part of a treatment procedure according to the 'Milwaukee Protocol' in 2004[19].

Hence, appropriate measures need to be taken, to prevent the untoward consequences of this deadly virus. The WHO has devised three interventions for the prevention and management of rabies. The first point talks about the awareness of rabies disease prevention and management among the public and understanding when rabies needs to be suspected and what needs to be done to prevent and take care of oneself. The second point emphasizes the Post-exposure Prophylaxis which consists of a series of rabies vaccines, and appropriate wound management. The third point talks about the mass dog vaccination, in which we can combat the virus at its root source since dogs account for about 99% of rabies exposure[20].

The limitation of our study is that detailed history was lacking and immune-histochemistry methods to demonstrate the viral inclusions could have been present.

CONCLUSION

Rabies deaths have been on the increase recently in India. The only way to overcome these incidents is to bring awareness to the society. They need to be aware of the control, prevention, and first aid measures in case of animal bites. The immediate admission of oneself to the health facility prevents deaths due to this fatal virus. Vigorous post-exposure prophylaxis needs to be given to the patients. Rural health setups need to be more vigilant on these matters, as the rural areas are the most affected by this disease. High-risk groups need to be more careful and stick to protocols of pre-exposure prophylaxis. Antemortem diagnostic methods need to be implemented and health professionals need to be trained on the management protocols. Awareness needs to be created among health professionals because dogs are not the only carriers of the virus and many more animals like cats, foxes, etc also play a role in it. Autopsy surgeons are required to send the appropriate samples for confirmation of these deaths, as it gives 100% sensitivity and specificity. Since the Government gives compensation to the deceased relatives, false claims need to be disproved by scientific methods.

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None

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REVIEW

A JUVENILE HOMICIDE: A CRIMINOLOGICAL SUMMARY OF THE MURDER OF JAMES BULGER

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ABSTRACT

The progenies sometimes commit crimes with extreme cruelty and barbarity and the purview of such crimes is vast. Some children are involved in senseless and brutal killings and such crimes do not show any motive or explanation. The article is an analysis of the murder of James Bulger, who was a toddler and faced a tragic death in 1993. The death of Bulger was not natural but a result of the delinquent mentality of two young children John Venables and Robert Thompson, who were 10 years old at that time. The horrific death of the toddler petrified the world and it was shocking news as it was considered one of the cold-blooded murders in the world. Through the analysis of this case, the author attempts to expound the causes which compel children to commit acts of brutality. A child's upbringing, and bad and ineffective parenting result in emotional instability which prominently drives him/her to commit gruesome murders. The methodology adapted by the author in this paper is qualitative in nature and involves content analysis of secondary sources of law.

Keywords: *Brutality; Crimes; Ineffective Parenting; James Bulger, Juvenile*

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INTRODUCTION

The February 1993, the British were horrified by the murder of a two-year-old toddler named James Bulger. The focal point of the case was the commission of the crime by two juveniles who were 10 years old at the time and the fact that the victim of the ruthless crime was a toddler. The murder was considered a reflection of the moral decay in Britain and one of the most gruesome juvenile homicides in history. It was a 'senseless killing' which did not show any kind of a motive or an explanation. In the view of the US Department of Justice, murders of children and youth are labeled as the ultimate juvenile victimization, which deserved publicity in recent years[1]. The murder of James Bulger attracted the attention of the world and is considered a landmark case in British history. The case has two facets for inquiry, one which is legal and the other, psychological. The terms 'juvenile delinquency' and 'crimes' are seen as legal definitions than behavioral and psychiatric symptoms[2]. The author's objective in this paper is to present a summary of the aspects of juvenile homicide with reference to the murder of James Bulger. In addition to this, the author signifies the concept of 'nurture and nature' influencing the behavior of children.

The methodology of the research is qualitative in nature. The research has taken the form of a literature review.

DISCUSSION

The cold-blooded murder of a toddler

James Bulger was a two-year-old toddler when he wandered away from his mother at a shopping center in Liverpool, United Kingdom. The toddler was missing for a day and his mutilated dead body was found two days after the date of abduction. The

toddler was subjected to a battery and was hit by the train[3]. Doubts arose as to who committed the ruthless act and at first it was imagined that it was a crime committed by an adult. The CCTV footage of the shopping center revealed evidence on the perpetrators where it showed that two boys were taking the toddler out and both were 10-year-old[4]. John Venables and Robert Thompson are considered the youngest children to be convicted of murder in the UK. The case led to a public uproar on juvenile homicide and raised questions on 'what compels children to kill?' and 'what induces a young, innocent person to commit a crime of evil and barbarity?'[5].

Nature or Nurture?

The evil acts of John Venables and Robert Thompson brought forth different questions relating to the reasons for committing such a gruesome murder[5]. The child's upbringing has a direct influence on the emotional instability that pushes him/her to kill. Particularly, the violent surrounding including the lack of financial security has resulted in the deviant behavior of the juveniles[5]. In the simplest sense, there is a difference between 'nature' and 'nurture'[3]. Nurture is considered more influential than nature in the formation of criminal behavior[6]. The family and parents exert a considerable influence on the children[7]. When comparing the incidents faced by the two delinquents, the situation of Robert Thompson was tragic as he was destined to live in a violent environment[3]. He was constantly prey to bullying and violence inflicted by his father. Being the fifth son of a family comprised of seven sons, Thompson spent a life without parental care as his mother was drunk and neglectful[5]. Thompson was constantly tortured and hit by his elder brother. Unlike Thompson, Venables lived in a peaceful family. However, he had a disposition to bully others.

Parenting as a hammer shaping a child's personality

Bad parenting is not a single type of behavior or an action, but it is considered a 'chain of destructive acts', that will affect the well-being of a child in a harmful way[7]. The modes of ineffective parenting include insulting the child in front of others, not providing proper guidance, and lack of communication between the parents and children[7]. In view of the literature on criminology, 'bad parenting is ineffective and a risk factor for unhealthy social development which finally causes the anti-social behavior'[8]. Among the two young children, Robert Thompson witnessed the worst type of parenting in comparison to John Venables. Thompson's parents were not successful. Thompson's father tortured the family, and the child was a constant victim and a witness of physical and sexual violence[3]. Venables' parents were separated but that did not create violence. Venables' mother was a victim of a psychiatric disorder and would have been overwhelmed to conform to the norms of parenting[5].

John Venables and Robert Thompson: Are they psychopaths?

'Psychopathy' is a devastating psychiatric disorder characterized by antisocial traits such as untruthfulness and irresponsibility. Psychopaths also tend to lack feelings of remorse or empathy. It is devastating, not merely due to the severity and association with violence but because it necessitates the use of a wide range of services, namely the prisons, courts, and places promoting mental health[9]. In the view of Robert Hare, psychopaths are 'predators of their own kind', and they use power, manipulation, and violence in controlling others[9]. The injuries inflicted on the toddler Bulger by the ten-year-old boys were harsh. He was abducted, tortured, and murdered. The description of the murder of the toddler creates doubt about whether the criminals are truly psychopaths. Psychopathy is considered to be associated with genetics[3]. However, external environmental factors may cause aggravation of the existing 'medical' condition. John Venables had a history of being violent to younger children. Even though he lived in a positive environment and a privileged situation in comparison to Robert Thompson, it depicts that, there was a manipulation between each other[3].

Application of law and the doctrine of '*doli incapax*'

Justice Harper in R (A Child) V. Whitty (1993) was of the view that *'no civilized society regards children as accountable for their actions to the same extent as adults. The wisdom of protecting young children against the full rigor of the law is beyond argument.*' In the context of England, the age of criminal responsibility is ten years, and children under the age of ten are capable of escaping the prosecution on the ground that, they are too young to comprehend the consequences of the act[5]. The presumption is that a child is incapable of doing wrong or appreciating or understanding the seriousness of the action'[5]. The prosecution must rebut the presumption by proving that, the child knew the fact that the act was seriously wrong and not merely mischievous[5]. In Bulger's murder case, the prosecution dealt with four questions. The four

questions were, on the day of committing the crime, did they know the difference between right and wrong? Did they know that taking the child from the mother was wrong? Did they know that injuring the child is wrong? and did they know that leaving the child on a railway is wrong? All the questions of the prosecution were answered in the affirmative[5]. However, after the conviction, Section 34 of the Crime and Disorder Act 1998 in the UK abolished the rebuttable presumption of doli incapax. However, the current law in England and Wales marks the age of criminal responsibility as 10 years. The children under 10 years are exempted from arrest whereas children between the ages of 10-18 years can be arrested. The approach of law to a case of a child between 10-18 age categories is prominently different from that of a case of an adult.

CONCLUSION

James Bulger's murder was one of the most gruesome and ruthless juvenile homicides reported in the legal history of Britain. The severity of the case was aggravated once it was detected that, the perpetrators were two ten-year-old children namely John Venables and Robert Thompson. The two child perpetrators had abducted the toddler, tortured him with stones, and finally left the toddler's body on a railway line to show that, the death was an accident. The series of events that had taken in the course of the murder proves that they are cruel and remorseless. The commission of crime by a child would probably be the result of genetics and external factors such as the home environment, violence, psychopathy and mental disorders, and bad parenting. 'Nature' is simultaneously decisive in determining the criminal behavior of a person. The genes prominently drive the experiences of an individual. In essence, the 'genes' are considered the basis of human development[10]. However, Thompson's behavior signs that he has inherited some of the traits of family members and there is an influence of genetics. When studying the confrontations of John Venables and Robert Thompson, it was very evident that, both the young perpetrators were more or less victims of social disorganization, violence within the family unit, stress, and ineffective/bad parenting.

The concluding perspective of the paper denotes that, both nature and nurture influence the children in the commission of crime. However, there is a greater inclination of children to absorb negativity by nurture. The nurture of a child is a cogent evidence to impose the liability of a criminal act committed with the knowledge of the nature and consequences of the same. Amidst different interpretations of the legal term '*doli incapax*' in different parts of the world, it can be concluded that it's the reformatory approach and not the rigorous punishment under law suitable for developing a child victimized by social disorganization.

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AUTHOR CONTRIBUTIONS

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REVIEW

EFFECTIVENESS OF FORENSIC MEDICINE PRACTICES: RWANDA FACING SHORTAGE OF FORENSIC PATHOLOGISTS

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ABSTRACT

Forensic pathology has often been disregarded in both Western and non-Western countries, including the African nations. In this article, we highlight the shortage of forensic pathologists in Rwanda and make recommendations to encourage physicians to pursue the subspecialty of forensic pathology. Critically, we analysed issues and challenges related to the inadequate supply of forensic pathologists in the healthcare sector of Rwanda. The authors referred to scientific and legal literature from books, journals, national and international reports, and electronic sources on forensic pathology training and workforce. As a result, authors have identified several reasons for the shortage, including lack of exposure to forensic pathology, absence of a direct path for forensic pathology training, and insufficient funding for fellowships in forensic pathology. It is important to note that there is a global shortage of forensic pathologists, which hinders the effective practice of forensic medicine, including examinations and assessments of various types of deaths and incidents. This ultimately affects the administration of justice. However, it is hopeful that Rwanda's efforts in the field of forensic medicine will have a positive influence on other African nations in the coming years.

Keywords: *Forensic Medicine; Forensic Pathologist; Forensic Practice; Medical Education; Rwanda*

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INTRODUCTION

Following the 1994 Genocide against the Tutsi, Rwanda continues to face numerous challenges in the areas of economy, education, and health as well as other socio-cultural aspects. Currently, initiatives in the field of forensic sciences primarily focus on equipping young scientists and medical doctors with foundational skills in all forensic sciences. This will enable them to provide basic medico-legal opinions whenever required in courts of law. Forensic pathologists have the responsibility of investigating deaths that may involve possible terrorism, biohazards, emerging infectious diseases resulting in unexplained death, mass fatality incidents, disaster-related deaths, and other types of deaths that could pose national security, public health, or public safety concerns[1,2].

The Republic of Rwanda is a landlocked nation in Central Africa, sharing borders with Uganda to the north, Tanzania to the east, Burundi to the south, and the Democratic Republic of Congo to the west[3,4]. Rwanda is home to over 12.6 million people live in Rwanda, covering an area of 26,338 square kilometres, resulting in a population density of 445 individuals per square kilometer[3]. Due to its high

elevation, Rwanda is often referred to as the "land of a thousand hills", and its landscape features mountains and savannah. Additionally, the country is blessed with numerous lakes. Rwanda has received international recognition for its progress towards universal health coverage[5]. Through the mutuelle de santé, more than 84% of Rwandans insured through the mutuelle de santé have access to primary healthcare services[6]. The healthcare system in Rwanda is highly decentralized and efficiently operated, comprising 1700 health posts, 500 health centers, 42 district hospitals, and 5 national referral hospitals. Moreover, Rwanda boasts a thriving private healthcare sector, which includes two preferred hospitals, eye hospitals, 50 clinics and polyclinics, eight dental clinics, four eye clinics, and 134 dispensaries[7]. However, like many other countries around the world, Rwanda also faces a significant shortage of board-certified forensic pathologists or those with equal qualifications[8-0].

This article delves into the causes behind the shortage of forensic pathologists in Rwanda and presents suggestions for addressing this issue. Firstly, despite the presence of three medical schools in Rwanda—namely, the University of Rwanda School of Medicine, the University of Global Health Equity, and the Adventist School of Medicine of East-Central Africa[11], there are currently no accredited training programs for forensic medicine. As a result, medical students do not have a direct pathway to pursue forensic pathology training. Additionally, the medical school curriculum in Rwanda offers limited exposure to forensic pathology, leaving most students with little to no knowledge in this field. Moreover, the absence of mentors in forensic medicine further compounds the negative experience of forensic autopsy during pathology training[12].

The lack of exposure to forensic pathology during medical school and basic pathology training, or the negative experiences encountered during such exposure, creates a situation where students and residents do not recognize forensic medicine as a worthwhile pursuit[13]. This limited exposure to pathology may subsequently result in fewer medical students selecting pathology as their chosen residency speciality, which is a prerequisite for pursuing a career in forensic pathology[8]. Another issue is the absence of funding from the Ministry of Health for forensic pathology fellowship. Currently, in Rwanda, there are no incentives in place to encourage medical students to pursue a career in forensic pathology, nor are there any specific loan forgiveness programs related to the field of forensic medicine. Importantly, by identifying the reasons behind the shortage of forensic pathologists and implementing the recommendations outlined in this study, the government of Rwanda can enhance medico-legal death investigations by increasing the number of trained forensic pathologists and promoting research in this field.

MATERIALS AND METHODS

The methodology utilized in this present article is purely doctrinal. The authors extensively relied on scientific and legal literature from books, journals, national and international reports, and Google Scholar, to gather information regarding forensic medicine training and workforce. The primary objective of this article is to conduct a critical analysis, shedding light on the issues and challenges related to the shortage of forensic pathologists in the Rwandan healthcare sector. The ultimate goal is to improve the effectiveness of the criminal justice system, as the lack of experts proficient in the examination of deceased individuals poses a significant hurdle in delivering justice in murder cases in today's society.

Medico-Legal Death Investigation of Rwanda

The primary objective of the Forensic Medicine division goes beyond the conventional applications of scientific methods in assisting criminal law enforcement. Forensic medicine concerns the application of scientific medical knowledge to the administration of law, the advancement of justice, and the legal relations of the medical practitioner. Practitioners of this branch of medicine assist the law in assessing the liability of medical practitioners in issues such as consent to treatment, therapeutic intervention, and post-death phenomena.

In Rwanda, until a few years ago, forensic medicine was not considered one of the typical medical specialities a doctor would pursue as a career, and the use of autopsies for medico-legal purposes was uncommon. It was only less than ten years ago that a forensic medicine specialist at the Rwanda Forensic Laboratory started performing autopsies.

A forensic pathologist, a trained medical doctor, plays a crucial role in conducting post-mortem examinations to determine the cause of death. These experts in forensic medicine are specifically tasked with investigating deaths that may have broader implications for the public. As part of their educational journey, undergraduate students in the medical faculty and aspiring forensic pathologists

pursuing diploma, master's, and doctoral degrees in forensic medicine undergo comprehensive coursework in this specialized field[14]. However, the education and training in forensic medicine in Rwanda are currently lacking, and there is an absence of qualified or adequately trained forensic pathologists. Rwanda faces a severe shortage of skilled forensic medical examiners.

Rwanda currently boasts an efficient decentralized healthcare public service system, comprising 1700 health posts, 500 health institutions, 42 district hospitals, and 5 national referral hospitals[15]. However, it is unfortunate that there are no forensic medicine centers affiliated with the Ministry of Health (MOH), leading to a lack of accessible, high-quality forensic medicine services across the country.

The roles and responsibilities of forensic pathologists vary across different countries. In some nations, these examiners visit death scenes, perform autopsies, and conduct histopathological examinations. However, in other countries like the Kingdom of Saudi Arabia, forensic medical examiners are involved in preliminary examinations at crime scenes in collaboration with investigative authorities. They conduct external examinations, and autopsies, collect samples for toxicology screening and histopathological examinations, and prepare medico-legal reports for relevant authorities such as the general prosecutor, court, director of health affairs, or higher MOH committees. Additionally, in cases of sexual assault or injuries, forensic medical examiners conduct clinical forensic medical examinations on living individuals with authorization from law enforcement officials[17].

While Rwanda has seen an increase in the utilization of autopsies for medico-legal purposes, government medical officers in the country still lack advanced training in this area. Furthermore, Rwanda currently does not have a specific forensic science act that mandates autopsies to be performed by trained forensic medical experts. As a result, the responsibilities typically assigned to forensic pathologists in Rwanda are carried out by anatomical pathology specialists and non-pathology medical doctors.

While Rwanda's medico-legal death investigation system strives to uphold justice and ensure accurate determination of deaths, it is imperative to shed light on the challenges and shortcomings that exist within the system. Comparisons with other systems worldwide further highlight areas where improvements can be made.

One of the significant hurdles faced by Rwanda's medico-legal death investigation system is the scarcity of resources. Limited funding and inadequate infrastructure hamper the efficiency and effectiveness of investigations. Insufficient equipment, outdated forensic technologies, and a shortage of trained personnel hinder the system's ability to carry out thorough examinations and analyses.

Another critical aspect that negatively impacts the system is the shortage of skilled forensic professionals. Insufficient training opportunities and a lack of specialized education programs limit the expertise of forensic pathologists, anthropologists, and toxicologists. This deficiency in knowledge and skills can lead to errors in the determination of cause and manner of death, potentially compromising the integrity of the investigations.

Rwanda's medico-legal death investigation system faces challenges in maintaining standardized procedures across different regions or districts. Inconsistent protocols and varying levels of expertise among investigators can result in discrepancies in the quality and reliability of investigations. This lack of uniformity undermines the credibility and fairness of the system.

Cultural and social factors can impede the effectiveness of the system in Rwanda. Traditional beliefs and practices may clash with scientific methodologies, leading to difficulties in obtaining consent for autopsies or other necessary procedures. Additionally, societal stigmas, fear, and intimidation can deter witnesses from coming forward, hindering the gathering of crucial evidence.

The lack of awareness among the general public about the importance of medico-legal death investigations poses a significant challenge. Limited understanding of the system's role and processes can result in misconceptions, mistrust, and reluctance to cooperate. Encouraging public education and engagement is crucial for fostering trust and cooperation in the investigations.

Medico-legal death investigation systems vary across countries due to variations in legal frameworks, available resources, and cultural contexts. For instance: a) United States: In the U.S., the system operates at both state and federal levels, with forensic pathologists playing a crucial role in death investigations. b) United Kingdom: The UK

employs a coroner-based system, wherein coroners oversee investigations into sudden, unexpected, or suspicious deaths. c) Australia: Australia has a decentralized system, with each state and territory having its own medico-legal death investigation processes.

Rwanda's medico-legal death investigation system combines traditional practices with modern forensic methodologies, emphasizing collaboration and holistic approaches. While variations exist globally, the ultimate goal remains the same: to ensure accurate determination of the cause, manner, and circumstances surrounding deaths for justice and public safety. Increased investment in resources, enhanced training programs, standardized procedures, and public awareness campaigns are necessary steps toward improving the system's efficacy and ensuring justice for all.

Literature concerning the shortage and need for more forensic pathologists

The outcomes of medico-legal death investigations can have profound implications for the safety and well-being of vulnerable populations and society as a whole. Within the legal system, forensic physicians play a crucial role, intersecting with the law more than any other branch of medicine[17]. Even though forensic pathology in crime investigations in recent years[18], many professionals in the criminal justice field remain unfamiliar with the term[8,13.] The shortage of forensic pathologists significantly impacts various types of cases, including suicide, child deaths, maternity and domestic abuse deaths, work and product safety deaths, new illnesses, and natural disasters. Resolving the substantial workforce shortage in the field of forensic medicine[19] is essential to ensure effective investigations within the medico-legal system.

However, in the real world, the forensic team at a hospital performs painstaking labour that is anything but glamorous to determine how and why death happens. Forensic science may appear to be an exciting vocation in literature and on television[20]. However, a global scarcity of forensic pathologists exists. The paucity of fresh forensic pathologists continues to be a severe global concern, according to research studies on medical education. The demand for forensic pathologists is rising in tandem with the prevalence of new diseases and criminality [0,13.] There are not enough board-certified forensic pathologists in the US and Canada at the moment to meet the country's needs. Additionally, forensic pathologists who are currently in practice in Canada, particularly in Ontario, are overworked due to the severe lack of these professionals[21]. The forensics center for the province, the Saint John Regional Hospital, is run by forensic pathologist Dr. Ken Obenson, who also supervises autopsy services there. Dr. Ken Obenson says there is a shortage of trained forensic pathologists in Canada. According to him, Canada only has a small number of 30 to 40 trained certified forensic pathologists because it takes so many years (Four years of undergrad, four years of medical school, five years of residency, and one year of sub-speciality training, so it's quite long) to obtain the necessary credentials. Therefore, some people would be deterred from pursuing a career in the industry[22].

Medical examiners are in low supply in the United States. Like everything else, the COVID-19 pandemic has just made this long-standing issue worse. The opioid problem has contributed significantly to the nationwide increase in mortality before the pandemic. The president of the National Association of Medical Examiners at the time, Dr. Brian Peterson, told The New York Times in October 2017 that the crisis had resulted in staff burnout, financial issues, and accreditation threats because many offices had to conduct more autopsies than were permitted by industry standards. Unfortunately, things didn't get any better as time went on. Another New York Times piece, titled "Piled Bodies, Overflowing Morgues: Inside America's Autopsy Crisis," reaffirmed this on February 25, 2020. Peterson once again expresses his worries, this time giving readers a graphic view inside America's overcrowded morgues and observing that there aren't many remedies to the issue[23].

In the United States, even though forensic pathologists operate as medical examiners in medical examiner and coroner agencies, there are still not enough forensic pathologists to serve the entire country, according to numerous published reports, testimonials, research studies, and data gathered[0]. In fact, despite there being approximately 2000 coroner offices and 400 medical examiner offices in the United States, only about half of the population is served by a medical examiner[24]. Shockingly, less than 500 forensic pathologists are working in the United States, which is not sufficient to handle even half of the annual deaths that require autopsies, as warned by the National Research Council eleven years ago[20]. This means that one forensic pathologist is responsible for serving at least 5 coroner offices. Due to this shortage, autopsies may not be conducted on time or within the local area. The scarcity of future

forensic pathologists is not limited to the United States but is a critical issue worldwide[9,24].

After 1960, autopsies performed for medical and legal reasons in Nepal started to become popular. In Nepal, three aspects of forensic sciences are practised in forensic medicine: forensic pathology (autopsy), clinical forensic examination (examination of sexual assault victims and perpetrators, victims of injury and torture, age estimation, mental status examination, drunkenness examination),[15] and forensic anthropology (examination of human skeletal remains). However, it is important to note that while it excludes histological examination, it includes the additional work of clinical forensic examination and forensic anthropology, making it a condensed type of forensic pathology. Unfortunately, the medico-legal investigative system in Nepal falls significantly behind that of developed countries. Doctors performing medico-legal and post-mortem work at local level hospitals are frequently unskilled in this delicate task. Medico-legal work in Nepal is primarily performed by medical officers, the majority of whom lack forensic qualifications. Additionally, the lack of a centrally designated unit or department is one of the reasons why the medico-legal sector in Nepal has not developed as much as it could[25]. In cases of unnatural deaths, a police inquest is held[26], after which the body is subjected to a medico-legal autopsy at the nearest government hospital[27]. It is concerning to note that there are currently less than 50 forensic medicine experts practising in a country with a population of approximately 30 million people[27]. Furthermore, there is a lack of adequate equipment in forensic science labs in Nepal.

A shortage of forensic pathologists in Africa is having a significant impact on the efficiency of death investigation systems. In the Eastern African region, where Rwanda is located, the current state of medico-legal services in Uganda is being discussed, with a particular focus on forensic pathology and plans for improvement to ensure the delivery of high-quality services. In Uganda, these services are provided partly by pathologists attached to universities, medical officers employed by the police, and medical officers attached to hospitals[28].

Similarly, in Burundi, there have been numerous recorded murder cases in recent years, and some perpetrators have been apprehended[29,30]. However, many of these crimes remain unsolved due to a lack of evidence that can be used to charge the offenders. Unlike Uganda, Burundi does not employ any forensic science methods in criminal investigations of murder. Instead, investigations rely solely on traditional methods of testimony. While some forensic methodologies are employed in Uganda, the police officers responsible for conducting criminal investigations often lack the necessary training and technical competence to effectively analyse and interpret the various pieces of evidence obtained at crime scenes[29].

In Kenya, forensic pathology is managed by the government under the Ministry of Health. However, the National Public Health Laboratory in Kenya faces a shortage of forensic pathologists, with only four capable of covering the entire country. Consequently, the state of forensic investigation in Kenya is severely lacking. The field has not yet reached its full potential due to issues such as inadequate infrastructure and tools, a lack of standardized procedures, a lack of policies governing forensic investigation, and a shortage of specialized experts to handle crime scenes. Furthermore, there are no international credentials or qualifying procedures for forensic pathologists practicing in the country[30-33].

The main difficulty faced by Tanzania's forensic science services is the lack of access to its own accreditation services, which would assist forensic units in meeting both local and international accreditation criteria. There is a shortage of expertise in forensic fields, such as forensic pathology [33,34], in Tanzania. Additionally, forensic science has been used only in cases involving more serious crimes rather than in minor events, as noted by Jilala and Lwoga. This limited usage has made the profession less visible to the general public and its services accessible to only a small number of people.

Suggested recommendations on how to increase the availability of forensic pathologists in health faculties

In research conducted in the USA, recommendations were made to boost the supply of forensic pathologists in the country. To encourage young doctors to pursue forensic medicine as a solid career in our setting, we may need to adopt certain measures. One key measure is to make the specialization of forensic medicine and death investigation more prominent in the pathology residency curriculum at medical schools[34]. The Higher Education Council (HEC), medical universities, and the Ministry of Health, through the National Strategy for Health Professions Development (NSHPD), should collaborate to develop a comprehensive course on forensic pathology and medicolegal death investigation. This course, as

detailed by the Scientific Working Group on Medico-legal Death Investigation (SWGMDI)[35], would cover various important topics such as obtaining permission for hospital autopsies, reporting cases to the medico-legal death investigation systems, understanding the death certificate and how to complete it accurately, the training path required for anatomic pathology and subsequent specialization in forensic pathology, and the different types of job opportunities available to forensic pathologists[34,35]. The Ministry of Health and the HEC, through the NSHPD, could play a crucial role in supporting the development and widespread implementation of this course. It is not enough for the HEC to merely endorse this project; they should also mandate medical schools to include this course in their curricula. Furthermore, to further promote the field of forensic pathology, the Ministry of Health, university teaching hospitals, and medical universities should collaborate on establishing a forensic pathology mentoring program for medical students. This program could introduce students to the exciting field of forensic pathology and encourage them to pursue it as a career option[33]. One potential component of such a program could involve medical students using intriguing forensic pathology cases as the basis for writing case reports, which could be presented or published[33,34]. By implementing these recommendations, we can aim to address the shortage of forensic pathologists and ensure a strong pipeline of professionals in this field.

In Rwanda, new medical schools are opening to increase the production of primary care physicians who can serve areas in need. As detailed by SWGMDI[35], these schools could also place an emphasis on forensic pathology to cultivate the production of forensic pathologists to serve areas in need. Additionally, efforts to recruit students into medical schools, pathology, and forensic pathology should begin at the undergraduate level. Strategies should be developed to specifically target college students in a way that will pique their interest in the medical field and foster an early passion for pursuing forensic pathology as a career.

In pathology residency programs, there is a need to improve and promote autopsy, forensic pathology, and death investigation exposure. This will help establish forensic pathology as a legitimate medical and academic career[33- 35]. Medical schools and university teaching hospitals should request that anatomic pathology training programs provide opportunities for exposure to forensic pathology. Moreover, pathology residency programs should ensure that their residents spend at least 1 or 2 years[36], in a forensic pathology fellowship after completing their training in anatomical pathology, clinical pathology, or forensic medicine. This will enable them to gain the necessary expertise and experience to become certified forensic pathologists in Rwanda Forensic Laboratory, Department of Legal Medicine, and assist forensic pathologists in conducting medico-legal autopsies. The Legal Medicine department should consider providing a stipend to pathologists for their services, even if they are not regular members of the department. Furthermore, the Legal Medicine department should ensure that the pathologists assigned the responsibility of supervising the autopsy service possess the requisite autopsy skills and a genuine interest in autopsy performance and reporting. By addressing these areas, we can strive to strengthen the field of forensic pathology in Rwanda and meet the growing demand for qualified professionals.

Ministry of Health (MOH) and HEC need to encourage faculty to support residents who are considering a career in forensic pathology. The RMDC needs to enforce its requirement for meaningful exposure to forensic pathology during pathology residency. Without these rotations, pathology residencies would not be able to function properly, and it is crucial for the MOH to recognize this and provide appropriate support to the forensic pathology service and faculty. Recently, the establishment of the National Association of Forensic Pathology has become necessary to address some of these issues.

Financial incentives must be provided to attract medical students and pathology residents to pursue a career in forensic medicine[34,35]. The Higher Education Council (HEC), in collaboration with the medical schools in Rwanda, should develop a medical school loan forgiveness program specifically for medical students entering the field of forensic pathology. Loans should be deferred for a significant period following the completion of forensic pathology training, and if the student continues to practice forensic pathology, their loan should be forgiven. The HEC, university teaching hospitals, and medical schools should seek national support for this program, potentially through proposed legislation related to the forensic sciences. Additionally, it would be beneficial to make more affordable loans available alongside any loan forgiveness programs.

Wages for forensic pathologists must be brought up to par with other medical professions with similar educational education qualifications[34,35]**.** The MOH, in collaboration with the National Public Prosecution Authority (NPPA), should establish relationships and

liaise with the Ministry of Justice (MINJUST) to educate them about the crucial roles played by forensic pathologists and medico-legal death investigation systems in areas such as public health, vital statistics, criminal justice, civil courts, public safety, homeland security, the medical profession, and the wide range of state and national agencies and programs that rely on information generated through death investigations. Simultaneously, it is important to educate these organizations about the challenges in recruiting forensic pathologists into the field, one of the major factors being the relatively low salaries for individuals with medical degrees and advanced postgraduate training. By addressing these aspects, we can work towards strengthening the field of forensic pathology and ensuring its attractiveness as a career option in Rwanda. The numerous national agencies that rely on death investigation information, including hospitals, Rwanda Biomedical Centre (RBC), and Rwanda Forensic Laboratory (RFL), should collectively develop a comprehensive plan to assist states and local jurisdictions in funding their forensic pathology positions. For example, RFL could shift some funding and support away from novel research and towards the practical aspects of forensic pathology practice, which could facilitate research. Rwanda Forensic Laboratory and hospitals should strengthen relationships with medical schools to offer stipends and other benefits to forensic pathologists involved in pathology resident training. The HEC, university teaching hospitals, and graduate medical schools should work together to ensure that funding for forensic pathologist positions in forensic pathology training programs includes salaries that will attract well-qualified individuals with teaching skills. Finally, as described by SWGMDI [35], forensic pathology fellowships should not be tied to the postgraduate year level. Instead, salaries should be increased to attract pathology residents into the field. The state should provide stipends that could augment fellow salary funding provided by medical schools, with strings attached to the funding to keep the fellow in forensic pathology practice, perhaps even within the state that provided the funding directly or with state assistance.

Medical universities should develop forensic pathology-cantered initiatives to attract students[12,23]. In medical schools, there is a lack of pathology training programs, forensic pathology training programs, and an adequate number of fully qualified forensic pathologists working in the universities[38]. As detailed by SWGMDI, these universities should develop an incentive program to attract forensic pathologists to the institution[35]. For example, the state could provide scholarships to individuals who wish to study forensic pathology subspecialty in medical school. Currently, students who want to train in forensic pathology (Forensic Medicine) would have to leave the country to do so. Efforts to improve and modernize the physical facilities in hospitals for medicolegal death investigations may also assist in recruiting forensic pathologists and encouraging their long-term employment[6]. Another option could be to implement a system similar to primary care practice, with special considerations and incentives to attract physicians to underserved areas[35].

The number of forensic pathology training programs, as well as the number of sponsored forensic pathology fellowship posts, need to be raised[33,34]. The lack of forensic pathology training programs should be addressed by providing government incentive funds to develop new programs. Existing medical colleges and universities should be encouraged to train forensic pathology talents and job transfer training should be implemented to involve medical personnel in forensic work. International cooperation can also be utilized to expand the number of forensic teachers in Rwanda and train more forensic reserve talents.

Pathology training schools must actively inform their students about the forensic pathology profession[32,35]. Program directors should ensure that their interviews of potential trainees thoroughly evaluate the candidate's intent to practice forensic pathology and to what extent. This is crucial since there is currently a shortage of forensic pathologists and a lack of available training positions. The Higher Education Council (HEC) should establish requirements for training programs in forensic pathology that better reflect the unique aspects of the field. The HEC needs to understand that forensic pathology requires distinct qualities and that the patient-care-focused requirements may not be directly applicable. Training should primarily focus on learning forensic pathology subject matter and developing the skills necessary for conducting medico-legal post-mortem examinations and investigations. During the training years, direct observation and supervision should allow supervisors to determine the trainees' capability for independent practice.

Medical schools and pathology departments in hospitals should have more formal links with the Rwanda Investigation Bureau (RIB). These institutions should provide support services to forensic pathologists, such as consultations with experts, peer support, research assistance, and specialized laboratory and diagnostic services.

Academic collaborations can enhance the professionalism and professional development of forensic pathologists. The government should prepare a document that addresses the relationships between pathology departments and RIB, including recommendations regarding death investigations and other relevant factors. Spencer et al.[9] suggested that while formal relationships with medical schools and pathology departments are beneficial for supporting forensic pathology practice, it is important to consider revising the training path for forensic pathologists and exploring alternative models.

New funding methods for death investigation systems must be developed[35,38]. As an example of novel funding mechanisms, the NPPA and RIB should collaborate with medical care funding sources and hospitals to ensure that hospitals whose patients undergo autopsies by the medico-legal death investigation system provide funding to support these services. Insurance companies should also contribute financially to the medico-legal death investigation system, as it is in their best interest to have autopsies conducted in quality settings by qualified personnel[8,9]. However, these measures alone are insufficient and do not align with international standards for evidence-based medico-legal practice. For instance, medico-legal autopsies primarily conducted in peripheral district hospitals are performed by young non-specialist medical officers who have only received a theoretical 3-credit forensic and legal medicine course during their undergraduate medical studies at the University of Rwanda Medical School. Even in the more specialized RFL located in the capital city of Kigali, medico-legal autopsies are performed by an anatomical-pathology expert who is not board-certified in forensic pathology. This poses challenges whenever the delivery of medico-legal expertise is required in courts of law. Moreover, without the necessary skills to respond to catastrophes, disasters, migration, or other situations of violence, the deceased are not managed in a dignified manner, which creates difficulties for their families seeking clarity about the fate of their loved ones. Equipping these medical officers with basic skills is thus an essential starting point to enable them to respond effectively to these challenges. The shortage of forensic pathologists at the national, regional, and global levels should be acknowledged[0,12], to encourage government authorities and legislators to take action and provide adequate funding and support to address this problem.

CONCLUSIONS

In conclusion, this article has examined the shortage of forensic pathologists, provided background information on the problem, and proposed suggestions that could help increase the number of forensic pathologists available in healthcare facilities in Rwanda, the region of East Africa, and around the world. The next research will assess the historical progression of forensic medicine in Rwanda and the need for further advancements.

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The Authors declare that there is no conflict of interest.

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REVIEW

THE PERPLEXITIES OF E-DISCOVERY IN THE INDIAN HEALTHCARE SYSTEM - A NARRATIVE REVIEW

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ABSTRACT

With the rapid advances in medical technology and the digitization of healthcare systems, the importance of collecting and analyzing digital evidence in the medical field has grown significantly. This evidence plays a crucial role in investigating medical malpractice cases and preparing for legal proceedings in India. As medical devices and electronic health records become more prevalent, vast amounts of data are generated, stored, and accessed. While having substantial evidence to support medical claims is beneficial, it is essential to find a balance between retrieving and admitting digital evidence while respecting patient privacy. This article examines the use of electronic evidence in Indian medical litigation, the challenges it presents, and the initiatives taken to manage these challenges. However, the absence of clear legal guidelines on electronic discovery in medical cases exacerbates the problem. Medical procedure rules often fail to address electronic discovery, resulting in inconsistent case law across different courts in India and the world. Consequently, healthcare practitioners are left to develop ad hoc solutions through informal discussions and negotiations. Thus, this paper highlights the necessity for a comprehensive legal framework and active judicial management to handle electronic discovery in the medical domain.

Keywords: *Digital healthcare; Medical malpractice; Medical technology; Patient privacy*

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INTRODUCTION

In the vast realm of healthcare, the pursuit of truth is both a moral obligation and a legal necessity. Enter e-discovery, revolutionizing information retrieval in litigation. Within this digital labyrinth, complexities challenge those navigating its corridors.

Imagine a medical malpractice lawsuit against a prestigious hospital. The plaintiff believes critical electronic evidence lies concealed within the hospital's network. Patient records and internal communications could hold the key. However, attorneys face a maze of complexities that could make or break their case[1].

The field of e-discovery in healthcare is rife with legal dichotomies. One such dilemma revolves around the admissibility of printouts of computer data as evidence, which poses challenges when converting dynamic electronic medical records into static documents[2]. Metadata-related concerns and the presence of pop-up warnings in electronic medical record systems also contribute to the legal dichotomies, requiring careful navigation to ensure accurate and relevant information is obtained. Balancing the preservation of record integrity with admissibility as evidence remains a constant challenge in this intricate landscape[3].

The process of e-discovery in the healthcare industry encompasses various stages, including identification, preservation, collection, processing, evaluation, and production of electronic information relevant to a legal dispute. While the concept of discovery is not novel, the proliferation of digital communication channels and the advent of electronic records have

significantly amplified the volume and intricacy of data that necessitates examination.

In an era of technological progress, one might assume that deciphering the enigmas concealed within the digital realm would be a straightforward endeavor. However, the reality proves to be much more intricate. Vast quantities of data, often dispersed across disparate systems, demand the expertise of proficient professionals armed with cutting-edge tools to meticulously reconstruct the evidential jigsaw puzzle. The challenges are manifold, encompassing concerns regarding data security, privacy, technical acumen, and the ability to distill actionable insights from a vast expanse of digital clutter.

Exclusion Criteria:

- **Irrelevance:** Sources that did not directly discuss e-discovery challenges within the Indian healthcare context were excluded.
- **Non-English sources:** Given the limitations of language comprehension, sources in languages other than English were excluded.
- **Publication date:** In alignment to present contemporary insights, sources published before a predetermined date (before January 2000) were excluded.
- **Duplicates:** Instances of multiple iterations of the same study were omitted to maintain clarity and avoid repetition.

The review's comprehensive search strategy encompassed prominent academic databases such as PubMed, IEEE Xplore, and Google Scholar. Strategic keyword combinations, including "e-discovery," "electronic evidence," "medical litigation," "healthcare technology," and "Indian healthcare system," were employed to pinpoint relevant sources.

The selection process underwent a two-stage screening. Initial screening involved evaluating titles and abstracts to gauge relevance based on the predefined criteria. Full-text articles were subsequently obtained for sources that met the preliminary screening requirements. These full-text articles were subjected to a thorough review to ascertain their alignment with the inclusion criteria and their potential contribution to the narrative review. The data extraction process involved meticulous retrieval of pertinent information from the selected sources. Key findings, challenges, initiatives, legal framework gaps, and other relevant insights were systematically organized. This extracted data was then synthesized thematically to identify recurring trends and challenges specific to the Indian healthcare context.

As with any research endeavor, the review acknowledges certain limitations. The potential for bias due to source selection and the absence of quantitative analysis were noted. Moreover, the scope was confined to sources within a specified timeframe and published in English. The dynamic nature of healthcare technology also poses the challenge of rapidly evolving information.

CHALLENGES WITH VARIED FORMATS

In the realm of legal proceedings, the transition from paper medical records to electronic medical records (EMRs) has given rise to various intricate challenges. Within the context of an Indian legal research paper, it is essential to explore how these challenges manifest and affect the production of EMRs for lawyers[4].

One significant predicament revolves around the presence of multiple EMR systems within a healthcare facility, each catering to different departments or specific purposes. The lack of standardization among these systems results in diverse data formats and variations in information presentation[5]. Consequently, healthcare providers must grapple with the question of how to compile an EMR that effectively consolidates data from these disparate systems.

Another issue pertains to the inclusion of metadata in the produced EMRs. For instance, EMR systems frequently display warnings regarding potential negative interactions between prescribed medications[6,7]. Determining the extent to which such warnings should be incorporated in the EMR poses a considerable challenge.

Furthermore, healthcare providers must address the dynamic nature of EMRs while adhering to the discovery rules prohibiting evidence tampering. As new patient information is continually added, EMRs undergo constant changes. Healthcare providers must find ways to navigate this evolving landscape without running afoul of the rules governing the handling of evidence. The functionality of copy and paste in EMRs presents another noteworthy concern. Healthcare providers must establish robust protocols to mitigate the risks associated with inaccurate or incomplete information resulting from the indiscriminate use of this feature.

Resolving these challenges within the Indian legal framework requires careful consideration. EMRs lack standardization not only in terms of the software

systems used but also in relation to the specialization of medical professionals. In India, there exists a plethora of EMR programs, each designed to cater to specific medical care providers. Government institutions and those within the Armed Forces may even employ their own bespoke systems based on Linux. Moreover, different departments and personnel within healthcare systems may utilize distinct versions of the same EMR system, tailored to their respective fields, or even entirely separate systems[8]. This results in discrepancies in the display of medical information for the same patient, depending on the interface used by nurses, doctors, or other healthcare professionals. Additionally, the persistence of mixed paper and electronic record systems necessitates the consolidation of data from various sources to construct a comprehensive EMR.

METADATA RELATED CONCERNS

In the context of legal proceedings in India, metadata assumes a pivotal role as it encompasses information concerning the characteristics, origins, usage, and validity of electronic evidence. From a legal perspective, it is important to recognize that metadata is not a static entity and can undergo modifications over time as a result of the software and operating system functions, even without human intervention. In this regard, there are two primary categories of metadata: application metadata and system metadata.

Application metadata is typically embedded within the file it pertains to and remains associated with the file throughout the process of copying or transferring. An illustrative example of application metadata can be observed in Microsoft Word documents. By default, Word documents contain metadata such as the name of the author, computer name, last save time, creation date, and the name of the creator's company. This information is automatically generated and updated in real time within the document.

Conversely, system metadata is stored in a separate file within the computer system and serves the purpose of tracking the location of files and providing details about each file. It encompasses information such as the file's name, size, creation date, modification history, and usage. As the data within a computer system undergoes changes, the system metadata dynamically adapts accordingly to reflect the current state of the file.

Nevertheless, it is crucial to acknowledge the practical limitations associated with producing metadata, especially in the context of traditional paper-based formats for electronic medical records. Not all forms of metadata are easily translatable into a printed format, and attempting to reproduce the entire set of metadata for an entire electronic medical record in paper form would be impractical and pose challenges for legal professionals to comprehend. Therefore, in such situations, it is advisable to generate and present only the relevant metadata that can be effectively reproduced on paper. This may encompass elements such as audit trails, pop-ups, preliminary questions, and checkboxes that constitute a finalized doctor's note, which are amenable to reproduction in a printed format.

1. Ensuring Authenticity and Accuracy of Electronic Medical Records

The production of an audit trail, which meticulously records every alteration or addition made to an electronic medical record (EMR), can be requested, and supplied by healthcare providers[9,10]. This feature assumes particular significance in verifying the authenticity and accuracy of the EMR. Unlike traditional paper records, where the potential for modifications or lack of veracity exists, audit trails provide a comprehensive chronicle of changes. They encompass pertinent details such as the terminal employed to access the record, the precise date and time of each modification, and the identity of the author. However, challenges emerge concerning the accuracy and reliability of audit trails. For instance, discrepancies may arise when the timestamp in the record inaccurately reflects the actual time of data entry[11]. Moreover, situations where multiple healthcare professionals contribute to a patient's care may result in an audit trail that does not distinctly attribute specific actions to individual personnel. Discrepancies in terminology and content across diverse electronic medical record software systems can engender confusion and raise doubts regarding the completeness of the data provided.

2. Balancing Clinical Alerts and Alert Fatigue in Electronic Medical Records

Many electronic medical record systems incorporate alert and reminder pop-up features, which serve to caution physicians about potential medication interactions or adverse reactions that a patient may experience[12]. However, physicians often perceive these warnings as excessively conservative, as they generate a significant number of "false-positive alerts" that fail to consider the patient's comprehensive medical context. Consequently, physicians may become desensitized to these alerts, a phenomenon known as "alert fatigue," whereby an overwhelming number of notifications cause

both significant and trivial warnings to be disregarded[13]. Conversely, other manufacturers opt to include additional alerts to assuage liability concerns and shift the burden of responsibility onto physicians who may overlook pertinent warnings. In the event of a patient experiencing complications due to a drug-drug interaction, metadata demonstrating that the EMR program issued an alert regarding the potential adverse reaction can serve as valuable evidentiary support.

3. Metadata Considerations for Documenting Patient Visits

Metadata can also be found within doctors' notes, often structured according to the SOAP (Subjective, Objective, Assessment, Plan) format, encompassing subjective and objective descriptions of the patient, an assessment of their condition, and a treatment plan. Various electronic medical record systems employ distinct methods for documenting these notes, including dictation, typing, or utilizing a series of screens comprising questions and checkboxes to capture relevant information. The question arises as to the appropriate extent of production by healthcare providers, specifically whether the finalized doctor's note, the answers to the questions and checkboxes, or both should be furnished. This issue remains unresolved and lacks standardized practices within the field[14].

MANIPULATION OF EVIDENCE

The use of electronic medical records (EMRs) raises significant concerns regarding their authentication and preservation in legal contexts. Adhering to the Indian Evidence Act[15], EMRs may be admitted as exceptions to the hearsay rule if they are generated as part of routine business activities and are regularly created. Additionally, authentication of EMRs is required before their admission as evidence, necessitating the producer to demonstrate the consistency between the retrieved record and the original one placed in the file[16]. Authentication can be achieved through the identification of distinctive characteristics or the testimony of expert witnesses who can compare the record with authenticated ones[17].

EMRs, being dynamic in nature, continually change as new information is recorded. However, tampering or altering such records can result in sanctions under the CrPC. Courts have the authority to issue legal holds, ensuring the preservation of relevant data for ongoing or anticipated litigation. In cases where data is improperly destroyed, claims of spoliation arise, which refers to the intentional destruction, alteration, or concealment of evidence[18]. In such instances, healthcare providers bear the burden of proving to the court that the loss of data was in good faith[19]. Failure to demonstrate good faith may lead to court sanctions or the obligation to reconstruct the data, incurring significant costs.

Transitioning to EMRs prompts healthcare providers to digitize and dispose of paper records, but this practice poses challenges. Illegible scanned images may lead to spoliation claims, as the originals could have been more readable. Furthermore, in anticipation of litigation, preserving potential evidence is essential. With evolving EMRs and real-time data changes, authentication, and spoliation prevention are critical concerns for medical providers[20]. To address the authentication aspect, healthcare providers must utilize reliable methods to verify the integrity of EMRs. This can involve identifying distinctive characteristics within the records, such as metadata, which can serve as evidence of their legitimacy[21]. Additionally, expert witnesses can play a pivotal role in validating the authenticity of EMRs by comparing them with previously confirmed legitimate records[22].

COPYING AND PASTING CHALLENGES IN EMRS: IMPLICATIONS FOR DISCOVERY

The utilization of the copy-and-paste function in electronic medical records (EMRs) presents significant challenges within the realm of discovery. Computers equipped with EMRs allow healthcare professionals to effortlessly duplicate and transfer information from one part of the record to another[23]. While the act of copying medical records existed prior to the advent of EMRs, the process has become notably more efficient and rapid with the aid of computers. This practise, however, introduces complexities that affect the comprehensibility of the record and may result in the inclusion of redundant information[24]. Research has identified copying and pasting as a prominent source of errors in EMR documentation, particularly when medical staff neglect to carefully proofread the copied text to ensure its continued accuracy[25].

From a legal standpoint, the act of copying and pasting complicates the determination of the original author responsible for a specific segment of the record. This raises uncertainties surrounding the identification of liable doctors and the necessity of their depositions. Questions arise as to whether doctors who employ the original text share liability with the author, and whether every doctor utilizing an incorrect portion of the record has committed an error[26]. The accuracy and currency of copied text in electronic medical records raise uncertainties for subsequent doctors, prompting questions about

their responsibility to independently verify the information. These considerations also create challenges in determining which doctors should be deposed due to these uncertainties.

CONCLUSION

The implementation of an electronic medical record (EMR) export format within the context of the discovery process offers significant benefits. It provides healthcare providers with control over access, enabling the selective transmission of specific patient data in response to subpoenas or valid discovery requests. This format facilitates data transfer and physical storage through mediums such as USB flash drives, CDs, or DVDs. Legal practitioners benefit from accessing records through a digital interface, overcoming formatting challenges associated with printed versions of EMRs.

By utilizing the export function, legal professionals can access metadata information that may be difficult to obtain from paper printouts. It also helps mitigate the risk of intentional or accidental destruction of evidence by providing an alternative method for generating static backups of patient data, thus serving as an additional safeguard.

Nevertheless, there are drawbacks to this approach. Implementation may be intricate, costly, and time-consuming compared to remote login methods. Establishing a functional standard applicable across different EMR systems is a challenge, which may require further governmental action. Additionally, the export format is limited to generating static files and does not support real-time changes like the remote login method.

To address these concerns, remote electronic access or an interoperable export format can be employed during the discovery process to avoid the need for converting EMRs into tangible paper form. It is crucial to prioritize security, restrict access limited to viewing only, and the safeguard patient confidentiality when legal practitioners access records electronically. The electronic format must also allow the producing party to redact irrelevant content within the records, with a provision for appeals if pertinent material is not produced. Consequently, as electronic medical records represent the future of the healthcare industry, the legal community needs to establish novel standards that align with the digitally oriented realm we inhabit.

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ETHICAL ISSUES

None

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POINT OF VIEW

CRACKING THE CODE: CAN FORENSIC GENETICS DISTINGUISH IDENTICAL TWINS? A TECHNICAL PERSPECTIVE

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ABSTRACT

DNA fingerprinting has revolutionized the field of forensic investigation in recent times. The utility of DNA fingerprinting technology in differentiating between monozygotic twins has always been an area of academic interest for researchers. While traditional chiral fingerprinting effectively differentiates monozygotic twins, situations may arise where the absence of conventional fingerprints at a crime scene necessitates DNA analysis for conclusive identification. Although Short Tandem Repeats (STR) profiling is of not much help in that case, monozygotic twins can still be differentiated using current advancements in the field of forensic genetics. The methods that can help discriminate between identical twins are mitochondrial genome (mtGenome) analysis, Single Nucleotide Polymorphism (SNP) profiling, Epigenetic profiling (DNA methylation profiling), Copy Number Variants (CNV) profiling, and studying Single Nucleotide Variants (SNV) in the genetic material by traditional sequencing methods like sanger sequencing or advanced methods like Whole Genome Sequencing (WGS). In conclusion, these alternative methods may be able to distinguish between monozygotic twins, but they also have drawbacks that must be considered when using them in real-world crime investigations. To establish their accuracy, dependability, and application in forensic situations, more study, validation, and standardization are required. A combination strategy will strengthen the case and lessen the fallacy of individual profiling methods.

Keywords: *Copy number variants; mitochondrial DNA; monozygotic identical twins; single nucleotide polymorphism; single nucleotide variants.*

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INTRODUCTION

Identification is one of the cardinal objectives to be fulfilled in day-to-day forensic casework as and when a need arises. 'Dactylography' or fingerprint evidence remains a cornerstone of forensic practice due to its unique and reliable nature for individual identification. Across the globe, within the context of distinguishing monozygotic twins, forensic medicine experts often highlight the practicality and cost-effectiveness of traditional dactylography, while occasionally not fully exploring the capabilities of modern approaches like DNA fingerprinting. Despite the ease and familiarity of traditional methods, it is important to recognize the potential of advanced techniques for medico-legal identification in cases involving monozygotic twin differentiation. These techniques are of immense help when only trace evidence is recovered at the crime scene and traditional fingerprints are not recovered.

The history of crime is replete with infamous cases involving identical twins that have been documented both in the pre-DNA and post-DNA eras. The use of DNA evidence in criminal investigations marked a revolutionary breakthrough in forensic science[1]. In 1986, in the landmark Enderby murders case, geneticist Sir Alec Jeffreys

employed DNA fingerprinting to link a suspect to the crime scenes, establishing an unprecedented level of certainty in identification. In the modern era of DNA technology, instances like that of Hassan and Abbas O., accused of a bank robbery in Germany, have spotlighted the complexities of distinguishing between identical twins in criminal investigations. Being familiar with current trends in Monozygotic Twin (MZ) discrimination from a forensic angle is advisable due to its potential relevance in our practice.

Traditionally, STR (Short Tandem Repeat) DNA profiling is a widely employed method for identifying individuals based on their distinct genetic makeup. STR sequencing involves profiling multiple polymorphic variations within different individuals, specifically DNA fragments ranging in size from 10 to 500 base pairs (bp) that belong to the microsatellite region of the genome. The Taq Polymerase enzyme is utilized for multiplex PCR in this profiling technique, generating unique genetic profiles distinguished by varying repeat numbers (differences in the number of repeated DNA sequences), thereby ensuring a prominent level of identification precision. This method is characterized by its rapid execution and robust discriminatory capability.

Nevertheless, the STR method has limitations when it comes to identifying identical twins, who share the same DNA. Identical twins, also known as monozygotic twins, originate from a single fertilized egg that splits into two embryos, resulting in individuals with nearly identical genetic profiles. As a result, traditional STR DNA profiling, which relies on identifying variations in repetitive DNA sequences in the microsatellite region, fails to distinguish between the DNA of monozygotic (MZ) twins[2]. However, the following techniques have been used with some success in this area. Technically speaking mitochondrial genome (mtgenome) profiling, epigenetic profiling, single nucleotide variant (SNV) profiling, and copy number variant (CNV) profiling methods offer discrimination capabilities that can overcome the limitations of STR profiling in differentiating monozygotic twins.
The mitochondrial genome, inherited solely from the mother, can exhibit sequence variations due to random segregation during early development, resulting in divergent mtDNA profiles. Epigenetic marks like DNA methylation can vary due to environmental influences and stochastic processes, accumulating differences over time even in monozygotic twins. SNV profiling identifies rare genetic variants acquired through somatic mutations or environmental exposures, while CNV profiling detects structural genetic differences, allowing for comprehensive genome-wide discrimination that STR profiling, focused on specific repetitive regions, may not achieve.

Mitochondrial DNA (mtDNA) Profiling

Mitochondrial DNA (mtDNA) profiling is one alternative approach to discriminate between identical twins. Mitochondria are cellular organelles that contain their DNA, separate from the nuclear DNA found in the cell's nucleus. Unlike nuclear DNA, which is inherited from both parents, mtDNA is matrilineal in origin. MtDNA can potentially be used to differentiate between identical twins as their mtDNA can differ due to random mutations over time, known as mtDNA polymorphisms. The mitochondrial DNA variations compared to the nuclear DNA variations are a potential marker owing to higher mutation rates. So, studying the variation due to random segregation of mtDNA during early development or accumulated random mutations in mtDNA over time may be used for differentiating monozygotic twins with some success. The mtDNA can be sequenced using the traditional Sanger sequencing, which is easier, cost-effective, and with less turnaround time. However, much more advanced methods like massively parallel sequencing (Next Generation Sequencing) may be attempted for research purposes if feasible as has been done in some centers[3]. Moreover, it has been demonstrated that ultra-deep mtGenome sequencing could be used to differentiate between MZ twins[4]. Nevertheless, it is essential to note that mtDNA profiling's comparative discriminatory power is somewhat limited in contrast to routine nuclear DNA profiling and is never used alone as a tool for differentiation between monozygotic twins. This stems from the lower diversity of mtDNA and its distinct slow evolutionary pattern, which, although useful, warrants careful consideration during application.

Single Nucleotide Polymorphism (SNP) Profiling

SNP profiling is another approach that can provide greater discrimination between individuals, including identical twins. SNPs are variations in single nucleotides (building blocks of DNA) that occur in the genome. SNP profiling can be used to identify unique genetic variations between identical twins, as well as other individuals, by examining specific SNPs in their DNA. Some rare mutations may occur as soon as the human blastocyst splits into two (the origin of twins) and such mutations pass on into the somatic tissue and germlines. Hence, traditional genetic sequencing and Whole Genome

sequencing (WGS) to identify SNPs are good methods to discern between identical twins[5]. In one real-world case involving MZ twins, the use of SNP profiling from mtDNA has helped in identifying the perpetrator[6]. MZ twins were differentiated using WGS, allele-specific PCR, and deep-amplicon sequencing (a targeted high throughput DNA sequencing method, that involves PCR amplification and next-generation sequencing of specific regions). Mitochondrial DNA, due to its unique heterogeneous SNPs (both common SNPs and rare/private SNPs), proved superior in discerning twins, aiding in criminal identification and exoneration across cases. A major limitation of SNP profiling includes higher costs and more complex analysis methods, which may cause some difficulties (owing to the extreme similarity of the SNPs between all individuals including MZ twins) in its practical application in forensic cases. Additionally, the presence of certain commonly occurring SNPs may limit their discriminatory power for identifying unique genetic differences between identical twins and is never supposed to be used in isolation. This method also complements other methods in differentiating between MZ twins.

Epigenetic Profiling (DNA Methylation Profiling)

Epigenetic profiling is an emerging technique that holds promise for identifying identical twins. Epigenetics refers to changes in gene activity that are not caused by changes in the DNA sequence itself, but rather by modifications to the DNA molecule or to the proteins with which DNA interacts. Epigenetic profiling can provide information about an individual's unique epigenetic signature, which can differ between identical twins due to various environmental factors.

Many differentially methylated regions (tDMRs) with varying amounts of methylation in different cell types and tissues have been found through genome-wide methylation studies employing high throughput DNA technologies which can aid in differentiating between individuals including MZ twins[7,8]. The magnitude of the intra-pair or longitudinal methylation discordance of the CpG sites inside the CpG islands is more than those outside the CpG islands having the potential to discriminate MZ twins. CpG islands are regions of DNA where a cytosine (C) nucleotide is followed by a guanine (G) nucleotide in the linear sequence of the DNA strand, and they are often associated with gene regulatory regions. The "p" in CpG stands for the phosphate group that links the two nucleotides[9]. LINE 1 DNA methylation was also suggested to be a potential marker for discriminating MZ twins[10]. Interestingly, stochastic processes cause variations in methylomes which occur post-twinning during embryonic development and later life that can become a basis for discrimination. A new epigenetic fingerprinting method was also developed based on stochastic methylation variation[11]. However, the role of whole genome sequencing in this regard and its limitations have been described in detail here[12].
The limitations of epigenetic profiling include the ongoing establishment of its reliability and accuracy for forensic discrimination of MZ twins, as well as challenges in the standardization and interpretation of results for the same. The complexity and variability of epigenetic marks may affect accuracy and reproducibility, and further research is needed to determine their practical applicability in differentiating MZ twins. While several stable epigenetic variations have shown promise for applications in identification, it's crucial to recognize that epigenetics is a highly dynamic field within molecular biology, and it is extremely difficult to standardize it as an identification tool. Moreover, the evidence derived from epigenetic profiling should not only be indicative but must also possess probative value, meaning that it should provide substantial and conclusive support for identification purposes, which is still elusive.

Copy Number Variation (CNV) Profiling

CNV profiling is another approach that can potentially identify differences in CNVs between MZ twins. CNVs are structural changes in DNA that involve the deletion or duplication of DNA segments, resulting in changes in the number of copies of certain DNA regions. CNVs can occur naturally in the human genome and can vary between individuals, including identical twins. Analysing CNV profiles using techniques like array comparative genomic hybridization (aCGH), quantitative polymerase chain reaction (qPCR), or next-generation sequencing (NGS) can potentially identify differences in CNVs between MZ twins, allowing for discrimination due to genetic differences arising from early embryonic development or environmental factors. The potential application of CNVs in the field of forensic medicine has been explained in detail here[13].

The limitations of CNV profiling techniques include potential issues with accuracy and reliability due to sample quality, technique used, and presence of technical artifacts. CNVs can also occur naturally in the genome and may not always indicate genetic differences between identical twins, yet the variability shown between MZ twins can be of use for differentiating. These limitations should be

considered in forensic applications of CNV profiling for MZ twin differentiation.

This research question of distinguishing MZ twins has been given adequate importance by the scientific community across the globe. Some interesting methods like using Immune Repertoire (IR) as a potential biological marker for this purpose have been suggested[14]. Similarly, the differences in microRNA expressions between individuals can also be used to solve this question according to a published paper[15]. One can also explore the possibilities of metabolome and proteome level variations which can be useful to solve this question. Some researchers have proposed studying Single Nucleotide Variations (SNVs) for discriminating between MZ twins[16]. SNPs are a subset of SNVs that are commonly used as markers in population genetics and can be stably inherited by the offspring. Whereas, SNVs encompass a broader range of genetic changes, including any single-letter change in DNA, regardless of its frequency or relevance to a population. SNVs can include both common and rare variations and can result from various mechanisms and not solely by inheritance. They may or may not have functional consequences and cover a wider spectrum of genetic diversity beyond the specific characteristics of SNPs. However, not all SNVs are usable for the proposed purpose of differentiating MZ twins. SNVs can be either germline mutations, which are inherited from parents and present in every cell of an individual's body, or somatic mutations, which occur after fertilization and are only present in specific cells or tissues. Hence one must be cautious in choosing an SNP/SNV for identification purposes bearing in mind the common nature of presence in the population and the frequency of incidence. The variations which occur after the blastocyst formation are of much use for our purpose.

All these complex methods can be done after the successful extraction of DNA from the autopsy or clinical medicolegal samples in forensic casework apart from trace evidence collected at the crime scene. Nowadays, DNA extraction process is routinely conducted using kit-based methods and is easy to do with less training. However, each molecular genetics laboratory has its own customized protocol for further analysis of extracted DNA (sequencing and identification), which is the domain of a forensic molecular geneticist[17-22]. It is agreed that identification is police business and DNA casework is done in forensic science laboratories by scientists in most parts of the Eastern world, but as a forensic pathologist, one has to be aware of the new developments in the field of forensic genetics/ DNA profiling methods.

In summary, while these alternative techniques may have the potential for discriminating between MZ twins apart from the traditional chiral fingerprinting, they also have limitations that need to be considered in their practical application for forensic purposes. Further research, validation, and standardization are needed to establish their accuracy, reliability, and applicability in forensic settings. A combined approach will increase the weight of evidence and reduce the fallacy of individual profiling techniques. It would be of significant help to the scientific community if a consortium of forensic genetics experts came up with a workable standard operating procedure to be followed in cases involving discrimination between MZ twins by using a combination of all these methods. There is also a need to assess the costs involved in the application of several new technologists to solve this question *vis a vis* other method to solve the crime.

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CONFLICTS OF INTEREST

The author declared no conflicts of interest.

ETHICAL ISSUES

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AUTHOR CONTRIBUTIONS

ARK: Conception or design of the work; acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; and final approval of the version to be published.

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