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RESEARCH ARTICLE

"Pattern of electrocution deaths autopsied in South India" – A 16 year retrospective study

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ABSTRACT

Background: The eastern part of Bangalore is an IT hub. There is a continuous increase in the number of construction sites, work places and residential areas. As a consequence, cases of electric accidents are common and are steadily increasing. Electric injury increases the risk of morbidity and mortality. The purpose of the study is to outline the increased fatality rate due to electrocution and also aims at reducing the severity of electric injury related fatalities by promoting preventive measures.

Results: The study showed male preponderance, with increased incidence in age group of 20-30 years. Accidental deaths were common, and the majority of skin samples were taken from suspected site of electric contact and exit showed positive findings for electrocution.

Conclusion: The study provides the statistical data on electrocution fatalities in this part of Bangalore for researchers and law enforcement agencies. It also aids in emphasising the usage of protective equipment at the workplace, construction sites and precautionary measures for domestic use of the electricity.

Keywords: Electrocution, Histopathology, Electric contact mark, Metallization, Palisading nucleus.

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INTRODUCTION

Electrical energy is one of major sources of energy. It is used in industry, construction sites and domestic purpose as well. Even after long use, awareness about how to avoid its detrimental effects is still lacking among the public, resulting in considerable amount of morbidity and mortality. The term "Electrocution" has been coined for skin lesion, organ damage or death caused by the passage of electric current through bodily tissues[1]. Electrical injuries vary from minor physiological shock through minor burns at the point of contact, to extensive burns and fatality from cardiac arrhythmias. In some cases there may be no physical changes visible at autopsy, throwing additional demands on crime scene investigation[2]. Electrocution related fatalities are less common when the voltage is below 100V but more common at 200V and above. Supply for domestic and small-scale industries range from 220V to 240V, careless use of which is capable of resulting in electrocution and fatality. Electric injuries depend on voltage, path of passage of the current, the resistance offered and whether the power is direct or alternating current[3]. Most of the electrocution deaths are preventable. According to NCRB – National Crime Records Bureau 2015, electrocution accounts for 3.0% cases of unnatural accidental deaths in India[4]. The first related electric fatality was in France 1879[5].

Aims of the Study

1. To determine the pattern of injuries sustained in electrocution deaths.
2. To determine the demographic data of electrocution deaths.

3. To interpret histopathology findings in the electrocution deaths.

METHODS

This study was done in a tertiary care centre hospital; Department of Forensic Medicine & Toxicology which handles most of the autopsies in eastern part of Bangalore. The study is retrospective and covers a period of sixteen years between 2005 and 2020. A detailed proforma was prepared to summarise information from police requisition forms 146(i) and 146(ii), post-mortem examination reports, autopsy pathologists, histopathology and autopsy photographs. The study analyses the demographic data, pattern of injuries sustained, histopathological findings of the entry and exit points of electric current, and internal organs.

Inclusion criteria:
All autopsies with history of electrocution

All autopsies where cause of death was given as electrocution

Exclusion criteria:
All other thermal deaths including lightning deaths.

Statistical analysis:
Descriptive analysis was used.

RESULTS

Seventy one cases of death by electrocution were identified. Sixty seven were male. The most common incidence was in the 21-30 year old age group (33 cases), followed by 11-20 year age group (12 cases). Thirty four electrocutions occurred in the work place, 21 outdoors and 16 cases within the home. Upper limbs were involved in 43 cases, lower limbs in 12 cases, trunk in 10 cases, and head in 8 cases, 1 of which included the cornea of eye. Entry marks were seen in 65 cases (multiple entry wounds were present in 6 cases) **(Table 1).** Both entry and exit marks were present in 18 cases. Flame burns were seen in 7 cases. Thirty seven cases were associated with mechanical injuries including abrasions, contusions, lacerations and incised wounds. There were no contact marks in 6 cases.

Table 1: Pattern of injuries

Types of injuries	Number of cases	Percentage
Entry Wound	65	91.5
Multiple entry wounds	06	8.45
Entry and Exit wounds	18	25.3
Flame burns	07	9.8
Mechanical injuries	37	52.1
No injuries	06	8.45

Samples were sent for histopathology in 55 cases. In 16 cases histopathological examination was considered not necessary by the pathologist.

The most common microscopic feature noticed in organs was congestion, which is a nonspecific finding. Myocardial infarction was seen in 03 cases, oedema of brain in 01 case and pneumonia in 01 case. Myocardial infarction and pneumonia were incidental findings in the cases.

Toxicological analysis was done in 04 cases of which 01 showed presence of ethanol.

Incidences were more common in summer, there being 41 cases observed in March to June, followed by 15 cases during each of the periods from July to October and from November to February.

The manner of death in 70 cases was accidental and in 01 case it was homicidal. No case of suicide was observed. The cause of death was given as electrocution in 50 cases followed by electric shock in 12 cases; respiratory failure was given in 03 cases. Cardiac arrest, myocardial infarction, syncope, cardiorespiratory failure, aspiration and injury were stated as the cause of death in 06 cases.

On microscopic examination 35 cases showed nuclear streaming, 21 cases showed dermo-epidermal separation, 10 cases showed coagulative necrosis and 03 showed micro-blisters. (**Fig. 1, 2, 3 & 4**) There was metallisation in 02 cases. Skin samples were normal in 03 cases. Nuclear streaming and dermo-epidermal separation were coexistent in 02 cases.

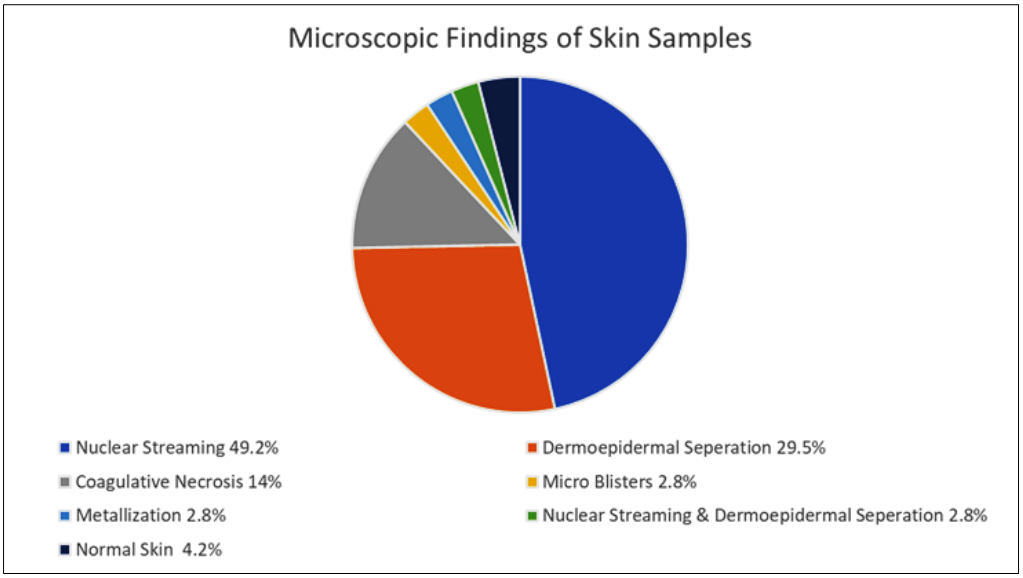

Figure 1: Microscopic findings of skin samples

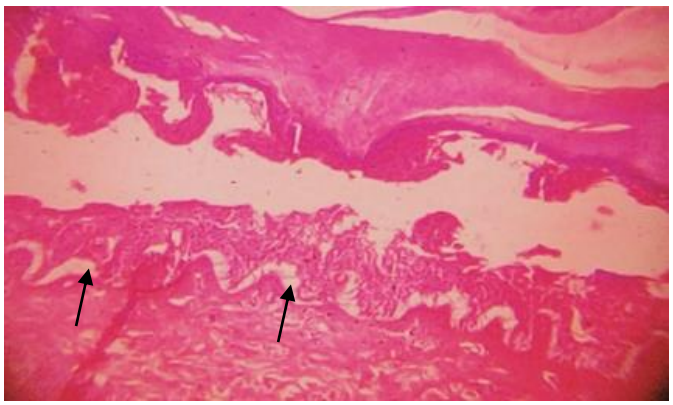

Figure 2: Microphotograph of intradermal blister formation (black arrows) (H&E x10)

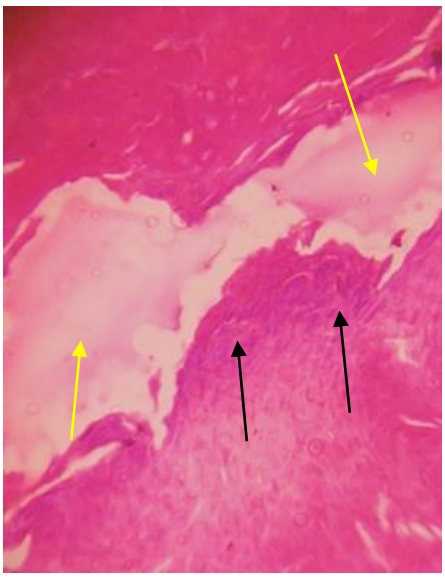

Figure 3: Microphotograph of nuclear streaming (black arrows) and coagulative necrosis (yellow arrows) (H&E x10)

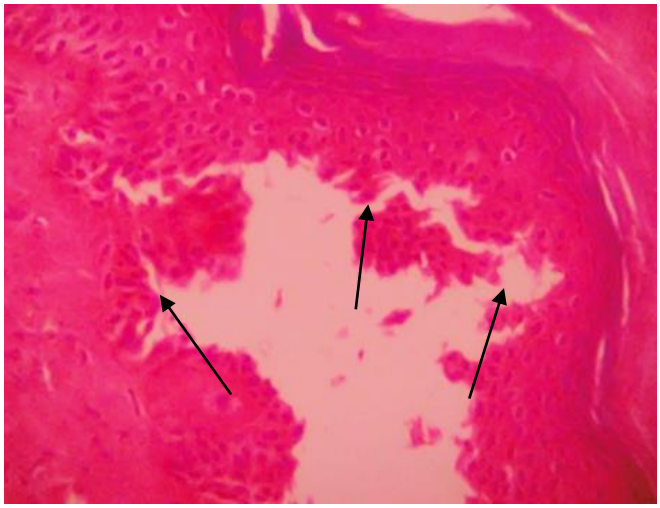

Figure 4: Microphotograph of micro blister formation (black arrow) (H&E x10)

DISCUSSION

The study was done in eastern part of Bangalore for a period of 16 years. Electrocution accounted for about 1.74% of all autopsies done during the study period which corresponded to two studies done in Puducherry, India where it accounted for 1.18% and 0.9% of all autopsies[6,7]. However, it contrasts with a study done in Raichur, Karnataka, India where electrocution contributed to 2.78% of all cases[8].

The current study showed a male preponderance (93.8%) compared to female (6.2%) similar to other studies; maybe because males are involved in more outdoor activities like work in construction sites/factories/other occupations. The 21-30 year age group followed by the 10-20 year age group is commonly affected in the current study which is similar to studies done in Chennai, India and Manipur, India, as it is the productive age group that is more exposed to outdoor activities[9,10]. In the current study youngest case was a 3-year-old girl and oldest was a 75-year-old male.

In the current study, 49% of electrocutions occurred in the workplace, 22% in households and 29% outdoors. This is in contrast to a study done in Aligarh, India and Chennai, India, where electrocution was more common in the domestic situation than workplace and outdoor situations[9,11]. The study is similar to a study done in Raichur, India. The possible reasons as to why the incidences are higher in the workplace in this study is probably due to the fact that this study was done in the eastern part of Bangalore where a larger number of construction sites, industries and IT companies are located and use of electricity is considerably high[8].

In the current study 93% of cases had an entry mark, 25% had an exit mark, 25% had both entry and exit marks and 7% did not have any electric contact mark. The mark may be absent due to brief contact with the live wire or due to collapse of person due to ventricular fibrillation resulting in falling away from the wire. When there is prolonged contact, burns may be produced[12]. The contact mark may be present only in 57-83% of cases as its appearance depends on several factors such as current flow per unit time, voltage, and duration of exposure[2,13].

In the present study the entry mark was predominantly seen in upper extremities followed by lower extremities and trunk. This may be explained by the fact that the upper extremities are the most used part of the body for finer activities. The findings are similar to studies done in Tehran, Zagreb and Northern India where upper extremities were the common site. In Tehran no contact marks were seen in 5.4% of cases. In Zagreb, the skin was normal in 21% of cases. In Northern India contact mark was present only in 61% of cases which contrasts with the current study[14,15,16]. In general, resistance is high in the skin of back and low in forearm, palms, arm and scalp[17].

Knight states that typical features of Electric contact mark may not be present in all cases of electrocution even though the entry mark generally shows the shape and size of conductor. No mark on the skin may be seen if contact point is broad and if there is water which will considerably reduce the resistance[1].

This study showed different types of mechanical injuries like abrasions, contusions and lacerations. In one case, the cause of death was given as due to mechanical injuries sustained due to a fall following electric contact. It is similar to a study done in South Delhi where cause of death was given as polytrauma as a result of fall from height[19]. Gordon had explained that associated injuries from mechanical trauma are due to the deceased being flung violently due to contact with high tension electrical conductor[20].

On considering the manner of death, the current study showed 70 cases as accidental and 01 case as homicidal. No suicidal deaths were identified in this study. In a majority of cases, the manner of death was accidental. In the current study there was one homicidal death where the victim was restrained and later assaulted resulting in loss of consciousness. She was then chairbound and electrocuted using cables entwined around her hand and forefinger. A study done in Gujarat revealed that most of the cases were accidental in nature. However, a study done in Australia revealed that 29% were suicidal deaths. The reason maybe that the study was done in a developing country where other methods are preferred to commit suicide[21,22]. Forty one incidents in the current study were in the summer and 15 cases each in winter and rainy seasons. This is similar to a study done in Coimbatore, where incidences were more during summer probable due to greater use of electric appliances and due to increased sweating, (lowered resistance at point of contact). However, this study contrasts with a study done by Sachin Giri et al from central India where the incidence is greater in the rainy season followed by summer[23,24].

In the current study the cause of death in 50 cases was stated as electrocution. Mode of death was not

indicated in many of the cases. Modes identified were syncope and shock. Syncope was stated due to possible sudden stoppage of circulation, and "shock" here meant electric shock. A study done in Maryland states that deaths due to electrical energy are functional fatalities, which may happen as a result of cardiac arrhythmias / ventricular fibrillations, asphyxia or electrically induced respiratory muscle contractions. In the present study in 03 cases, the death was stated as respiratory failure probably due to involvement of intercostal muscles and diaphragm, as a result of passage of electric current through chest and abdomen. In twelve cases death was concluded as due to electric shock; in one case cause of death was given as due to injury due to a fall from height following electrocution. Cause of death was given as myocardial infarction, Aspiration, syncope, cardiorespiratory failure and cardiac arrest in the remaining 05 cases. Myocardial infarction could be an incidental finding, Aspiration could be a terminal event, and the path of electric current passage through the heart could have caused sudden stoppage of heart resulting in syncope, cardiac arrest and cardiorespiratory failure.

In the current study the cause of death in 50 cases was given as electrocution. Mode of death was not stated in many of the cases. A study done in Maryland states that deaths due to electrical energy are functional fatalities, which may occur as a result of cardiac arrhythmias / ventricular fibrillations, asphyxia or electrically induced respiratory muscle contractions. In the present study in 03 cases, death was given as respiratory failure probably due to involvement of intercostal muscles and diaphragm, as a result of passage of electric current through chest and abdomen. In 12 cases the conclusion was that death was due to electric shock; in one case the cause of death was given as due to injury caused by falling from a height following electrocution. The cause of death was given as myocardial infarction, aspiration, syncope, cardiorespiratory failure and cardiac arrest in the remaining 05 cases.

Damage to biological matter occurs due to the passage of electrons through tissues. Fatality and damage depends on the vital structure through which the electrons had passed. The myocardium is involved when electrons passes from hand and earthed to feet or opposite hand, the most dangerous being contact in the hand with exit through feet. Histopathology of internal organs is a matter of debate because the internal tissues are largely aqueous and contain conductive electrolytes. The organ and visceral damage are mainly functional and involving especially nervous tissue and muscles[18,26].

Congestion and petechial haemorrhages are important features noticed in visceral organs. Focal necrosis, haemorrhages, myocardial infarction and acute contraction bands in myocardium and conduction system are seen. In the current study the heart was normal in 07 cases, 03 cases showed congestion and 03 cases showed features of myocardial infarction. In a study done in Bangalore and by D'Errico S et al, pathological changes that were noticed in myocardium were disarray, haemorrhages, myocellular fragmentation and rupture of myocardial fibres[26,27]. The current study showed 10 cases of congestion of lungs and a case of pneumonia which could be an incidental finding; however the literature shows that damage to lungs is rare. The brain in the current study showed oedema in one case, it was normal in 02 cases and congested in 03 cases; the literature shows cerebral axonal injury is seen in cardiorespiratory arrest which was not noticed in the present study. As a long-term sequel cerebral vein thrombosis were noticed but in current study all the deaths were immediate[28,29].

In the current study the brain was sent in 06 cases for histopathological examination, 02 cases of which had normal gross and microscopy, 03 cases showed congestion and 01 case showed oedema of brain tissue. Gordon had described focal petechial haemorrhages in brain and spinal cord, chromatolysis in nerve cells, dilatation of perivascular space, fragmentation of axon and changes in myelin sheath. These changes could have been missed in current study due less advancement in the detection and due to usage of only Hematoxylin & Eosin staining techniques.[30]

In the current study skin samples of 55 cases were sent for histopathology examination. Routine Hematoxylin and Eosin staining was done. Nuclear streaming was seen in 35 cases, dermo-epidermal separation was noticed in 21 cases, coagulative necrosis in 10 cases, micro-blisters in 03 cases, homogenization and metallic particles were noticed in 02 cases each and samples were normal in 03 cases. The study is similar to a study done in Nagpur. Sachin Giri et al and Deepti Sukheeja et al, noted nuclear streaming, dermo-epidermal separation and coagulative necrosis as important histopathology findings, which helped them in solving cases where clear cause of death was doubtful[24,31,32,33]. Metallization was noticed in 02 cases in current study which was described by Tsokos as evidence of burns due to electrical current, which occur when tissue anions combine with the metal of an electrode to form metallic salts that is seen on surface of skin[2,34].

CONCLUSION

This study provides the statistics in this part of Bangalore for researchers and law enforcement agencies. Electrocution deaths are rare; however, the morbidity and mortality with electric injury is rising. Arriving at cause of death is difficult by post-mortem examination alone in some cases. It may require methodical examination which includes scene visits and histopathological examination especially where electrical contact marks are not present. The study stresses the use of gross and microscopic findings in arriving at the cause of death. Some internal organ findings are also focused on. The study also concludes that the circumstances are accidental in a majority of cases and commonly occur in the summer. Skin changes consistent with electrocution were noticed in the majority of samples sent for microscopy.

RECOMMENDATIONS

Use of protective equipment at the workplace, construction sites and precautionary measures for domestic utility of the electric current should be emphasised. Strategies should be implemented by law enforcement agencies at construction sites. Regular field visits and educating the workers at workplace would help in greatly reducing fatalities.

CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL ISSUES

None

AUTHOR CONTRIBUTIONS

SSS: conceptualization, formal analysis, resource, writing original draft; **RKG:** writing review and editing

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RESEARCH PAPER

Profile of children presenting for clinical forensic examination to the Teaching Hospital complex, Peradeniya, Sri Lanka

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ABSTRACT

Introduction: Children are more susceptible to injuries due to their inability to protect themselves. Our study aims to determine the socio-demographic profile, causative factors, intent, and severity of injuries in children presenting to the Teaching Hospital Complex Peradeniya for clinical forensic examination (CFE).

Methodology: This is a cross-sectional descriptive study. Children who presented for clinical forensic examination for a period of one year (from September 2017 up to September 2018) to Teaching Hospital Complex, Peradeniya, Sri Lanka, were included. Data was collected using a questionnaire at the time of clinical forensic examination where the Medico-legal examination form (MLEF) was also completed. Written informed consent was obtained from both the patient and guardian for routine medico-legal procedures and for inclusion in the study.

Results: Two hundred and forty-two children were recruited. One hundred and fifty-seven (65%) were male. The majority (43%) were between 16-18 years of age. Most of the injuries were due to road traffic accidents (RTA) (61%) followed by assault (18%), sexual abuse (12%), and accidental falls (5%). 'Other' types of injury or presentations were seen in 9 (4%) which was due to poisoning, drowning, air gun injury or burns. Males were predominantly affected except in the category of sexual abuse. Twice the number of males sustained injuries due to RTA compared to females, while three times the number of males was affected by assaults compared to females. The main category of hurt was non-grievous (62%). In this cohort, 31% had intentional trauma with a male predominance.

Conclusion: In children presenting to the Teaching Hospital Complex Peradeniya for clinical forensic examination (CFE), road traffic accidents are the main cause for injuries. Males are more vulnerable to injuries in general, while females are more vulnerable to sexual abuse.

Keywords: Child sexual abuse, Road traffic accidents, Trauma, Violence

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INTRODUCTION

Injury is a leading cause of death and disability worldwide burdening countries especially with limited resources[1]. Those who survive may be disabled, temporarily or permanently having a profound effect on the individual, family, society, and the country[2]. Children are more susceptible to injuries due to their inability to protect themselves. They depend on caregivers for food, shelter, safety, education, health, and for other needs. Therefore, their protection is the responsibility of the family and society as a whole[1-3].

Children may be subjected to intentional or non-intentional injuries[3]. Children cannot protect themselves from intentional injuries and they do not possess communication skills to express their feelings and experiences or resist abuse in comparison to adults. Therefore, caregivers may not identify abuse, which leads to further victimization of the children[4]. Studies show that children who behave aggressively with their peers have been victims of intentional violence in the past[5,6].

The cost of injuries to society is very high. Such costs may be direct or indirect. Direct costs come from the use of goods, child protection, and health services. Indirect costs are incurred by the caregivers in following up, spending their time and income[5]. A healthy, strong, younger generation is the strength of a nation. Therefore, injuries to children adversely affect not only the victims but their families, friends and communities as a whole[7].

It has been reported by Manas K Akmatov in 2011, that children from a low socio-economic class are at a higher risk of experiencing intentional injuries[8]. Literature reveals that such injuries are often associated with socio-demographic factors such as culture, habit, and living conditions[9,10].

Currently, Sri Lanka has a population of 21 million. There is rapid growth of the population of children with the growth of the country's population. Approximately 31% of the total population is children[11]. In Sri Lanka a child is legally defined as a person less than 18 years of age, irrespective of maturity and the level of education.

Literature revealed a study conducted in the Western province, Sri Lanka to determine the cause of injuries in children. This showed that 71% of children admitted to hospital are referred for Clinical Forensic Examination (CFE). Of these, 55% were victims of RTA, 17% victims of intentional trauma, 12% were victims of sexual abuse, and 16% were victims of other types of trauma[12].

Sri Lanka is a country that provides a large labor force to foreign countries. Females leave their families to go abroad for employment. A study conducted by Siriwardhana et al in 2015, on labor migration and its impact on families, revealed that it contributes to child injury[13]. Furthermore, a study conducted in 2011 by Miller revealed that the abuse of coastline male children in Sri Lanka is aggravated as a result of tourism[14].

OBJECTIVES

With regard to children, presenting to the Teaching Hospital Complex Peradeniya (Dental hospital, Pediatric hospital, Professorial unit) following trauma of medico-legal significance to;

- describe medico-legally significant issues
- determine the socio-demographic profile of the victim, causative factors, intent, and severity of injuries.

METHODOLOGY

A cross-sectional descriptive study was conducted on children (individuals less than 18 years) presenting to the Teaching Hospital Complex, Peradeniya (Dental hospital, Pediatric hospital, Professorial unit) for clinical forensic examination for a period of one year. Data were collected prospectively and documented at the time of clinical forensic examination by the Judicial Medical Officer.

Written informed consent was obtained from both the patient and guardian for routine medico-legal procedures and for being included in the study. The children whose guardians refused to consent and children with cognitive impairment were excluded from the study. Mentally challenged children were excluded as their capacity to comprehend the gravity of giving consent is particularly challenging and requires psychiatric opinion.

Information was gathered by taking a detailed history from both the patient and guardian during the routine clinical forensic examination. Police records were accessed in cases of RTA, physical or sexual child abuse. Information regarding socio-demographic profile, causes for injury, whether intentional or non-intentional, and category of hurt were collected.

Confidentiality was ensured by coding the patients. Confidentiality of data was ensured by a way of storing completed questionnaires in a secure place and by securing electronic data by a password.
Ethical approval was granted by the Ethics Review Committee, University of Peradeniya, Sri Lanka.

RESULTS

A. Socio-demographic profile

Out of 242 children, 157 (65%) were male. According to the age distribution 103 (43%) were between 16-18 years, 72 (30%) were between 11-15 years, 30 (12%) children between 6-10 years and 37 (15%)

were 1- 5 years. Table 01 summarizes the distribution of gender across different age groups, which shows that males are predominantly affected in all age groups.

Table 01: Gender and age distribution

	Male	Female	Total
	n (%)	n (%)	
1-5 years	21 (9%)	16 (7%)	37
6-10 years	17 (7%)	13 (5%)	30
11-15 years	46 (19%)	26 (11%)	72
16-18 years	73 (30%)	30 (12%)	103
Total	157	85	

B. Type of trauma

Most of the injuries were due to road traffic accidents 148 (61%), followed by assault 44 (18%), sexual abuse 29 (12%), and accidental falls 12 (5%). Nine children (4%) had sustained injuries or had conditions due to poisoning, drowning, air gun injury, and burns which were categorized under other types of injuries. A significant association was found between the gender and type of trauma **(Table 02)**. Males were predominantly affected when considering all types of injuries, except in sexual abuse. In road traffic accidents males were affected twice as often as females. In assaults males were affected three times more than females. The number of affected children was increasing gradually as they aged, except in falls and 'other' types of injuries in which the incidence declined with age **(Table 02)**.

Table 02: Age and Gender distribution with Type of Trauma

	Assault	Sexual abuse	Falls	RTA	Others	Total
	n (%)	n (%)	n (%)	n (%)	n (%)	
Gender						
Male	33(14%)	11(5%)	7(3%)	100(41%)	6(3%)	157
Female	11(5%)	18(7%)	5(0.2%)	48(20%)	3(1%)	85
Age						
1-5 years	4(2%)		5(2%)	25(10%)	3(1%)	37
6-10 years	6(2%)	2(1%)	1(0.4%)	20(8%)	1(0.4%)	30
11-15 years	14(6%)	13(5%)	3(1%)	40(17%)	2(1%)	72
16-18 years	20(8%)	14(6%)	3(1%)	63(26%)	3(1%)	103

C. Severity of trauma

Injuries were classified according to the Penal Code of Sri Lanka[15]. Accordingly increasing severity was classified as 'Non-grievous', 'Grievous', 'Endangering life' and 'Fatal in ordinary cause of nature'. Non grievous injuries are predominant 150 (62%), when compared to grievous injuries 57 (24%). Four cases (2%) had injuries which could be classified as endangering life and 2 (1%) were fatal in ordinary cause of nature. Further analysis of category of hurt with gender showed that out of 150 cases presenting with non-grievous injuries, 66% were male. Similarly, the majority of grievous injuries were reported in males (75%), highlighting the possibility of males being subjected to severe trauma than females. Injuries that are endangering life and fatal in ordinary cause of nature were reported equally among both males and females **(Table 03)**. However, these types of injuries were reported in small numbers making it difficult to draw up any conclusions regarding the association between gender and category of hurt.

Table 03: Category of hurt and gender

	Male	Female	Total
	n (%)	n (%)	
Non grievous	99 (41%)	51 (21%)	150
Grievous	43 (18%)	14 (6%)	57
Endangering life	2 (1%)	2 (1%)	4
Fatal in Ordinary cause of nature	1 (0.4%)	1 (0.4%)	2
Other	12 (5%)	17 (7%)	29
Total	157	85	

D. Manner of the incident

Out of 242 victims, 168 (69%) had unintentional trauma and only 74 (31%) had intentional trauma. Table 04 represents the association between manner of injury with age and gender. Accordingly, more males (19%) had sustained intentional trauma. Incidence of unintentional trauma was high in 1-5 years age group compared to 6-10 years age group.

Table 04: Age and gender distribution with manner of the injury

	Intentional		Unintentional		Total
	n	(%)	n	(%)	
Gender					
Male	46	(19%)	111	(46%)	157
Female	28	(12%)	57	(24%)	85
Age					
1-5 years	3	(1%)	34	(14%)	37
6-10 years	10	(4%)	20	(8%)	30
11-15 years	28	(12%)	44	(18%)	72
16-18 years	33	(14%)	70	(29%)	103

DISCUSSION

In medico-legal practice application of medical knowledge to an injured individual is the main contribution to ensuring justice. In order to do so, judicial medical experts should identify the main causes for injuries, mechanism of infliction, risk factors, category of hurt, and the magnitude of the problem. In this research, we attempted to identify the medico legally significant factors among children who presented with injuries.

The number of affected children progressively increased from infancy to adolescence. This is confirmed by 103 out of 242 cases being in the 16-18 age group followed by 72 in the 11-15 age group. Further, we noticed that older children had sustained all types of injuries. This pattern is consistent with previous national and international studies where they have found that older children are more prone to injuries than younger children[16,17]. They are more vulnerable to injuries as they represent an active age group that engages in sports, recreational activities, confrontations, and riding or driving motor vehicles.[18]

Road traffic accidents were identified as the main cause for injuries. Nearly 148 (61 %) have met with accidents, where 100 were males and rest were females. RTAs have become a major problem worldwide[19]. Developed countries have safe roads, technically certified vehicles, and road rules to which majority of the citizens adhere[19]. In comparison, Sri Lanka despite good road rules has poor roads and vehicles. However, it is noted that people do not abide by the law[12,20]. In addition, there can be other reasons that increase the risk of RTA such as poor maintenance of roads, crowded roads, absence of footpaths, and inexperience of drivers and pedestrians.

Majority who met with RTA were in the 16-18 year age group. According to previous studies, most of them were riders or drivers. The main vehicles were motorcycles and three wheelers.[12,20] Studies have also identified that younger age groups (1-10 years) who met with RTA were pedestrians or passengers in vehicles. Often, it was revealed that they had not followed the traffic rules or the alleged drivers had not followed rules.[20,21] Females were injured while travelling in motorcycles as pillion riders while, males were injured as the rider of motor cycles.[21]

Eighteen percent of the victims had been assaulted, 12% were victims of sexual abuse, 5% were victims of a fall, and 4% were the result of 'other' causes such as poisoning, burns, drowning, or gunshot injuries. The incidence of accidental falls and 'other' injuries decreased with age. Conversely assault, sexual abuse, and road traffic accidents increased with age.

Assaults accounted for 44% of injuries. All were intentional, majority were male, and there was a gradual rise with age. Most injuries were due to violence. This reflects the younger generations trend

for violence which is consistent with previous studies.[22]

Child sexual abuse is a serious issue in the health sector as well as in the legal system of the country[23]. Our results showed that the incidence of sexual abuse was increasing with age. Sexual abuse victims were identified mainly in two age groups; 11-15 years and 16-18 years. Eleven males and 18 females were affected. Main underlying causes were teenage love affairs and eloping with the partners. This has become a major problem in our society[24] that needs to be studied further. The literature revealed that most perpetrators are well known to the victim, and are older (more than 18 years)[24,25]. Often they are married or having multiple sexual partners. Most of the perpetrators have faced sexual harassment in their childhood as well[23]. According to previous studies done in Sri Lanka, many victims were school-aged, younger than their assailants and shared risk factors such as being from a single parent family, parents who have gone abroad to work as house maids, working parents, peers having love affairs, and communication accessibility. In addition, all these activities have taken place in a pre-planned manner[24,25].

Young children are more prone to injuries due to falls[9]. The majority occurred in their own house or in preschools and schools while playing and were non-intentional injuries. There were 12 cases of accidental falls, and the 1-5 year age group was mainly affected. Incidence of falls gradually decreased with age.

The 'other' category of injury included burns, poisoning, drowning, and air gun injuries. However, only a few patients with these injuries were reported for CFE due to various reasons. Globally, burn injuries cause high morbidity and mortality in all age groups[26]. Children can have long term physical, psychological, economical, and social effects on them and their families due to burns[27,28]. Although a considerable number of burn patients are admitted and treated, most of these cases are not reported for medico legal examinations[28]. Drowning is the third leading cause of death from unintentional injuries with highest rates among children and has been a controversial subject medico-legally[29]. Hence, all cases of burn injuries and drowning may not be referred for forensic examination and can be the reason for this low incidence.

According to the severity of the injury, the majority (62%) were non grievous and only 24% were grievous injuries. Injuries that are endangering life and fatal in ordinary cause of nature were reported less.

Most of the injuries were non-intentional (69.4%). Among the injuries reported among younger children majority were non- intentional. However, the incidence of intentional injuries was gradually increasing with age. This also can be attributable to the increasing incidence of violence seen among adolescents[22.]

CONCLUSION

Road traffic accidents are the main cause for injuries in children. Males are more vulnerable to injuries in general, while females are more vulnerable to sexual abuse.

RECOMMENDATIONS

As older children are more vulnerable to RTA and sexual assaults, parents/guardians must be vigilant. Teachers and other school staff should pay attention to preventing non-intentional injuries. As there is increased risk of violence among older children/ adolescents, they should be educated on the importance of abiding the law.

LIMITATIONS

This study sample is of children who have sustained injuries and who were medico legally examined. Children who refused admission and those who sought alternate therapies are not included in the study. In addition, mentally challenged children were also excluded from the study.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

DISCLOSURE

ANV is an editorial board member of Sri Lanka Journal of Forensic Medicine, Science & Law. Therefore he did not participate in anyway in the publication / decision making process of this submission, as per journal policy.

ETHICAL ISSUES

None

AUTHOR CONTRIBUTIONS

MSS: writing project proposal, data collection, writing project report and manuscript; **ANV:** supervision of the process and editing the manuscript; **WMLNW:** finalizing the manuscript.

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RESEARCH ARTICLE

Radiological measurements of the skull and its use in sex estimation: A study in Sri Lanka

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ABSTRACT

Introduction: In identification of an individual, the forensic pathologists and the anthropologists examine skeletal material. The aim of this study was to determine the cranio-facial structures which can be used to estimate sex in the adult Sri Lankan population.

Methods: The study sample consisted of 166 patients (77 males and 89 females), who underwent computed tomography (CT) brain examinations. The volumes of the maxillary, and frontal sinuses, and the measurements of angular forehead, skull, and facial structures were taken by two observers on axial, sagittal, and coronal planes of CT images. The age and sex of the patient were recorded along with the measurements. Data were analyzed using the statistical tests including independent sample t-test and Mann-Whitney U test, available in the SPSS version 25 software with $P<0.05$ indicating level of significance.

Results: The left maxillary sinus volume (ML), right maxillary sinus volume (MR), skull length (SL), prostio-bregmatic height (PBH), and maximum skull width (MSW), frontal sinus volume (F), angle of deviation of actual from ideal forehead slope (ANB), angle of inclination of actual forehead slope (BNV), and nasofrontal angle (BNC) had a statistically significant differences between males and females ($P<0.05$). There was no statistically significant difference in the angle of inclination of ideal forehead slope (ANV) in the two sexes ($P>0.05$).

Conclusion: Left maxillary sinus volume (ML), right maxillary sinus volume (MR), frontal sinus volume (F), nasofrontal angle (BNC), angle of inclination of ideal forehead slope (ANV), angle of deviation of actual from ideal forehead slope (ANB), skull length (SL), prostio-bregmatic height (PBH), maximum skull width (MSW) can help estimate the sex of a Sri Lankan person.

Left maxillary sinus volume (ML), right maxillary sinus volume (MR), frontal sinus volume (F), skull length (SL), prostio-bregmatic height (PBH), maximum skull width (MSW), nasofrontal angle (BNC), angle of deviation of actual from ideal forehead slope (ANB) and the angle of inclination of actual forehead slope (BNV).

Keywords: computed tomography, estimation, measurements, sex, skull

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INTRODUCTION

The biological identification methods have always been of utmost importance for society, not only living individual identity authentication purposes but also for forensic anthropology as well. The identification of human beings has evolved since ancient times. The dactylography, forensic dentistry, deoxyribonucleic acid (DNA) profile, and skeletal analysis facilitate precise individualized recognition of human beings. The skeletal analysis has to be done even in the events where DNA analysis is

feasible because it helps to narrow down the possibilities and reduces the number of DNA analyses to be done[1].

The skeletal analysis estimates the sex of the deceased by utilizing the skeletal traits such as skull, pelvis, and long bones. Estimation of sex is more precise if the whole skeleton is available, so that the identity can be estimated with 100% accuracy by using the whole skeleton. Among skeletal components pelvis has 95% followed by cranium with 92%[2]. The skeletal analysis gives more attention to the skull to estimate the sex since it bears more information of age, sex and ancestry. It is therefore important to find means to correctly estimate the sex, age, and ancestry of deceased through craniometric analysis.

The frontal sinuses are lobulated air-filled cavities which are located posterior to the superciliary arches in the frontal bone and each of the sinus drains into corresponding middle meatus through an infundibulum. The frontal sinuses are often bilateral, divided by a septum. Each of these sinuses is further divided by incomplete accessory septa and results in several recesses that are communicating with each other. The frontal sinuses are not present at the neonatal stage and start to develop at the age of 2 years and it could be visualized radiographically at the age of 05 years. Throughout the life frontal sinus remains stable unless pneumatization occurs due to atrophy in geriatric period. Total ossification terminates at the age of 20 years[4]. As an alteration of the frontal sinus, unilateral or bilateral agenasia may be present. Even monozygotic twins have indicated unique characteristics when analyzing the frontal sinus[4]. The unique features of the frontal sinus can be used as a substitute for fingerprints[4]. Specific features of frontal sinus are used for verification of age and sex identity.

Apart from the uniqueness of frontal sinus, maxillary sinuses also contribute for sex and age detection. It is a triangular pyramid shape sinus which consists of three recesses called alveolar recess, zygomatic recess and intra orbital recess. The volume of maxillary sinus is unique from person to person, even each side of the sinus differs from the other side in everyone[5]. The maxillary sinus terminates its final configuration at age of 15 years[5].

Several studies have proven that there is an innovative approach provides for sex estimation by angular measurements of frontal bone and linear measurements of skull. On the other hand, identification can also be achieved by assessing these cranium components by using their unique features. These features include bizygomatic breadth, fronto-nasal angle, mastoid process height and width, cranial index, foramen magnum length, and orbital height. By combined analysis of all the prominent features of the skull, a conclusion can be drawn regarding sex[3].

Computed tomography (CT) is utilized to supplement autopsy. A synergistic effect is evident between conventional autopsy findings and CT based forensic findings which tend to improve the medico-legal investigations. On the other hand, forensic data in CT can be utilized as an auxiliary tool for assessment of facial reconstruction[6]. Much research has been conducted on image guided virtual autopsy which enhance the reliability of the conventional autopsy techniques, and these methods can be used for development of medico – legal investigations in Sri Lankan context[6].

It is known that there is volume variation of Maxillary sinus with ethnic group and sex[7]. Therefore, medico-legal practitioners in Sri Lanka are unable to use the guidelines given through similar studies done in other countries.

OBJECTIVE

To determine the cranio-facial measurements which can be used to estimate the sex in the adult Sri Lankan population.

METHODS

Patients over 20 and below 90 years of age, who underwent non-contrast CT brain examination with details of their CT brain scans in machine storage from 1st of October to 31st of December 2020 at the Department of Radiology, University Hospital, Kotelawala Defense University (UHKDU) were considered. Patients who had traumatic or any other pathological conditions associated with the frontal and maxillary sinuses and skull bones, patients who had anatomical variation that might affect the volume of frontal or maxillary sinuses, patients who had craniofacial anomaly or condition affecting mid facial development, those CT scans with artifacts and images that did not contain required anatomical reference points were excluded from the study.

The study sample consisted of 166 individuals including 77 males and 89 females.

A multi-detector computed tomography (MDCT) scanner (Philips, Brilliance iCT family, 256 slices, the Netherlands) located in the radiography department

at UHKDU was used to do the CT examinations. All the measurements were taken using a commercial interactive volumetric-assist software (Volume Tracing in Advanced Vessel Analysis, Philips Healthcare, Cleveland, Ohio, USA) with the guidance of an experienced radiologist. The CT machine was operated at 120 kVp, 80 mA, and with the scan time of 60 seconds with 1mm slice thickness for each scan.

The research proposal was approved by the Internal Research Screening and Monitoring Committee (IRMSC) of Faculty of Allied Health Sciences, General Sir John Kotelawala Defence University. The ethical clearance for the study was obtained from the Ethical Review Committee (ERC) of Faculty of Medicine, General Sir John Kotelawala Defence University. The collected data were handled and stored with highest degree of confidentiality, which has limited access protected by password. Permission for data collection was obtained from the institutional review board of UHKDU.

All the CT brain examinations were done by radiological technologists, who are qualified with a basic degree of radiography, and registered in Sri Lanka Medical Council (SLMC), using the same standard head protocol. All the measurements were taken using axial, sagittal, and coronal planes by two observers separately under the supervision of a board certified radiologist, without any inconvenience to the hospital setup. The age and sex of the patient were recorded along with the measurements.

The volume of frontal sinus, and right and left maxillary sinuses were calculated using a commercial interactive volumetric-assist software (Volume Tracing in Advanced Vessel Analysis, Philips Healthcare, Cleveland, Ohio, USA) available in Philips CT scanner after creating the 3D image of each sinus by marking the lumen of sinuses manually in each of the axial image using bone window, and by erasing the excessive marked areas and remarking unmarked areas on sagittal and coronal images.

The angle of inclination of ideal forehead slope (ANV), the angle of inclination of actual forehead slope (BNV), the angle of deviation of actual from ideal forehead slope (ANB), and the nasofrontal angle (BNC) were taken as the measurements of angular forehead. These measurements were taken in the bone window of middle slice of sagittal reconstructed image selected using a viewing workstation (Extended Brilliance Workspace, Philips Healthcare, Cleveland, Ohio, USA). The line H (the anterior base of the skull which is defined as the reference horizontal plane), line V (the line which is, perpendicular to line H, defined as the reference vertical plane using the sagittal view), line A (ideal slope/line drawn from the nasion (Point N) to the point immediately superior to the supraorbital ridge, at the junction where supraorbital bossing ends and the softer curvature of the forehead begins), line B (actual slope/line drawn from the point N to the most anterior point of the supraorbital ridge), and line C (nasal slope/line drawn from the point N to the most anterior/inferior point of the nasal bone) were used as horizontal, and vertical reference planes for obtaining angular forehead measurements **(Fig.1)**.

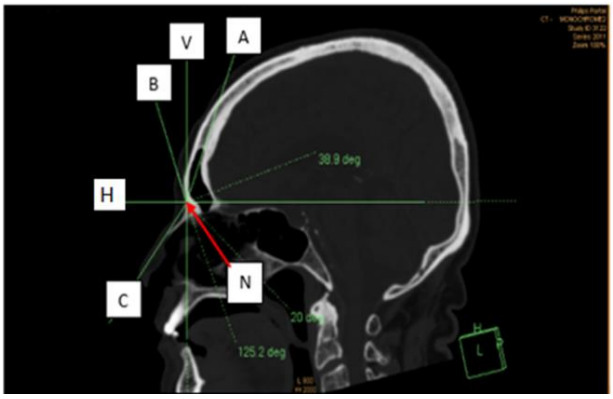

Figure 1: CT image showing the measurements of angular forehead

The glabella, external occipital protuberance, prosthion, bregma, and euryon were considered as the reference points to take the skull and facial measurements of each study participant. The skull length (SL) was measured from the glabella to the external occipital protuberance. The prostio-bregmatic height (PBH) was measured from the prosthion to the bregma. The maximum skull width (MSW) was measured from right euryon to left euryon. The SL, and PBH were taken using sagittal images while MSW was taken using coronal images (Fig.2). All these measurements were also taken in bone window by using a viewing workstation (Extended Brilliance Workspace, Philips Healthcare, Cleveland, Ohio, USA).

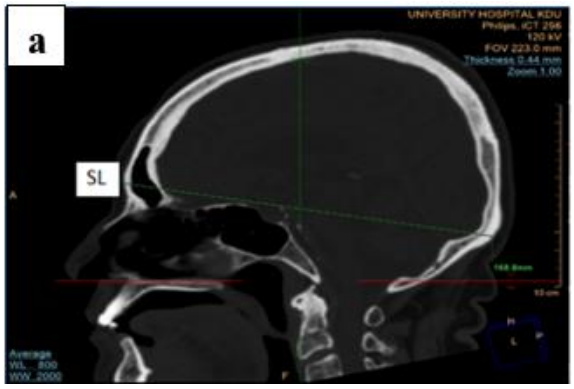

Figure 2a: CT image showing the SL

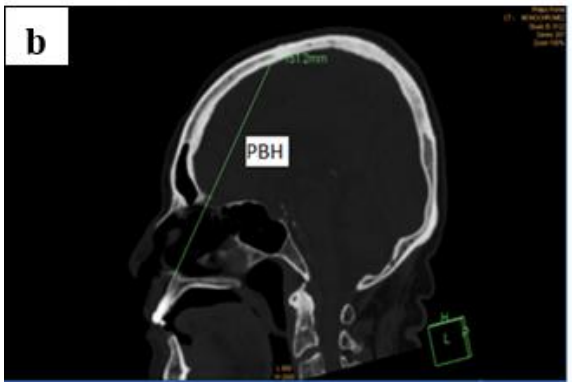

Figure 2b: CT image showing the PBH

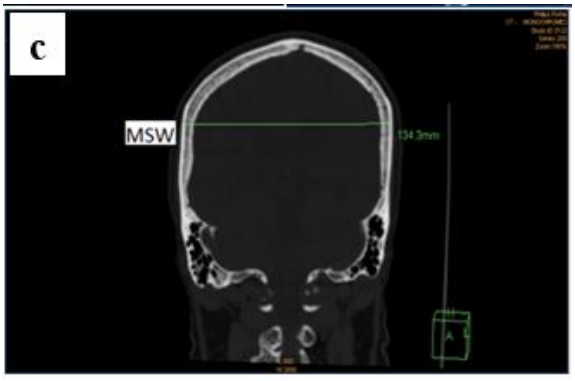

Figure 2c: CT image showing the MSW

All data were recorded in customized Microsoft Excel tables. The data were analyzed using the statistical tests such as independent sample t-test, Mann-Whitney U test, available in the SPSS version 25 software with P<0.05 indicating level of significance. The intraclass correlation coefficient (ICC) estimation was conducted to determine the inter-observer agreement. The independent sample t-test was used to determine if there is a significant difference of the left maxillary sinus volume (ML), right maxillary sinus volume (MR), MSW, PBH, and SL between males and females. The Mann-Whitney U test was used to determine if there is a significant difference of the frontal sinus volume (F), BNC, ANV, ANB, and BNV angles between males and females. The Point-biserial correlation was used to assess the correlation of ML, MR, MSW, PBH, and SL with the sex. The Spearman's correlation was used to determine the correlation of F, BNC, ANV, ANB, and BNV angles with sex.

RESULTS

The results of ICC estimation showed an excellent reliability between the measurements obtained by two observers with the inter-observer agreement greater than 90% (>0.90).

The study sample consists of 77 males (46.4%) and 89 females (53.6%). Study sample according to age groups is illustrated in table 1.

Table 1: Distribution of study sample among age groups

Age Groups	Frequency	Percent
20-29	12	7.2
30-39	8	4.8
40-49	13	7.8
50-59	36	21.7
60-69	36	21.7
70-79	35	21.1
above 80	26	15.7
Total	166	100.0

According to the results of Shapiro-Wilk test, ML, MR, SL, PBH, and MSW were normally distributed (P > 0.05) while F, BNC, ANV, ANB, and BNV angles were not normally distributed (P < 0.05). The descriptive statistics of normally distributed measurements and the descriptive statistics of the rest of the measurements is given in table 2. Furthermore, results of independent sample t-test and Mann-Whitney U test are included in table 2 and table 3 respectively.

Table 2: Comparison of male and female subjects on normally distributed measurements

Measure-ment	Sex	n	Mean	p*
ML	Male	77	14.41±4.49	<0.05
	Female	89	13.01±3.74	
MR	Male	77	14.95±4.68	<0.05
	Female	89	12.95±3.59	
SL	Male	77	174.12±6.31	<0.001
	Female	89	164.72±6.32	
PBH	Male	77	168.27±7.31	<0.001
	Female	89	158.65±7.57	
MSW	Male	77	139.65±5.41	<0.001
	Female	89	136.16±5.38	

***Student's t-test**

According to the results of independent sample t-test, ML, MR, SL, PBH, and MSW in females is lower compared to males and there is a statistically significant difference in measurements between the two groups.

Table 3: Comparison of male and female subjects on measurements which are not normally distributed

Measure-ment	Sex	n	Median	p*
F	Male	77	8.7	P<0.0001
	Female	89	6	
BNC	Male	77	11.3	P<0.0001
	Female	89	122.3	
ANV	Male	77	12.7	P > 0.05
	Female	89	13.3	
ANB	Male	77	43.1	P<0.0001
	Female	89	34.1	
BNV	Male	77	29.9	P<0.0001
	Female	89	19.6	

***Mann-Whiteny U test**

According to the results of Mann-Whitney U test, F, ANB, and BNV of males were significantly higher than those of females while BNC of females was significantly higher than that of males. In contrast, there was no significant difference of ANV between males and females.

DISCUSSION

The results of the present study showed that the males had a statistically significant higher volume in right and left maxillary and frontal sinuses compared to females. Like the present study, a study done in 2004 found that sex can be estimated by using the larger volumes in males' sinuses than in females' sinuses[7]. Further, another study done in 2017 found that the mean volumes of the sinuses were greater in men compared to women[8]. Moreover, a similar study done in 2018revealed that the volumes of right and left maxillary, sphenoid, and frontal sinuses were significantly greater in men compared to women[1]. Therefore it can be concluded that despite the ethnicity, sinus volumes were greater in males than in females.

The results of the present study found that ANB, and BNV of males were significantly higher than those of females while BNC of females was significantly higher than that of males. Further, there was no significant difference of ANV between males and females. In contrast, a study done in 2010 revealed that the angular forehead measurements such as BNC, ANV, ANB, and BNV were significantly larger in men compared to women[9]. The reasons for the discrepancy of the results might be due to the large number of study participant involved in their study compared to the present study, and the ethnic differences between studies.

Similar to the present study, a study done in 2010 found that all skull and facial structure measurements such as SL, PBH, and MSW were significantly different between males and females[13].

The present study was carried out on a study sample, taken from only one hospital, which is small compared to some similar studies done in other countries. Therefore, a further study is required in Sri Lanka with a larger sample size taken from multiple hospitals in different areas of the country to build up a model to predict the sex of a Sri Lankan person.

CONCLUSION

All the skull length measurements and maxillary and frontal sinus volumes used in this study showed a significant difference among male and female population of Sri Lanka. Moreover, angular forehead measurements except ANV significantly differ

among males and females. Therefore, the sex of a Sri Lankan person can be estimated using Left maxillary sinus volume (ML), right maxillary sinus volume (MR), frontal sinus volume (F), skull length (SL), prostio-bregmatic height (PBH), maximum skull width (MSW), nasofrontal angle (BNC), angle of deviation of actual from ideal forehead slope (ANB) and the angle of inclination of actual forehead slope (BNV).

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CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL ISSUES

None

AUTHOR CONTRIBUTIONS

SHGSS: designing the study, collecting, analyzing and interpreting the data, drafting and revision of the manuscript and approval of the final version to be published; **KMNGF:** designing the study, collecting, analyzing and interpreting the data, drafting and revision of the manuscript and approval of the final version to be published; **GS:** designing the study, collecting, analyzing and interpreting the data, drafting and revision of the manuscript and approval of the final version to be published; **LHMIMH:** designing the study, collecting, analyzing and interpreting the data, drafting and revision of the manuscript and approval of the final version to be published; **WMISW:** designing the study, collecting, analyzing and interpreting the data, drafting and revision of the manuscript and approval of the final version to be published; **RT:** designing the study, collecting, analyzing and interpreting the data, drafting and revision of the manuscript and approval of the final version to be published.

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RESEARCH ARTICLE

Impact of 100 days of COVID-19 lockdown on death patterns and mortality demographics of medico-legal autopsies done in the Northern Province of Sri Lanka

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ABSTRACT

Introduction: Effect of COVID-19 pandemic on main sectors including the judicial and medico legal system has been notable in Sri Lanka.

Objective: To determine the impact of lockdowns during COVID-19 on death patterns and mortality demographics of medico-legal autopsies conducted in Northern Province of Sri Lanka during the first wave of COVID-19 (between 20th March to 28th June 2020).

Methods: The data were compared on death patterns and mortality demographics of medico-legal autopsies conducted in Northern Province of Sri Lanka during the first wave of COVID-19 (between 20th March to 28th June 2020) (Group C) and autopsies done in the same pre-COVID period in 2019 (Group PC). Three hundred and fifteen autopsies were selected after exclusion of unclaimed bodies, reports with inadequate details and undetermined cause and manner of deaths.

Results: Number of cases in groups C and PC were 126 and 189 respectively. Majority of the deceased were males in both groups (C-73% and PC-67%). The proportion of natural deaths was similar in both groups (39.7% vs 38.9%). Proportion of suicidal deaths was higher in C (32.5% vs 24%). The proportion of home deaths was more during the lockdown period (34.1% vs 25%). The proportion of homicidal and accidental deaths collectively was higher in PC (36.5% vs 28.6%). No statistical significance was observed for any of the given parameters between the two groups.

Conclusion: Despite the absence of statistical significance, the increased percentage of home deaths and suicidal deaths could be attributed to the effect of lock downs such as reduced access to routine health care services and financial and psychological strain on individuals and families.

Recommendations: The effect of a high suicide rate even though not statistically significant should be considered in future lockdowns. More extensive studies are required in Sri Lanka in this aspect which might statistically be more revealing.

Keywords: Autopsies, cause of death, COVID-19 infection, lockdown, Sri Lanka

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INTRODUCTION

The spread of acute respiratory syndrome was first reported by the Chinese authorities in Wuhan City, Hubei province, China around December 2019[1]. It was caused by SARS–CoV-2 and titled as Coronavirus disease 2019 (COVID-19)[2]. The evidence suggests that patients become infectious before the symptomatology develops. This led to asymptomatic transmission in the community, whereas asymptomatic carriers were common among children and younger populations[3]. Conversely, the

disease severity and risk of death have been higher in the elderly population and people with co-morbidities, regardless of the age[4].

There were several methods proposed and implemented to control the transmission of the virus in the community. These included social distancing, generalized lockdowns, and controlled movement of individuals, closing businesses, and travel restrictions[5,6,7]. The first patient with COVID-19 was detected in Sri Lanka on 27th January 2020[8]. Later, government implemented curfews, lockdowns, inter-district travel restrictions during the first wave of COVID-19 spread from 20th March to 28th June[9]. Initially, a blanket curfew was implemented but later it was restricted to night time only.

Generalized lockdowns have serious negative effects, including psychological consequences in societies, especially in vulnerable groups. Most of the affected people belong to low socio-economic classes, migrant workers, the homeless, and refugees[10]. Impaired health care delivery to the public including routine services, increase in substance abuse and domestic violence, unhealthy lifestyle and dietary habits, loneliness and impaired cognitive functions are some of the direct detrimental consequences of lockdown[11]. Few reports were available in the literature on the impact of COVID-19 on medico-legal work. In a study done in Italy, during the first two months of the pandemic, it was reported that medico-legal autopsies were drastically reduced, but a considerable number of domestic violence cases were reported[12]. An autopsy study conducted in Greece revealed a reduced incidence of deaths from road traffic accidents and homicides, with no change in deaths following myocardial infarctions[13]. Up to date, there is no published data on the impact of COVID-19 on medico-legal autopsies in the Sri Lankan population. This study aims to describe and compare the types of autopsies performed during restrictions imposed in the first wave in 2020 with the same during 2019 pre-COVID period, in the Northern Province of Sri Lanka.

OBJECTIVES

To determine the impact of lockdown and restrictions following COVID-19 on death patterns and mortality demographics of medico-legal autopsies which were conducted in the Northern Province of Sri Lanka during 20th March to 28th June 2020 and to compare with the data of the same period in 2019.

METHODS

This was a cross-sectional descriptive study conducted in a retrospective observational manner. Data collection was done between 20th March and 28th June 2019(pre-COVID era) and same period of 2020 (COVID era) in the Forensic unit of the Teaching Hospital, Jaffna. Ethical clearance was obtained from the Ethics Review Committee of the Teaching Hospital, Jaffna. Medico-legal autopsies of unnatural deaths (accidents, suicides, and homicides) and natural deaths were studied. A total of 315 autopsies, with 189 in 2019 pre COVID-19 period and 126 cases in 2020, lockdown period were included in this study.

Information related to autopsies including medical history, place of death, cause of death and manner of death were obtained from completed post mortem reports, inquest reports prepared by inquirer into sudden death and police investigations reports. Anonymity was maintained at all times, denoting each case by a serial number.

Jurisdiction of the unit included the entire Jaffna peninsula and the only place where natural, accidental and complicated autopsies were performed by a board certified Forensic Pathologist. All cases are referred by the Magistrate and Inquirer into Sudden Deaths (ISD) to the Forensic Pathologist. A hospital death was defined as a death occurring in hospital after admission. In addition, deaths due to natural causes were defined as unexpected deaths while suicides, homicides and deaths following accidents were defined as violent deaths. Reports of unclaimed bodies, those with inadequate details, undetermined cause and manner of deaths following autopsy were excluded from this study. The cases which were still under investigation were similarly excluded for analytical purposes. Though assistance from two medico-legally trained doctors had been sought for collecting historical, clinical and autopsy data, reconfirmation and interpretation of such details were done by the investigators themselves. Total of 355 autopsies were selected for the study and later exclusions were made. Raw data collected on spread sheets were shifted to an electronic format. Data were coded and entered in Microsoft excel worksheets and analyzed by Statistical Package for Social Sciences (SPSS) version 21. Graphs and tables were used as appropriate to present the findings. Categorical variables were presented as percentages and numbers. Continuous data were presented as means and standard deviations. A P value of < 0.05 was considered as statistically significant. Pearson chi-square was used to calculate p value when the sample size was more

than 10 and Fisher's exact test, when the sample size was less than 10.

RESULTS

Total of 315 cases were selected for this study, with 189 cases in 2019 pre-COVID-19 period and 126 cases in 2020 lockdown period. Age of the deceased varied from one day to ninety-two years. In both pre-COVID and COVID periods the majority were male, being (66.7%) and (73%) respectively with a mean age of 49.9 ± 20.5 years in pre-COVID times and 47.9± 21.3 years in COVID times (**Table 1**).

Table 1: Distribution of details of autopsies according to the Place, type, manner and cause of death

Details of Autopsy	Variable	2019	2020	p-value
Autopsies performed (N)		189	126	
Age (Mean/median) ± SD years Range (min-max)		(49.85/52) ± 20.47 91(0-91)	(47.88/50) ± 21.29 92(0-92)	0.205
Gender N (%)	Male	126 (66.7%)	92 (73.0%)	0.232
	Female	63 (33.3%)	34 (27.0%)	
Age group N (%)	Below 20	12 (6.3%)	11 (8.7%)	
	21-40	49 (25.9%)	32 (25.4%)	0.954
	41-60	59 (31.2%)	39 (31.0%)	
	61-80	62 (32.8%)	37 (29.4%)	
	Above 80	7 (3.7%)	7 (5.6%)	
Place of Death N (%)	Hospital	116 (61.4%)	66 (52.4%)	0.113
	Home	47 (24.9%)	43 (34.1%)	0.075
	Outdoor	26 (13.8%)	17 (13.5%)	0.947
Death type N (%)	Violence	101 (53.4%)	72 (57.1%)	0.518
	Unexpected	88 (46.6%)	54 (42.9%)	0.518
Manner of death N (%)	Homicidal	5 (2.6%)	1 (0.8%)	0.408*
	Accident	64 (33.9%)	35 (27.8%)	0.254
	Suicidal	45 (23.8%)	41 (32.5%)	0.088
	Natural	75 (39.7%)	49 (38.9%)	0.888
Specific cause N (%)	Burns	10 (5.3%)	9 (7.1%)	0.630*
	Cardiac cause	35 (18.5%)	26 (20.6%)	0.641
	Hanging/Drowning	34 (18.0%)	29 (23.1%)	0.275
	Other medical causes	41 (21.7%)	23 (18.3%)	0.457
	Other traumatic causes	17 (9.0%)	9 (7.1%)	0.677*
	Poisoning	11 (5.8%)	6 (4.8%)	0.802*
	RTA	40 (21.2%)	24 (19.0%)	0.647

*Test performed by Fisher's Exact, others by Pearson chi-square

The number of autopsies was reduced by 33% during the locked down period in 2020 (n-126) than pre-COVID period on 2019 (n-189). An increased proportion of home deaths were noted in the lockdown period in 2020 (34.1%) compared to the same period in 2019 (24.9%) while hospital deaths were higher in 2019 (61.4%) compared to hospital deaths in the lockdown period in 2020 (52.4%) (**Table 1 and Fig. 1**).

Regarding the manner of death, percentage of homicidal deaths (0.8%), and accidental deaths (27.8%) were less in 2020 compared to 2019 (2.6% and 33.9% respectively).

Moreover, proportion of suicidal deaths was higher in 2020 (32.5%) compared to that of 2019 (23.8%). Natural deaths during the pre-COVID period, 2019 and COVID lockdown period, 2020, did not reveal significant difference in percentage (39.7 vs 38.9 respectively) (**Table 2**). The incidence of violent, unnatural deaths were higher in 2020 (57.1% vs 53.4) and natural, unexpected deaths were higher in 2019 (46.6% vs 42.9). Among the cause of deaths, more proportion of deaths have been due to cardiac origin in 2020 (20.6% vs18.5) whereas deaths due to non-cardiac origin claimed 18.3% in 2020 to that of 21.7% in 2019 (**Table 1 and Fig. 2**).

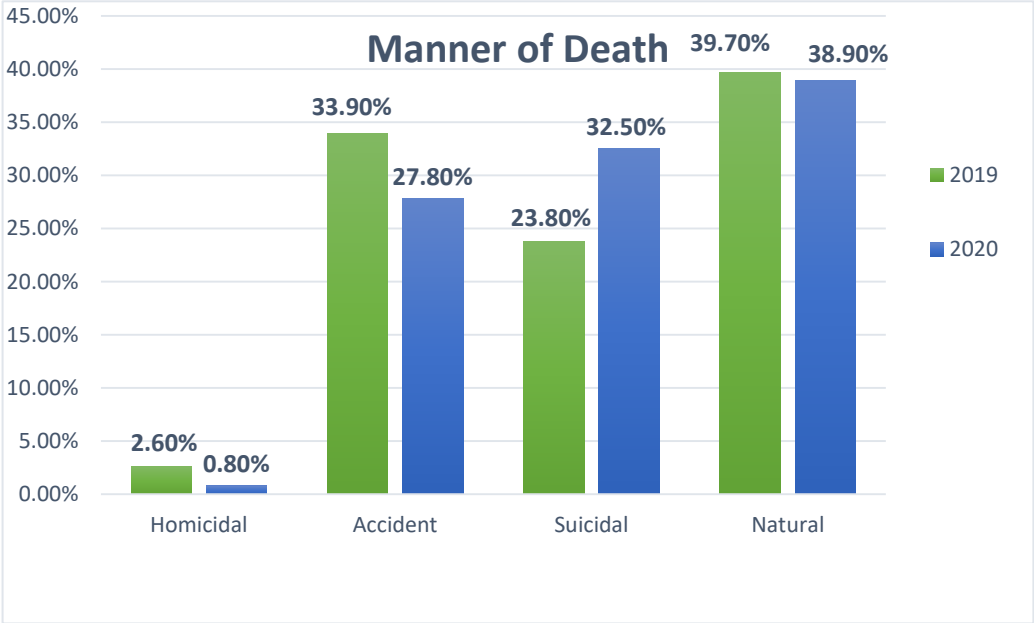

Figure 1: Distribution of details of autopsies according to the manner of death during pre-COVID period in 2019 and COVID lockdown period in 2020.

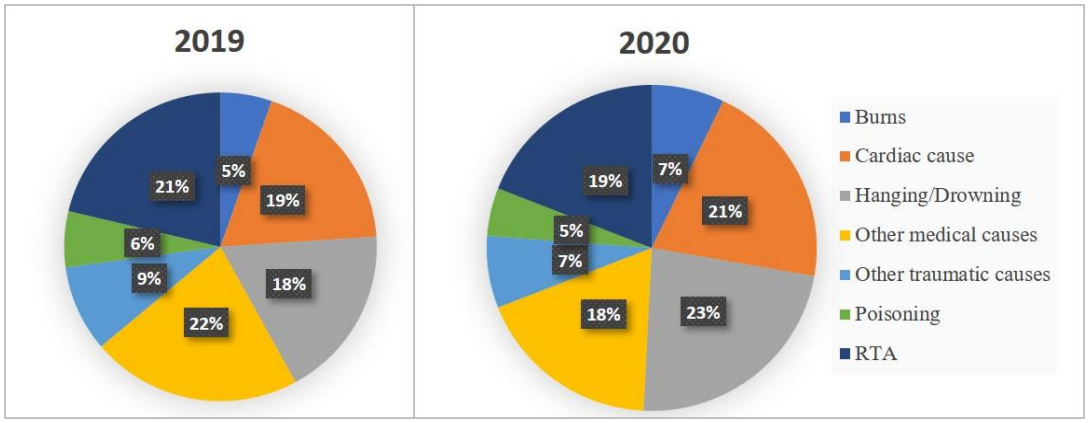

Figure 2: Distribution of details of autopsies according to the cause of death during pre-COVID period in 2019 and COVID lockdown period in 2020.

Pearson chi-square test revealed no statistically significant impact on autopsies done in Northern Province of Sri Lanka during COVID-19 lockdown period in 2020 when compared with autopsies done on the same period in 2019 (**Table 2**).

DISCUSSION

Autopsy examination is the key component of a medico-legal death investigation throughout the world. Sri Lanka follows the coroner system for this purpose. Several important issues related to personal safety and infection control arose when investigating deaths during the COVID-19 pandemic. Scene visit investigations, handling and transporting of dead bodies, are few of the primary concerns met by the medico-legal teams. Apart from the aforementioned, autopsy procedures, use of personal protective equipment, cleaning and disinfection are other practical concerns that were documented[14]. In Italy during the initial period of the crisis, due to lack of protective equipment and negative pressure autopsy rooms, targeted dissection was preferred than full autopsies[15]. In our setup, although several cases were reported during the first wave of COVID-19 infection in the Northern Province, no deaths were recorded. However, with the spread of the disease with the second and third wave, death rate rapidly rose proportionate to the number of patients, with more cases being presented to the Forensic Pathologists and warranting strict occupational safety measures due to the increased exposure to the public during the scene visit examinations, history taking process with relatives, public and law enforcement officers.

With regard to the findings of this study, the number of medico-legal autopsies during the lockdown period (2020) has been reduced to that of the same period in previous year by 33%. This finding correlates with similar studies of other countries[13,15]. The restricted and controlled transportation, decline in aggressive physical altercations due to social distancing and fall in occupation-related deaths due to limitation on factory and construction works, may be considered as causes for this reduction during the period of lockdown. In contrast, deaths due to suicide were high during the same period. This may be due to increased psychological distress following isolation for longer periods of time which has led to disputes in between couples, family members, lack of hobbies and exercise and loneliness. The profound effect on mental health due to the pandemic has already being identified[16]. Moreover, self-isolation, physical distancing, and anxiety play a considerable, negative role on patients with mental illness[17]. Importantly, the pandemic has led to financial constraints, unemployment, entrapment, loneliness, increased domestic violence, mental stress and alcohol consumption which are known precipitants of suicides[18,19]. Access to highly lethal means of self-harm is another known risk factor for suicide which has been facilitated by this pandemic. Staying at home can lead bereaved individuals to access pesticides, poison, analgesics and drugs which are readily stored at home[18]. In our study, percentages of suicides were higher during the lockdown period compared to the same period in last year. Though hanging was the leading cause of fatality in both years, this was proportionately higher during the lockdown period. Similar results of increased suicidal rates were reported during 1918- 1919 influenza pandemic in United States of America (USA) and 2003 severe acute respiratory syndrome (SARS) epidemic in Hong Kong[20,21]. On the other hand, Sri Lanka is well known for its high suicide rates, and this fact should be kept in mind while interpreting this study finding[22].

It is commonly conceived that the lockdowns can drastically reduce the fatal road traffic related trauma due to restrictions in vehicular movement. This is in par with our study, where there was an overall reduction in percentage of road traffic trauma related fatalities. This finding is comparable with a previous study conducted in Nepal[23]. In contrast, a study conducted in USA revealed increased number of fatal single vehicle crashes[24]. Several reasons were postulated by researchers of the latter study, for relatively high or static Road Traffic Trauma related death during the lockdown time. Increased driving speed with reduced traffic congestion, speeding of vehicles and risky behaviors of drivers owing to absence of traffic police officers are some of them[23,24]. This increased speeding due to less traffic was further strengthened by research studies on cognitive behavior of drivers involved in motor vehicular operation[25,26].

The homicidal deaths are associated with crime and COVID-19 lock down measures demonstrated a noteworthy but heterogeneous impact on this around the world. Studies conducted in Latin-American countries including Mexico reported a drop in homicidal cases since the COVID-19 restriction methods implemented[27]. However, a study in USA signified a significant increase in homicides in some parts of the country. For example, from 2019 to 2020, a 15 % increase in homicide rates was reported from Philadelphia[28], while no significant changes were noted in a study from Los Angeles[29]. In our study, there was an 80% reduction in homicide where only one case of homicide was reported during the lockdown period when compared to 5 cases in the previous year. Criminal activities, alcohol consumption, illicit drug

usage are some factors associated with homicides[28,29] and in Sri Lankan context, increased surveillance of law enforcement forces, and increased number of police roadblocks during the pandemic lock down could possibly have led to the reduction of homicides.

The current pandemic made the health care system to restructure itself to encounter the acute respiratory problems following COVID-19 infection. The restructuring was carried out by cutting down of the routine services and out-patient clinics and diverting the resources towards the emergency and critical care management in Sri Lanka. Nevertheless, this process had reciprocal effects on management of chronically ill patients and this fact was reported in several studies around the world[30,31]. In addition to the limitation of routine services, travelling restrictions, hesitancy of chronically ill patients to visit hospitals owing to the fear of acquiring infection might be other reasons for escalated home deaths during this period. This impression was reinforced by a UK based study on heart failure management, which revealed concomitant reduction (47 %) in admissions to treatment centers with increased home deaths following heart failure, during the pandemic[32]. In our study, even though increased percentage of home deaths were noted during the Covid period compared to the preceding year, no significant difference in natural unexpected deaths were identified. Among the natural cause of deaths, deaths due to cardiac origin were higher in 2020 (20.6%) and deaths due to non-cardiac origin were higher in 2019 (21.7%) in our study.
This simple descriptive study reveals that there is an impact on death patterns and mortality demographics of autopsies done during COVID-19 lockdown period to that of pre-COVID period. Even though a statistical significance was not observed, there was an impact on autopsies done in Northern Province of Sri Lanka, during COVID-19 lockdown period in 2020 when compared with autopsies done on pre-COVID period in 2019. Important reason for non-significant statistics may perhaps be a comparison samples only limited to autopsies of 2019, which did not include samples of 2018, 2017, etc. of pre-COVID era. Other reasons for non-significant statistical results may be multifactorial, which include small sample numbers, difference in sample sizes during pre-COVID (N-189) and COVID-19 locked down period (N-126), exclusion criteria, extreme outliers and random chance of occurrence of deaths.

CONCLUSION

Autopsy rates were reduced by 33% during the lockdown period. Even though it was not statistically significant there was an impact of COVID 19 on autopsies done in the Northern Province of Sri Lanka, during the COVID-19 lockdown period in 2020 when compared with autopsies done in pre-COVID period in 2019. These trends of change in the cause and manner of death during the COVID-19 period will guide health care providers to implement control measures to minimize suicides, homicides, accidental and natural deaths with new strategies which may be different from those during the non-COVID era.

RECOMMENDATIONS

The authors recommend larger scale, multicenter studies at medico legal morgues of other provinces locally and internationally and comparison with multiple control samples of pre-COVID years to obtain more valid data with statistically significant results.

LIMITATIONS

The study compares autopsy details of the lockdown period of 2020 with the autopsy material collected from the same period of 2019. Therefore it limits the outcome analysis of the study, as analysis did not compare autopsy material in previous years to ascertain a significant effect of lockdown on medico-legal autopsies done in the Northern Province of Sri Lanka.

LIST OF ABBREVIATIONS

ISD - Inquirer into Sudden Death
SPSS - Statistical Package for Social Sciences
USA - United States of America
SARS - Severe acute respiratory syndrome

CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL ISSUES

None

AUTHOR CONTRIBUTIONS

SP: conception, design, data acquisition, analysis, interpretation, manuscript preparation, final approval; **SR:** conception, design, data acquisition, analysis, interpretation, manuscript preparation, final approval; **UM:** conception, design, data acquisition, analysis, interpretation, manuscript preparation, final approval; **BMM:** design, data analysis, interpretation, manuscript preparation, final approval; **KV:** conception, design, data acquisition, analysis, interpretation, manuscript preparation, final approval; **NS:** design, data analysis, interpretation, manuscript preparation, final approval.

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CASE REPORT

Injury interpretation and reconstruction of events in a victim of a 'hit-and-run' road traffic incident

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ABSTRACT

Forensic reconstruction of events is akin to assembling a jigsaw puzzle. Missing pieces of the jigsaw puzzle exacerbates the difficulties. Deductions or conclusions arrived should be supported by scientific evidence during the medico-legal investigation. A case where a man was found dead by the roadside with a damaged motorcycle is reported. The police investigation determined that the incident was a "hit-and-run" road traffic injury with no evidence of "run-over".

This case study reveals how meticulous injury interpretation and event reconstruction by the Forensic pathologist helped unravel an "atypical run over injury "in a hit-and-run traffic injury.

Keywords: Run-over-injury, hit-and-run accident, reconstruction of events, road traffic trauma

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INTRODUCTION

A medico-legal expert (forensic pathologist) is obligated to address any medico-legal issues that arise following violent deaths. Investigation of a crime scene by investigating police officers and available post-mortem findings are often enough to reconstruct events during most routine medico-legal investigations. However, there are some instances in which extensive analysis and interest is required to address medico-legal issues. Incorrect reconstruction has grave consequences in the medico-legal field, as it may effectively exonerate the perpetrator while concluding an innocent person as guilty. Events occurring during a victim-vehicle collision can be complicated. Therefore such events should also be analysed and interpreted with caution[1]. Due to the scarcity of biomechanics and its applications in Sri Lanka, scene investigation and scientific observations were used to reconstruct the events in this case.

It is not infrequent to sustain bizarre-patterned injuries during road traffic accidents. As result, it is possible that certain injuries are overlooked. This case report is an instance where reconstruction of each injury in a logical manner proved to be of major benefit in revealing an atypical run over injury that was not initially suspected by the investigating police officer.

CASE HISTORY

A 49-year-old male was discovered dead by the side of the road along with his damaged motorcycle. This was suspicious of a hit and run accident. There were no eyewitnesses or CCTV footage of the incident. However, a sudden moderately loud noise had made a neighbour visit the scene. He had noticed the unresponsive victim lying on the road. He was wearing a helmet with no other protective wear. The victim's severe damaged motorcycle was located by the side of the road with.

External examination of the upper back of the T-shirt revealed three tears, blackish dust/grease marks and dried 'saturated bloodstains'. The middle

tear showed a concavity towards the midline (**Fig. 1**). The other external injuries were lacerations to his left external ear and to the lower lip, as well as a contusion measuring 3x4 cm in size over the left side of his neck. All injuries were simple in nature. A roughly rectangular abraded contusion measuring 20x15 cm was observed, across the back of his upper chest, sparing the mid-chest with an oval shape (15x10 cm) (**Fig. 2**). There were no de-gloving or avulsion injuries. Grazed abrasions, injuries to genital region, long bone fractures and skull fractures that are typically expected in a motorcyclist following a collision with another vehicle were not evident in this case.

Internal examination revealed diffuse axonal injury (grade 3 level), diffuse vascular injury, and diffuse subarachnoid haemorrhage with no skull fractures (**Fig. 3**). (No histopathological studies were performed which is a drawback of this study). Bilateral rib fractures were observed posteriorly. There were bilateral lung contusions, lung lacerations and bilateral haemothorax (approximately 200 ml in total). The 2-8th ribs were posteriorly fractured in two locations, bilaterally. These fractures were stacked one on top of the other, resulting in the formation of two imaginary lines (**Fig. 4**). The most medial "fracture lines" were drawn parallel to the vertebral column, while the most outer "fracture lines" were drawn a few centimetres away and equidistant from those (**Fig. 4, 5, 6 & 7**). The most lateral fracture lines were "curvilinear" in shape, which corresponded to the oval-shaped skin marking and also to the middle tear on the T-shirt (**Fig. 1**). There was an undisplaced fracture of the vertebrae at the T1 and T2 levels, resulting in partial spinal cord damage.

The cause of death was determined to be blunt force trauma to the head, chest, and spine sustained by a motorcyclist as a result of a vehicular collision. The incident was described as a run over injury by a heavy vehicle of which the driver had driven away without informing the police (hit-and-run road traffic injury). The injury pattern was consistent with those sustained due to acceleration and deceleration (head injury), and run-over (upper back of chest) by a heavy vehicle. The run-over injury was unequivocally diagnosed by considering the torn areas, faint grease/dust marks on the back of the T-shirt, and by the underlying injures that were unexplained otherwise.

Figure 1: The arced-shaped tear in the back of the T-shirt (yellow arrow). Two other tears (black arrows). The blackish marks gradually decrease in density from left to right.

Figure 2: The roughly rectangular abraded contusion across the upper back of the chest, with an oval-shaped sparing of skin centrally. The injury is more pronounced towards the left side than the right side.

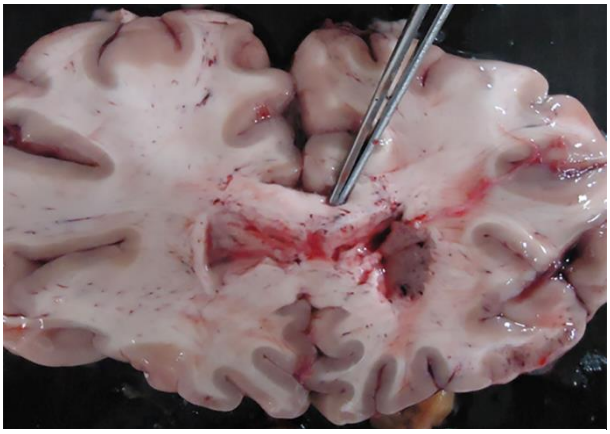

Figure 3: A coronal section of the frontal lobes of the brain with the typical haemorrhage in the corpus callosum that indicates severe diffuse axonal injury.

Figure 4: The schematic diagram depicts the locations of posterior rib fractures (note the curved pattern of the fracture lines situated on the ribs).

Figure 5: A schematic diagram of how a bony flap could have been formed as a result of a tyre being run over the back of the rib cage while victim was in a prone position.

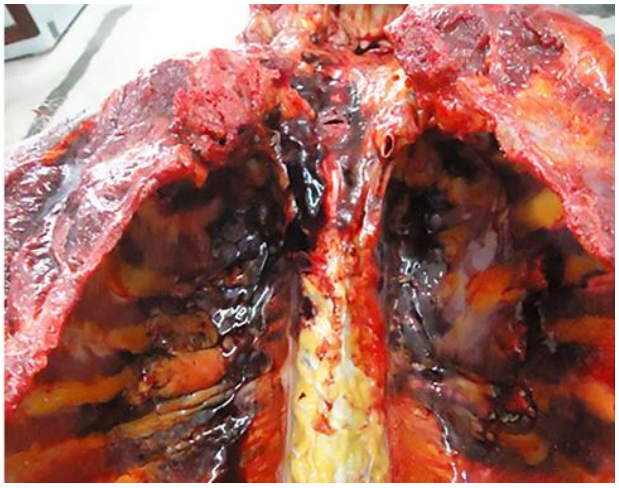

Figure 6: The interior of the rib cage with "fracture lines" and vertebral fractures at T1 and T2.

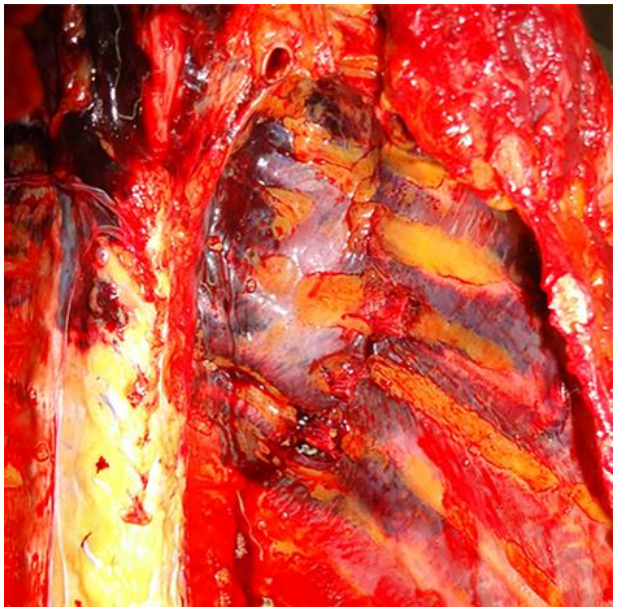

Figure 7: The "curved fracture line" on the left hemithorax.

The large injury in the form of an abraded contusion that extended across the back of the upper chest was initially not explainable during the post-mortem examination. However, a degree of suspicion as to why the undamaged peculiar patterned injury was seen within the contused abrasion was the trigger to analyse injuries extensively. If the injury over the back of the chest was not analysed and interpreted as a whole, this deduction would have been impossible.

DISCUSSION

A "hit-and-run" accident is where a driver of a vehicle who collides with another vehicle, property,

or human being leaves without providing the investigating party with his/her identity[2,3]. Because the case at hand involves a "hit-and-run" accident, it is necessary to reconstruct the dynamic events that occurred and to interpret the injuries in order to identify the implicated vehicle and the driver. Reconstruction essentially requires the correct identification of the mechanism of causation of injuries. It is easy when the injuries are typical in a given instance. When the injuries are atypical or not consistent with the usual appearance it is difficult to interpret. This may result in wrongful interpretation and lead to incorrect inferences that will lead to a miscarriage of justice.

The author was unable to interpret or provide an opinion on the injury situated on the upper back of the chest despite considerable efforts. It did not show features of a primary impact injury or secondary injury. However, subsequent to injury documentation the internal dissection was initiated without any interpretation of external injuries. The internal examination revealed multiple posterior rib fractures, lung lacerations and contusions, and vertebral column damage arousing suspicion of a run over injury. There was no other convincing explanation for the severity of the injuries that he had sustained on his chest.

An examination of the scene was conducted retrospectively by the author. This did not result in any convincing evidence to ascertain the reason for the spared skin in the upper mid-back of the chest. Given that those injuries were sustained as a result of being run over, the author was then compelled to look for possible tyre marks on his body and clothing. The mark observed on the back of the upper chest which did not have a viable explanation at the outset of the postmortem examination was then subjected to study in-depth. If the mark was caused as a result of a run-over accident, it was necessary to determine the reason for absence of typical tyre marks and the reason for sparing of an oval-shaped area of skin in the centre or either side of the midline. The absence of typical tyre tread marks on the alleged run-over injury was may be attributed to the vehicle having wasted tyres. The T-shirt that the deceased was wearing may have also partly contributed to the absence of tyre-thread marks.

Absence of injuries over the upper mid-back of the chest should also be explained as the second query that was encountered during the medico-legal investigation. However, the reason for that was not clear and required further meticulous observations and reasoning.

As shown in Figures 4, 6 and 7, the 2-8th ribs had been bilaterally fractured in two locations, resulting in the formation of two vertical imaginary lines on each side. The symmetrical rib fractures in the 2-8th ribs allowed for the formation of 'a separate bony flap' that could be pressed into the posterior thoracic cavity while the tyre ran over the upper back of the chest in the prone position. The fractures at the first and second thoracic vertebrae may have facilitated indentation of the bony flap, thereby preventing skin contact with the running tyre (**Fig. 5**).

Another medico-legal issue that needed to be addressed was the vehicle's travel direction. The concentration of dust and grease marks on the victim's clothes, which decreased from left to right while the victim was prone, was used as evidence[4,5]. The severity of the skin injury was also gradually reduced from his left to right while he was in the prone position. By considering those two facts the author was able to provide an opinion that the offending vehicle was moving from left to right of the victim while he was in prone position.

Severe diffuse axonal injury (DAI) (grade 3) in conjunction with diffuse vascular injury (DVI) suggested the acceleration, deceleration, and rotating movements inflicted on his head[6,7]. The presence of unequivocal DAI and DVI indicates (**Fig. 3**) that his body was subjected to significant force as a result of the incident[8].

It is the duty of the forensic pathologist to provide useful information after the post-mortem examination to the investigating police officer to continue his investigations. On this body, there were no primary or secondary impact injuries or secondary injuries. Instead, a run over injury was identified. At the end of the post-mortem investigation, the author informed the investigating Police officer that there has been a component of "run over" in addition to it being a hit and run incident. The estimated minimal width of the tyre from one sidewall to another of the offending vehicle and the direction of travel of the vehicle was also determined (The width was 15 cm and the vehicle moved from left to right of the victim while he was in the prone position at the scene). The police were further informed that no paint flakes or any other trace evidence was collected from the dead body.

On query by the Police, the possibility of being run over by two vehicles was ruled out due to the 'uncomplicated nature' of the injuries confirmed by the judicial medical officer and also by the direct

testimony from neighbour who rushed to the scene immediately upon hearing the moderately loud noise.

The technical examination of the motorcycle that was conducted by the Police investigators along with findings of run over injury, revealed that the offending vehicle had collided with the motorcycle, imparting significant kinetic energy to his body, causing him to be thrown off from his seating position resulting in run over by the same vehicle.

In this case, the dynamic events were reconstructed using knowledge from basic sciences and empirical studies. The width of the tyre mark injury provided information about the tyre's dimensions. As per the dimensions of the injury situated over the back of the chest, the width of the tyre from the sidewall to the opposite sidewall was around 15 cm (**Fig. 2**). It provided a clue or evidence to trace the offending vehicle. Furthermore, if sufficient research had been conducted on the force required to cause this level of damage and chest compression, the weight of the vehicle, whether it was loaded or not could have been reconstructed to a certain extent[9]. This case highlights the fact that forensic biomechanics needs to be incorporated into the Sri Lankan medico-legal investigations because such techniques will help the investigative process by providing reliable evidence[10]. Hence this case report highlights the importance of the application of biomechanics.

A medico-legal expert must suggest the dynamic actions that could have occurred during a road accident. The dynamic movements of the victim that could have occurred during the incident/impact should also be considered with great care while arriving at conclusions. However, there is no standard scientific procedure to cross-check or double-check the conclusions reached based on reconstruction of events in this case. Further there is no other convincing explanation for this case scenario within the limits of examination. As a result, it was concluded that the 'bony flap' supposedly created by the moving tyre on the upper back could have resulted in the atypical "run-over injury".

CONCLUSION

Since extensive internal injuries along with bizarre external injuries are common in fatal incidents of road traffic accidents meticulous injury interpretation and event/injury reconstruction would be useful in determining the sequence of events.

RECOMMENDATIONS

It is essential to develop the field of biomechanics in order to make more useful conclusions such as positive identification of the perpetrator and the offending vehicle.

CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL ISSUES

None

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CASE REPORT

A fatal seizure - A large cerebral abscess in a child with uncorrected Tetralogy of Fallot: A case report

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ABSTRACT

Cerebral abscesses are relatively common among children with cyanotic heart diseases. Tetralogy of Fallot is the leading cardiac structural abnormality which leads to cerebral abscesses. Despite recent reductions in mortality largely brought forth by early diagnosis and aggressive treatment protocols including surgery and/or parenteral antibiotics, such life-threatening cerebrovascular complications are still witnessed in low-resource settings such as Sri Lanka. The resulting mortality and morbidity is potentially preventable, with high degree of suspicion, directed history and examination, guided investigations and immediate surgical or non-surgical therapy, whenever appropriate. The presentation varies but fever, behavioral changes, and focal neurological signs are common and can point towards the diagnosis. This case report discusses a 2-year-old child diagnosed with Tetralogy of Fallot who initially presented with fever and generalized malaise, subsequently developed seizures and succumbed following a large cerebral abscess which was diagnosed post-mortem. The sequence of events following the initial medical contact suggest the potential reversible nature of the acute outcome, reinforcing the knowledge that first responders including doctors should be aware of life-threatening presentations of diseases.

Keywords: Congenital cyanotic heart disease, Tetralogy of Fallot, Cerebral abscess, Paediatric

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INTRODUCTION

Tetralogy of Fallot (TOF) is the commonest cyanotic heart disease, which predisposes to brain abscesses in the newborn and child[1-5]. These cyanotic heart diseases occur either as isolated anomalies or as a part of a syndrome and/or an association[6-7]. Complications following TOF are relatively rare at present especially in developed countries due to advances in palliative surgery and complete repair during infancy[7]. In contrast, these are not uncommon in developing countries due to inadequate resources and limited or delayed access to advanced cardiac care[1,2,8], which ultimately leads to increased morbidity and mortality among the affected. The delay in diagnosis of the underlying life-threatening cerebral abscess which is not an uncommon clinical presentations and potentially treatable, emphasizes the need for a high degree of suspicion and expedited investigation and treatment as it may be missed in non-specialized clinical settings.

CASE HISTORY

A 2-year-old boy diagnosed with TOF and ventricular septal defect (VSD), presented to a private hospital with fever, poor feeding, and drowsiness for about three days. There was no history of vomiting or fits on admission. He was born following vaginal delivery to non-consanguineous parents.

Examination revealed, a conscious, ill-looking, febrile child (Temp 102ºF), with a pulse of 110/min, blood pressure of 80/60 mmHg, parasternal heave, pan systolic murmur, moderate clubbing, and conjunctival congestion. An echocardiogram revealed 50% overriding aorta, stenosis of the pulmonary artery at the infundibular and valvular level, right ventricular hypertrophy. Infective endocarditis was excluded.

He was transferred to a government hospital based on financial, administrative, and clinical reasons after about 12 hrs. On admission to the second health care institution, the child developed one episode of generalized tonic colonic movements of a few minutes duration with spontaneous recovery. The child was treated empirically with intravenous ceftriaxone and metronidazole for sepsis. Arterial blood gas analysis revealed severe hypoxemia with metabolic acidosis. X-ray chest revealed right ventricular hypertrophy, uplifted apex, and oligaemic lung fields. CT brain was opted but was not available at this point. The child's condition rapidly deteriorated and he succumbed within six hours of admission.

The reports received after death showed a raised white blood cell count of 30,000/mm^3, (neutrophils - 87%, lymphocytes - 4.4%), platelet count of - 265,000/mm^3, haemoglobin level of 19 g/dl, hematocrit of 60%, and CRP of 133 mg/l.

He had been followed up and further investigated for the above condition at three-monthly intervals since birth and had been referred to a pediatric cardiothoracic surgeon for surgical correction at 12 months of age with suggestions for a Blalock (BT) shunt if significant desaturation developed before surgery. Surgery was planned at 18 months of age, but, was delayed twice due to the COVID-19 pandemic.

A Judicial postmortem examination was ordered by the inquirer into sudden death.

The autopsy revealed features of failure to thrive, fingernail clubbing, features of TOF during cardiac dissection revealing a large VSD with accompanying overriding of aorta, right ventricular hypertrophy and pulmonary stenosis, (**Fig. 1**).

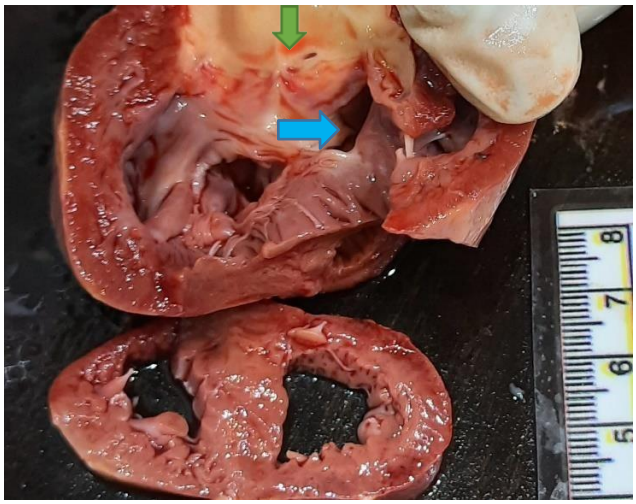

Figure 1: Large VSD (blue arrow) and 50% overriding aorta (green arrow), with right ventricular hypertrophy

There was oedema of the brain (weight of 1200 g), obliterated gyri and flattened sulci, a large purulent abscess (5x7x6 cm) within the right cerebrum which had ruptured into the right ventricle and purulent cerebrospinal fluid (CSF). (**Fig. 2, 3, 4**)

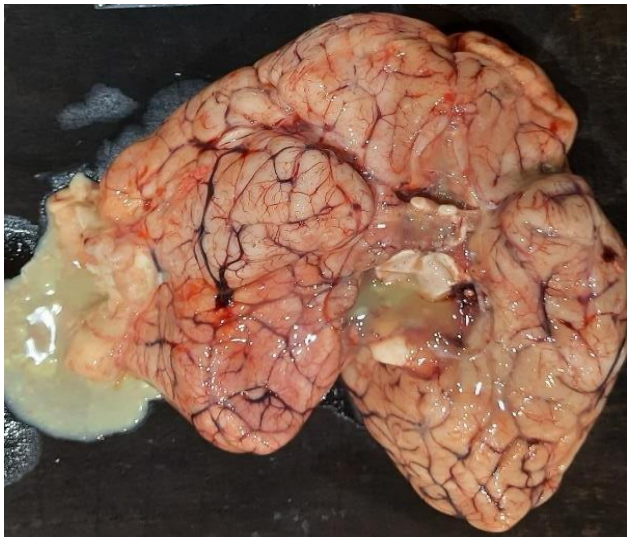

Figure 2: Turbid colour CSF leaking at the base of the brain and post mortem rupture of the abscess

Figure 3: Isolated large abscess of right parietal lobe ruptured into lateral right ventricle

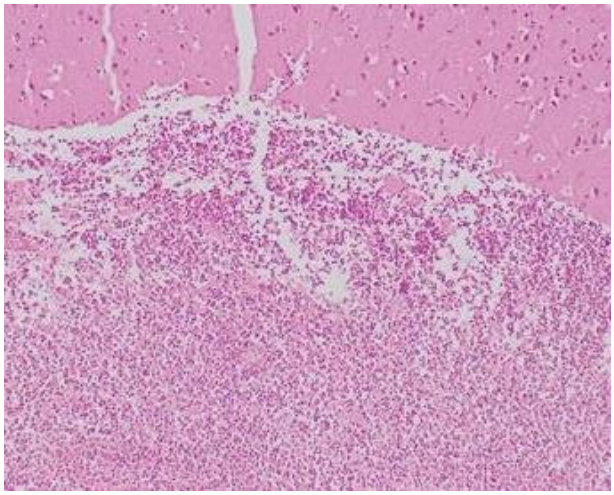

Figure 4: Collection of leukocytes with predominant neutrophil abscess with borderline brain parenchyma (H&E low power)

The spleen was diffluent and there were adrenal haemorrhages. Meninges were unremarkable. Blood and Pus culture did not yield any organisms. Full histological analysis of internal organs was performed and the cause of death was elucidated as sepsis following brain abscess in a child with Tetralogy of Fallot.

DISCUSSION

According to the most recent statistics, around 0.5-0.8 % of live births are complicated by congenital heart diseases (CHD)[7]. The incidence is tenfold higher in the stillborn[6]. Approximately 12% of the patients with CHDs have chromosomal defects. The causality is mostly multifactorial, precipitated by a complex interplay between genetic and environmental factors[6]. Implicated cardiovascular teratogens include maternal infections, drugs, and maternal diabetes which interfere with the normal development of progenitor cells of the primary and secondary heart field, neural crest cells, and endocardial cushions[6]. TOF represents 5-7% of all congenital heart diseases and 9.6/10000 live births[6-7]. This has been attributed as the leading cause of brain abscess in children[1,2,4].

The right to left shunting of blood in TOF results in bypassing the phagocytic activity of lungs which allows direct entry of this unfiltered blood into cerebral circulation, seeding of microorganisms, and consequent abscess formation[8,9]. Low perfusion of selected areas in the brain due to associated polycythemia leads to tissue hypoxia and acidosis[10]. Decreased oxygenation of blood due to pulmonary stenosis and pulmonary shunting through septal defects further aggravate the tissue hypoxia and acidosis.

In cyanotic congenital heart disease, microorganisms in shunted blood could lead to a cerebral abscess. [8] Most commonly, cerebral abscesses are caused by *Streptococcus milleri* and are rarely due to *Peptostreptococcus, Streptococcus intermedius, Bacillus* species, and *Staphylococcus epidermidis*[4,5]. Interestingly, however, no organisms have been identified in cultures in some studies[11] which is similar to our case, where blood and the pus culture revealed no growth. This may be due to the time lapse between death and postmortem examination, delays in collection, errors in sampling, delays in transport to the laboratory[11], and prior treatment with intravenous antibiotics. With regard to the outcome following cerebral abscess, the mortality is around 10-12% with significantly reduced long-term morbidity (up to 30 to 50%) in developed countries[13-17]. A large cohort study based on two centers in London and Paris which included 144 infants and children, reported a mortality rate of 4% and approximately 80% of acceptable outcomes[13]. The main explanations may relate to the availability of radiological studies (MRI) leading to early diagnosis, improvements in surgical techniques facilitating safer access to abscesses, and the utility of broad-spectrum antibiotics. If the cerebral abscess was diagnosed earlier with CT/ MRI scan, this child could have survived with timely, empirical antibiotics and/ or surgical drainage.

In contrast to developed countries where, ear, nose and throat infections are the commonest precipitants of cerebral abscess among children[13], cyanotic CHD is still largely responsible for the latter in developing countries[1-5]. This noticeable difference may be due to the early correction of congenital heart disease by advanced surgery in high-resource settings of developed countries. In this particular child, surgical correction had been planned but delayed due to longer waiting times and the ongoing COVID-19 pandemic.

In general, complications such as cerebral abscess and cerebral thrombosis usually occur after the age of two years in cyanotic CHD[7]. Several anatomical variants have been discussed in the literature, which might lead to differing clinical course and symptomatology. In 'Pink type TOF' minimal or no right ventricular out flow tract obstruction (RVOTO) is witnessed. 'Profound cyanosis TOF' denotes a complete RVOTO and the 'classic TOF' describes a partial RVOTO and overriding of aorta[19]. In autopsy studies in patients with TOF who present following sepsis, it is imperative to look for possible foci. Cerebral abscesses are the commonest foci. However, infective endocarditis and pulmonary infections should also be looked for.

There is a possibility of litigation regarding the outcome, delay in corrective surgery and diagnosis, and definitive treatment of this child. Increased demand for surgical interventions amidst limited skilled manpower and resources, reduced access to sophisticated investigations and therapy play an important role in determining outcomes in these time-critical medical conditions in developing countries.

CONCLUSION

Despite considerable advances in the diagnosis and management of TOF and resultant cerebral abscess, the incidence of mortality and morbidity is still high among the paediatric population in developing countries. Developing and upgrading relevant diagnostic and therapeutic modalities and enhanced and timely access to health care would have a definite and positive impact on the short and long-term outcomes.

CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL ISSUES

Informed, written consent was taken from the parents prior to preparation of the manuscript and publication of relevant medical details and clinical images.

AUTHOR CONTRIBUTIONS

SR: clinical work, conception, data acquisition, initial drafting, revising, final approval; **SP**: clinical work, initial drafting, revising, final approval; **BMM:** conception, initial drafting, revising, final approval.

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POINT OF VIEW

Strengthening Forensic Anthropology in Sri Lanka: The way forward

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ABSTRACT

Forensic Anthropology is the application of the science of physical or biological anthropology to the legal process. The contribution of this field to the death investigation system in Sri Lanka has a long history. However, for the death investigation system to get the benefit of global advances in this field, it needs to be developed into a subspecialty. This can only be achieved through development of human resources, infrastructure and by establishing population-specific references.

Key Words: Forensic Anthropology, Sri Lanka, death investigation.

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INTRODUCTION

Forensic Anthropology (FA) is an applied area of physical (i.e., biological) anthropology which specifically uses science, methodology, and technology of physical/biological anthropology and related fields to help address medicolegal issues, such as personal identification and circumstances surrounding death[1]. The traditional perspective of FA includes recovery and analysis of human remains[2]**.** The analysis of human remains includes separation of human remains from similar objects, estimation of time since death, determining the taphonomic history, building the biological profile, recognizing the features that may assist in identification and determination of cause and manner of death where possible[2-5]. Thus, FA plays a significant role in routing autopsy investigations (when the identity of the remains is an issue), in identification of victims of mass disasters[6,7] and in human rights investigations[8,9]. In the modern era FA also occasionally extends to the investigation of living individuals[2,3].

History of forensic anthropology in Sri Lanka

The formal death investigation system in Sri Lanka has a history that goes back to 1883[10]. Nevertheless, the initiation of the use of anthropology in death investigation in Sri Lanka is not clear. In 1954, research conducted on age estimation from bone development was published in the Journal of Criminal Law and Criminology[11,12]. This is considered the 1st documented anthropology research study in Sri Lanka. The case of *E. Alfred de Zoysa vs The Queen* (75 NLR 534) which is commonly known as the Kalaththawa murder case highlights the use of anthropology in forensic investigations, which was decided in 1960s[13]. FA has made a significant contribution in the exhumations of mass graves presumed to be from the 1980-2009 civil war[14] and in the identification of deceased from recent natural disasters[15].

In the absence of formally trained Forensic Anthropologists in the Medico-Legal Service, Forensic Medicine specialists are responsible for providing the "anthropology opinion" in death investigations in Sri Lanka. These Forensic Medicine specialists obtain a basic knowledge in FA during their 5-year postgraduate training in Forensic Medicine[16] and by participating in various workshops and short-term training programs conducted by renowned Forensic Anthropologist around the world (Personal experience). The first such workshop was conducted in Colombo by Professor Clyde Snow in 1993 (Personal communication).

In 2017, the Postgraduate Institute of Medicine (PGIM) in Sri Lanka identified FA as a subspecialty in Forensic Medicine[16]. Since then, the PGIM allows post-MD (Forensic Medicine) trainees to select FA as a subspecialty and undergo specialist training in FA during their local and overseas post-MD training.

The ministry of health in Sri Lanka identified the 1st cadre position for a Forensic Anthropologist in 2018 (Ministry circular of appointing the Forensic specialist to the unit[17]). This paved the way to establish the 1st FA Unit at the Institute of Forensic Medicine and Toxicology (IFMT).

The way forward

Even though FA has contributed greatly to the death investigation system in Sri Lanka it has not been considered as a separate specialty in forensic medicine training since of late. For FA to be developed into a subspecialty the following is suggested.

1. Human Resource development
2. Infrastructure development
3. Conducting population-based research

Human resource development

The qualifications that are required to become a Forensic Anthropologist vary from country to country and depend on the Medico-Legal system of the country. In the United States, ABFA (American Board of Forensic Anthropologists) certified Forensic Anthropologist shoulder the responsibility of practicing FA[1]. However, in European countries, the training is dishomogeneous[3]. In Sri Lanka the Forensic Medicine Specialists are held responsible for providing FA opinion in death investigations. Hence, they need to have a sound knowledge in FA.
The post-doctoral FA training program recently introduced by the PGIM offers the opportunity for Forensic Medicine specialist to obtain a comprehensive training in FA. Trainees of this program will have at least one year of exposure to FA at a recognized Centre before being board certified as a specialist in Forensic Medicine with special interest in FA[16]. This development has been recognized by the PGIM as an effective pathway to produce qualified experts in this field, and its continuation is essential for further development of the specialty. However, such training does not result in the award of a postgraduate degree in FA and is limited to post-MD (Forensic Medicine) trainees. The recently approved postgraduate Diploma in FA appears to be a sustainable solution for both the issues i.e., professional training and certification[18]. Moreover, the diploma is open to any medical officer and it opens to a wider community once it's implemented.

The Sri Lanka Medical Council (SLMC) being the regulatory body of the medical profession, issues licenses to qualified Forensic Medicine Specialist and maintains the specialist registries. Those who have successfully completed the said Postgraduate Diploma will be able to register their qualification with the SLMC. Hence the Postgraduate Diploma would result in qualified as well as certified Forensic Anthropologist in Sri Lanka.

A certification/licensing for FAs would not only give due recognition to the specialization and specialists, but would also act as a gatekeeper and help maintain standards of the profession and professional training

Infrastructure Development

FA is partially a laboratory-based science, and each practitioner requires appropriate tools and a suitable workplace to conduct proper analysis of remains. The FA unit at the IFMT is the only FA unit that has been established within the health sector thus far. Therefore, cases from all corners of the country are referred to the FA unit at the IFMT for analysis. The unit is equipped with basic equipment such as casts (both adults and sub adults), calipers, osteometric boards etc. However, the unit needs to be upgraded with other necessary equipment such as microscopes, mandibulometer, etc. To facilitate postgraduate and undergraduate training, a documented skeletal collection consisting of complete skeletons, fragmented skeletons, skeletons with trauma and bone pathology is essential. Currently the unit can meet the demands. Nevertheless, decentralizing the service should be considered in the long-term. This will not only reduce the burden on the centre but also provide easy access for clients, and may reduce the cost and the waiting time for reports.

Conducting population-based research

Conducting research is an integral part of the development of a discipline. In Sri Lanka, a few population-based studies in FA have been conducted. The method developed to estimate stature is one such study[19]. As most anthropological indicators are population-specific, to perform a reliable Forensic Anthropological assessment in a medico-legal case, population-based references are

essential, and such can only be established through population-based studies.

CONCLUSION

FA plays a significant role in the medico-legal death investigation process. To maximize the application of FA in forensic cases, it is necessary to have qualified practitioners. Without sufficiently equipped laboratories, an accredited training or proper research, high-quality standardized services cannot be provided. In the absence of population-specific reference data, a reliable opinion with regards to the biological profile cannot be expressed in all medico-legal cases. Therefore, human resource development, infrastructure development and establishing population-specific references are the main areas that need to be focused on in strengthening the FA capacity in Sir Lanka.

CONFLICTS OF INTEREST

There are no conflicts of interest.

DISCLOSURE

SPAH is an editorial board member of Sri Lanka Journal of Forensic Medicine, Science & Law. Therefore he did not participate in anyway in the publication / decision making process of this submission, as per journal policy.

ETHICAL ISSUES

None

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INSTRUCTIONS TO AUTHORS

The Sri Lanka Journal of Forensic Medicine, Science & Law (SLJFMSL) publishes leading articles, original research papers, reviews, points of view, case reports, technical notes and letters to the editor, in all areas of Forensic Medicine, Forensic Sciences, relevant Law & Ethics.

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The manuscript should be prepared in accordance with the guidelines developed by the International Committee of Medical Journal Editors. The British Medical Journal, Lancet and Annals of Internal Medicine are recommended to authors as guides to style, clarity of presentation and conciseness.

The manuscript should be submitted to **sljfmsl@med.pdn.ac.lk** or uploaded to the SLJFMSL on the Sri Lankan journals Online site at **https://sljfmsl.sljol.info/about/submissions/**

The paper should be typeset with double spacing in Microsoft Word format. All pages should be numbered.

The title page should give the full title, running title, names of authors with qualifications, institutional affiliations, e-mail addresses and 16-digit ORCiD number of all authors. Please underline the name of the corresponding author.

The abstract should not exceed 250 words and should illustrate what was done, the main findings and conclusions. Up to five key words should be given under the summary.

The text of research papers should be divided into Introduction, Materials and Methods, Results, and Discussion. Only generic names of drugs should be given, if applicable. Abbreviations should be spelt out when first used in the text. Scientific measurements should be given in SI units. Statistical methods should be specified in the methods section and any term which is not in common usage should be referenced.

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Journal article

Westaby S, Evans BJ, Ormerod O. Pulmonary artery dissection in patients with Eisenmenger's syndrome. *New England Journal of Medicine*. 2007; 356:2110-2. DOI: 10.1056/NEJMc063492

Book

Saukko P, Knight B. Knight's forensic pathology. 4th ed. New York (NY): CRC Press; 2016. P.402.

Chapter in a book

Blaxter PS, Farnsworth TP. Social health and class inequalities. In: Carter C, Peel JR, editors. Equalities and inequalities in health. 2nd ed. London: Academic Press; 1976. p. 165-78.

Report

Rowe IL, Carson NE. Medical manpower in Victoria. East Bentleigh (AU): Monash University, Department of Community Practice; 1981. 35 p. Report No.: 4.

Web page

Diabetes Australia. Diabetes globally [Internet]. Canberra ACT: Diabetes Australia; 2012 [updated 2012 June 15; cited 2012 Nov 5]. Available from: http://www.diabetesaustralia.com.au/en/Understanding-Diabetes/Diabetes-Globally/

Conference paper

Patrias K. Computer - compatible writing and editing. Paper presented at: Interacting with the digital environment. 46th Annual Meeting of the Council of Science Editors; 2003 May 3-6; Pittsburgh, PA.

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