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EDITORIAL

FORENSIC TOXICOLOGY: A RETROSPECTIVE

Ann-Sophie Korb

Forensic toxicology is the science of determining poisons and xenobiotics in mainly, but not limited to, biological matrices. It has been a crucial component of criminal justice systems for centuries, assisting in the analysis and interpretation of drugs, poisons, and other chemicals in biological samples to determine their role in injury, death, or criminal activity.

Its evolution from rudimentary practice to the sophisticated, highly specialised discipline it is today is a testament to advances in science and technology, as well as an increased understanding of biology, pharmacology, and drug science. This retrospective aims to explore the historical development, key advancements, challenges, and future directions of forensic toxicology.

The roots of forensic toxicology can be traced back to antiquity, where the use of poisons for both medical and criminal purposes was well-documented. In ancient Rome, poisoning was a common method of assassination and political intrigue, and the early practices of poisoning detection were basic but nonetheless important. However, the scientific discipline of forensic toxicology emerged during the 19th century, coinciding with the rise of modern chemistry and advances in analytical techniques. One of the earliest milestones in the field was the development of chemical assays for the identification of poisons. In 1813, chemist Mathieu Orfila, often considered the father of forensic toxicology, published '*Traité des Poisons*' (or '*Treatise on Poisons*'). This laid the groundwork for systematic toxicological analysis in criminal investigations through laboratory experimentation. It also emphasised the importance of scientific rigor in forensic investigations and ensured that chemical analyses became a routine part of forensic medicine.

However, it is Paracelsus who is considered the founder of modern toxicology. It was Paracelsus who claimed "*sola dosis facit venenum*" ("only the dose makes the poison"). This has possibly had the biggest impact on the interpretation of toxicological findings.

Today, toxicological investigations serve several purposes in criminal investigations, which can be summarised in two main categories: ante-mortem and post-mortem investigations. Ante-mortem investigations involve criminal investigations of cases involving drug-facilitated crime and investigations of workplace- or driving-impairment. Investigating driving under the influence, whether under the influence of alcohol or drugs, remains a challenge with the continued decriminalisation and legalisation of substances, e.g., cannabis, in several countries. For the investigation of ante-mortem cases, a toxicologist's work will focus on determining the presence of substances that may have had a psychological effect on the individual involved. In post-mortem settings, the toxicologist's role is to aid the forensic pathologist and inform the inquiry into an individual's death. Determining the drug, often also the concentration of the drug present in the system at the time of death, may aid the forensic pathologist in determining the cause and category of death.

When it comes to the interpretation of toxicological results, antemortem interpretation poses an added challenge as outcomes will have an impact on an individual's life, which is not necessarily pertinent to post-mortem investigations. Conversely, post-mortem toxicology is based on several assumptions and has an added layer

of difficulty as the biological samples available for analysis are not always 'clean' and representative. These post-mortem challenges may include drug concentration variability based on the sampling site, post-mortem redistribution, and *in-vitro*/*in-vivo* drug changes.

Understanding the challenges that are associated with the interpretation of drug concentrations, along with reporting the results, leads us to consider some of the other factors that will influence the workings of a forensic toxicologist.

One very clear contest, which the field has seen increase steadily over the past years, is the increase of poly-drug use in the drug-using communities. This leads to an increase in the complexity of the cases presented, as a toxicologist must consider drug interactions and the pharmacokinetic and pharmacodynamic effects of the multitude of drugs present.

This is further complicated by the emergence and continued influx of new, primarily synthetic, drugs. These new psychoactive substances present unique challenges to the laboratory and toxicologists as they are not often well-documented, and methods for detecting them may not be readily available. In the past, forensic toxicology has relied on pharmacokinetic models to understand how substances are absorbed, distributed, metabolised, and eliminated in the body. With further synthetic compounds inundating the market, it is, therefore, vital to study these at a pharmacological level. We should further consider integrating molecular biology into forensic toxicology to uncover new avenues for research and understanding. The field of toxicogenomics, studying the genetic response to toxic substances, holds the potential to improve the understanding of individual susceptibility to toxins. Additionally, the further use of biomarkers of exposure and effect can be increasingly useful for detecting and quantifying substances in forensic investigations. Finally, the constantly evolving landscape of drug use requires toxicologists to stay up to date with published literature on new substances and expand current or develop new detection methods. Associated with this is the potency of these new substances, which may be much greater than that of the "classical" drugs of abuse, which require sensitive instruments to determine very low concentrations of drugs within a biological matrix.

So, what does this then mean for the future of forensic toxicology? Forensic toxicology is poised for continued innovation. We monitor advances in molecular biology, genomics, and machine learning to further enhance the precision and scope of toxicological analyses. Additionally, as global awareness of new psychoactive substances and their potential harms grows, the field will need to continually adapt rapidly, developing methods to detect and understand these substances. We hope to work more closely with law enforcement and public health, as there is a growing emphasis on collaborative approaches to preventing and addressing toxicological issues in society. This should also include research on the social and psychological impacts of drug and alcohol use, improving the education and training of toxicologists to ensure they are equipped to handle the increasing complexity of modern forensic investigations.

We can see that the field of forensic toxicology has come a long way from its origin to its present role as an integral part of criminal investigations. The evolution of analytical techniques, alongside a deeper understanding of pharmacology, has enriched the field's capacity to detect, analyse, and interpret toxic substances with extraordinary accuracy. Whilst challenges remain, such as the rapid influx of new drugs of a fleeting nature and the complexities of interpretation, future advancements in technology and research promise to further refine the field, making forensic toxicology an even more indispensable tool in forensic investigations.

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ORIGINAL ARTICLE

WIFE BATTERING: VICTIMS REPORTED FOLLOWING PHYSICAL VIOLENCE AT THE TEACHING HOSPITAL JAFFNA, SRI LANKA

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ABSTRACT

Wife battering has been extensively researched in specific regions of Sri Lanka and other countries. The goal of this study is to examine the pattern of injuries as well as the impact of demographic and socioeconomic factors. A hospital-based descriptive cross-sectional study of 155 victims was conducted in 2021 and 2022. Results showed that 83% (n=129) of victims and 68% (n=106) of perpetrators were under the age of 25; 78% (n=121) of victims and 87% (n=135) of perpetrators had studied up to grade 11; and while 72% (n=111) victims were housewives, 79% (n=122) perpetrators were blue-collar workers. One hundred twenty-seven (82%) households were nuclear families, and 91 (59%) families earned less than Rs.30,000 (USD 100) per month. 79% (n=123) of the perpetrators were alcoholics, whereas 19% (n=29) consumed illegal narcotics. As the method of battering in 120 (77%) victims, bare hands were used, while more than half (57%, n=88) were assaulted with weapons. The most involved anatomical sites were the head (74%, n=114) and upper limbs (39%, n=60), and the most common injuries sustained were contusions (66%, n=102), followed by abrasions (31%, n=48) and lacerations (17%, n=27). Most victims (90%) sustained injuries that were not life-threatening. The sociodemographic and socioeconomic factors that influenced this crime, as well as the nature, distribution, and weapon used in the injuries, have remained unchanged since the previous study conducted in the same region four decades ago.

Keywords: *Perpetrators; socio-demographic factors; socio-economic factors; victims; wife battering*

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INTRODUCTION

Wife battering (WB) is the most common form of violence against women globally[1,2]. Throughout history, WB has been condoned and even mandated by some societies and religions. The first written laws dating back to 2500 B.C. enforced punishment for women who verbally abused their husbands, and physical punishment of wives was commonly practiced in Greek, Roman, Jewish, Christian, and Islamic cultures[3]. WB can be physical (punching, slapping, kicking), psychological (belittling, intimidation, humiliation), or sexual. Physical abuse is more visible, but psychological abuse is often not immediately apparent[4].

Adverse health is a significant outcome of WB, alongside issues in many other domains, such as legal, social, psychological, cultural, and

political. Health professionals for a long time have been reluctant to intervene in cases of violence against women, even when encountering battered women as patients[5].

Over the past three decades, there has been an increasing amount of evidence indicating high rates of violence against women by their spouses. This phenomenon is now recognized as a serious health problem by professionals around the world. Physicians are often seen as the first line of defence in identifying and intervening with battered women. They are often required to refer women to specialists or outside resources, report to local law enforcement agencies, provide emergency contact numbers and shelter information, formulate a follow-up plan that includes future visits to the healthcare institution, and coordinate with community resources[6].

WB is a significant problem in Sri Lanka, with an estimated lifetime prevalence ranging between 20% and 60% in 2011[7]. However, very few victims have reported these incidents to the authorities. In many cases, victims of WB may have gone unnoticed as they might have sought medical attention under false complaints. To address this issue, clinicians need to be aware of WB risk assessment tools to identify victims more effectively. An evidence-based intervention program is crucial to provide holistic management, decrease morbidity and mortality, and strengthen the criminal justice system to tackle this pressing concern[8]. A study conducted by Saravanapavananthan in Sri Lanka during the 1980s examined the socio-demographic factors, weapons used, and injuries sustained in cases of WB in Jaffna[9]. Our recent study, conducted in the same location after four decades, aimed to analyse the medico-legal aspects of WB and the impact of demographic and socio-economic factors.

METHODS

This descriptive cross-sectional study was conducted in a hospital setting. The study sample consisted of 155 married females who had experienced domestic violence from their husbands and were referred to the office of the Judicial Medical Officer at the Teaching Hospital Jaffna, Sri Lanka, between the period of April 2021 and March 2022. These individuals were either referred from other hospitals or brought directly by the police for clinical forensic examination. Subjects below the age of 18 were excluded from this survey because the legal age for marriage in Sri Lanka is 18 years[10].

Informed written consent was obtained from the study subjects. Data was collected using an interviewer-administered questionnaire during the medico-legal evaluation of the victims. Additionally, data from the medicolegal examination forms and bedhead tickets were used when needed. The respondents were given the choice of time and location of the interview as per their preference. The interviews were conducted strictly, maintaining privacy and confidentiality. Participants had complete autonomy to terminate the interview at any point, omit any questions they preferred not to answer, or discontinue the interview at their discretion. The statistical analysis was conducted using IBM SPSS Statistics version 21. Ethical clearance was obtained from the Ethics Review Committee, Teaching Hospital, Jaffna.

RESULTS

The study included interviews with a total of 155 victims of WB. Among them, 83% (n=129) of victims and 68% (n=106) of perpetrators were aged less than 26 years. Additionally, 78% (n=121) of victims and 87% (n=135) of perpetrators had not studied beyond grade 11. The ethnic group of almost all the participants (99%) was Tamil, while only two (1%) were Muslims. No Singhalese participants were in this study group. Most of the families, 83% (n=129), followed Hinduism, while 16% (n=24) and 1% (n=02) followed Christianity and Islam, respectively. The majority of victims (72%, n=111) were housewives, while most of the perpetrators (79%, n=122) were blue-collar workers. Despite facing financial constraints, most families managed to survive on a meagre income. Among the families, 91 (59%) had a monthly income of less than Rs. 30,000 (100 USD). The socio-demographic factors of the study population are summarized in Table 1.

Table 1: Socio-demographic factors of victims and perpetrators of wife battering

Factors	Husband	Percentage (%)	Wife	Percentage (%)
Age (years)				
<=25	106	68	129	83
>25	49	32	26	17
Ethnicity				
Tamil	153	99	154	99
Muslim	02	01	01	01
Religion				
Hindu	129	83	128	82
Islam	02	01	01	01
Roman Catholic	15	10	17	11
Non-Roman Catholic	09	06	09	06
Education qualification				
Up to O/L	135	87	121	78
>O/L	20	13	34	22
Job				
Housewife	-	-	111	72
Manual labourer	45	29	19	12
Farmer	05	03	-	-
Mason	31	20	-	-
Fisherman	14	09	-	-
Shopkeeper	04	03	-	-
Others	51	33	25	16
Job skill level				
Skilled	33	21	-	-
Non-skilled	122	79	-	-
Income (LKR)				
<30000	91	59	-	-
>=30000	64	41	-	-

In the study, it was observed that in most marriages (79 out of 155), the wives (51%) were either younger or of the same age as their husbands. The maximum age difference between spouses was three years. However, 35% (n=54) of the husbands were more than three years older than their wives. Among the victims, 22 women (14%) were older than their husbands. Most of the marriages (79%) were a result of a love affair, while the remaining (21%) were arranged marriages. Out of the 155 families, 127 (82%) were nuclear families, while the remaining 28 (18%) were extended families. Furthermore, among the perpetrators, 79% (n=123) were found to abuse alcohol, while 19% (n=29) used illicit drugs. The study found that almost half of the women, 48% (n=75), experienced domestic violence from their husbands within the first year of marriage, whereas, in 22% (n=34) of cases, WB occurred between two to five years after the marriage and in 11% (n=17) within six to ten years of marriage. Out of 155 women surveyed, 111 (72%) reported between 2 to 10 episodes of abuse, while 44 (28%) reported more than ten episodes. Most attacks took place during the daytime (38%, n=59) compared to the nighttime (25%, n=38). However, 58 (37%) of the victims experienced it both during the day and night. The factors that could contribute to WB are summarized in Table 2.

Table 2: Factors that could contribute to the WB

Common	Frequency	Percentage (%)
Age difference (years)		
<=3 Husband	79	51
>3 Husband	54	35
> Age of wife	22	14
Type of Marriage		
Arranged	32	21
Affair	123	79
Family type		
Nuclear	127	82
Extended	28	18
Interval for 1st assault		
<1 year	75	48
1-5 years	34	22
5-10 years	17	11
>10 years	29	19
Frequency of assault		
2-10 times	111	72
>10 times	44	28
Time of assault		
Day time	59	38
Night time	38	25
Both	58	37
Substance Abuse		
Alcohol	123	79
Illicit drugs (cannabis, heroin, amphetamine and pregabalin)	29	19
Method of physical abuse		
Punching	86	55
Kicking	50	32
Pushing	29	19

Bare hands were used to assault 120 (77%) of the victims, while more than half of them (57%, n=88) were assaulted with weapons. The most common weapon used was a broomstick, accounting for 40% (n=36) of the cases. Other weapons that were used included firewood (n=18, 20%), club and stick (n=14, 16%), helmet (n=9, 10%), and knife (n=7, 5%). In our study, injuries were observed in 114 individuals (74%) in the head, in 94 individuals (61%) in the neck, and in 60 individuals (39%) in the upper limb. Contusions were the most common type of injury and were observed in 102 individuals (66%), followed by abrasions (31%) and lacerations (17%). In the majority of cases (90%), the injuries were non-grievous. Table 3 tabulates the methods, nature, weapon, distribution, and severity of injuries.

Table 3: Methods of battering, nature of injuries, distribution of injuries, and weapons used in WB

	Frequency (n=155)	Percentage (%)
Methods of physical abuse		
Punching	86	55
Kicking	50	32
Pushing	29	19
Slapping	64	41
Strangling	11	07
Burning	2	1.3
Weapons used	88	57
Bare hand injuries	120	77
Nature of injury		
Laceration	27	17
Abrasion	48	31
Contusion	102	66
Cut	05	03
Strangulation	01	01
Fracture	11	07
Others	11	07
Anatomical distribution of injuries		
Head	114	74
Neck	94	61
Upper Limb	60	39
Chest	31	20
Abdomen	15	10
Pelvis	07	05
Lower limb	27	17
Type of Weapon used	**Frequency (n=88)**	
Clubs and sticks	14	16
Firewood	18	20
knife	07	05
Broomstick	36	40
Helmet	09	10
Axe	02	02
Bottle	02	02
Door bar	01	01
Chair	01	01
Injury severity	**Frequency (n=155)**	
Grievous[11]	139	90
Non-Grievous	16	10

DISCUSSION

Foetuses may be aborted, infants may be killed, girls may be neglected or abused, adolescents may be raped, married women may be beaten, raped, or killed by their husbands, and widows may be neglected just because they are female[4]. The son-preference mentality that causes female infanticide and sex-selective abortions has left millions of women "missing" in Asia and Africa. Approximately 5,000 dowry-related deaths occur annually in India[3]. Public service agencies, such as the police, medical institutions, and social services tasked with the duty of offering aid and assistance to the general population, have demonstrated only a restricted inclination and understanding of methods to support victims of domestic violence. This assertion suggests that wife beating continues to be a significant issue in contemporary civilizations worldwide[1].

We have conducted a comprehensive analysis of 155 women who have experienced battering. Our research findings indicate that getting married at a younger age increases the likelihood of experiencing spousal violence. A study conducted in Sri Lanka found that 80% of women who experienced WB were less than 40 years of age[8]. Another study done by Vadysinghe in 2019 at Teaching Hospital Peradeniya revealed that 69% of their victims of interpersonal violence were between the ages of 21 and 40[12]. Hofner in 2005 and Ibrahim in 2010 have also emphasized that getting married at a younger age is associated with a greater occurrence of domestic violence[13,14]. Roy et al. suggest that the lower age of husbands (75% of them falling between 26 and 50) also exerts a notable influence on the occurrence[15]. A similar finding (male median age was 36 years) was also reported by Vidanapathirana in 2014[8].

Lawoko et al. in 2007 found that the age difference between the victim and her husband is significant in determining the type of abuse. When the age difference between a couple is between three and ten years, there is a higher incidence of sexual violence reported. Additionally, when the age difference is equal to or less than three years, there is a higher incidence of physical violence reported compared to couples with an age difference of more than four years[16]. In the present study, 79 couples (51%) had an age difference of three years or less. It is noteworthy that all these couples experienced physical abuse. Even though 35% (n=54) of the husbands had an age difference of more than three years with their wives.

A study done by Premawardhena et al. in Sri Lanka in 2020 observed 71% of marriages to be love marriages[17]. Similarly, in our study, we found that 79% (n=123) of marriages have happened following a love affair. Interestingly, Saravanapavananthan (1982) conducted research in Jaffna, Sri Lanka, between 1978 and 1981, including 60 women who had been subjected to battery by their husbands. Among the victims, 80% of the marriages were arranged by parents[9]. This shift may be attributed to transforming from a family-centered society to one focused on urban living. According to the literature, the low level of education, income, and low-status employment of both the husband and wife likely contributes to domestic violence[4,8,9,18-21]. According to the findings of the present study, most victims and perpetrators had poor incomes and low levels of education. The majority of victims were housewives, while the majority of attackers were unskilled labourers. Table 4 shows a comparison between the present survey and Saravanapavananthan's study.

Table 4: Comparison between findings of Saravanapavananthan (1978-1981) and the present study (2021-2022).

	1978-1981 Percentage (%)[9]	2021-2022 Percentage (%)
Nature		
Laceration	22	17
Abrasion	05	31
Contusion	60	66
Cut	08	03
Strangulation	05	01
Fracture	07	07
Distribution		
Head	42	74
Neck	05	61
Upper Limb	37	39
Chest	05	20
Abdomen	03	10
Pelvis	03	05
Lower limb	10	17
Methods of abuse		
Punching	18	55
Kicking	05	32
Pushing	-	19
Slapping	-	41
Strangling	05	07
Burning	02	01
Weapons used	62	57
Bare Hand injuries	-	77
Weapon Used		
Clubs and sticks	25	16
Firewood	10	20
Knife	10	05
Broomstick	03	40
Helmet	-	10
Axe	02	02
Bottle	02	02
Door bar	03	01
Chair	02	01
Injury severity		
Non-Grievous	93	90
Grievous	07	10
Substance Abused		
Alcohol	80	79
Illicit drug	-	19
Type of Marriage		
Arranged	80	21
Affair	20	79

In the current study, 79% (n=123) of participants had spouses who abused alcohol, whereas 19% (n=29) consumed illegal substances. Saravanapavananthan (1982) observed that 80% of the husbands in the same geographic area were alcoholics[9]. Gayford et al. (1975), Vidanapathirana (2014), and Nandasiri et al. (2015) revealed that 52%, 69%, and 80% of the husbands were regular alcohol consumers, respectively[4,8,22].

Our research indicates that the first episode of physical assault occurred during the first five years of the marriage in 70% of cases (n=109). Conversely, Nandasiri in 2015 reported that 80% of women encountered violence after five years of their marriage[4]. Gayford in 1975 also noted that the average time when individuals first experienced violence was after 8.8 years of marriage[22]. According to Saravanapavananthan (1982), 60% of women filed police complaints after ten years of marriage due to the cultural expectations of South Asian women to submit to their husbands. These women endure assault because they fear public censure and the potential loss of social standing. They have numerous challenges when attempting to dissolve their marriage, primarily due to their lack of literacy and complete reliance on their husbands for their survival. Women tolerate violence due to their responsibilities towards their children, and only when the situation becomes unbearable do they seek protection from the police and other sources[9].

In our study, we found that most incidents of WB occurred during the daytime (38%), and 37% of violence took place during both day and night times. A study conducted in Colombo revealed that 56% of violence occurred in the daytime[8]. However, a study conducted in Jaffna between 1978 and 1981 showed that most beatings occurred at night. The common scenario is that of a man returning home after work, completely intoxicated, losing control at the slightest provocation, and repeatedly battering his wife[9].

The study conducted by Saravanapavananthan (1982) showed that among the victims, 18%

had been punched, 5% were kicked, and 62% were assaulted with a weapon. The main weapons used were mostly clubs and sticks[9]. The current research revealed that 55% (n=86) of the individuals were subjected to punching, 32% (n=50) experienced kicking, and 57% (n=88) of the victims were assaulted with a weapon. Commonly utilized weapons were clubs and sticks (16%, n=14), firewood (20%, n=18), and knives (5%, n=07). Our study, in contrast to the previous research conducted by Saravanapavananthan (1982), has observed that broomsticks (40%, n=36) and helmets (10%, n=09) also have a substantial role in inflicting injuries. Nandasiri (2015) from the Southern region of Sri Lanka and Vidanapathirana (2014) from the Western region of Sri Lanka have also reported similar findings in their studies on WB[4,8].

The most frequently seen injury in our study was contusions, accounting for 66% (n=102) of cases. The head, neck, and upper limbs were the regions most significantly injured, with percentages of 74%, 61%, and 39%, respectively. Saravanapavananthan (1982) also observed contusions to be the most common type of injury, accounting for 60% of cases. The regions most frequently afflicted were the head, neck, and upper limbs, with percentages of 42%, 5%, and 37% respectively[9]. The findings from the study conducted in Colombo, Sri Lanka, which reported a prevalence of 69% for contusions and 60% for head injury, as well as the study conducted in Galle, Sri Lanka, which reported a prevalence of 53% for contusions, further supported our observations[4,8]. Although there was a wide range of injuries and various weapons that caused them, the majority of the injuries were non-grievous. Four decades ago, 93% of the injuries were classified as non-grievous[9]. A study conducted in Western Sri Lanka revealed a significant occurrence of non-grievous injuries, accounting for 87% of the cases[8].

A key limitation of this study was the inability to represent the diverse multi-ethnic groups in Sri Lanka, as the sample did not include individuals from the Sinhala population. Future research with a more inclusive and representative sample is necessary to overcome this limitation and provide a more comprehensive understanding on the subject.

CONCLUSIONS

Factors such as early marriage, lack of education, alcoholism, and low income are the common contributors to WB. Over the past four decades, there has been no significant change in the nature, distribution, and severity of injuries caused by domestic violence. Even the weapons used and most of the socio-demographic patterns have not changed much over time.

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CONFLICTS OF INTEREST

The author declared no conflicts of interest.

ETHICAL ISSUES

Ethical clearance was obtained from the Ethics Review Committee, Teaching Hospital, Jaffna, Sri Lanka.

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None.

AUTHOR CONTRIBUTIONS

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

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ORIGINAL ARTICLE

THE PATTERN OF UNNATURAL DEATHS IN FEMALES IN MAHARASHTRA

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ABSTRACT

The occurrence of unnatural deaths in females is a reflection of the prevailing social structure and the state of mental health of the society. Today, in the age of social media, we are discussing the liberalisation of women's empowerment. However, it is important to bear in mind that there has been an increase in crime against women in our society. The present study analyses the different causes of unnatural death and the factors that influence them.

The maximum number of study cases, i.e., 49 (24.02%), were from the 21-30 age group. 53.43% of cases were reported from urban areas. Most unnatural deaths occurred due to road traffic accidents (39.71%). Amongst the manner of death, accident (59%) was the most common, followed by suicide (33%) and homicide (8%). Amongst suicidal deaths, poisoning was the most common cause of death (44.78%), followed by hanging (28.36%). The family quarrel was the most common reason for both suicides (31.34%) as well as homicide (47.06%). The husband was the perpetrator in 64.71% of cases of homicide. A hard, blunt object was used as a weapon in the majority of cases of homicide (47.06%).

Most of the cultural and socio-economic factors in a particular country are generally linked to the cause of female deaths. Data related to female deaths in a specific geographical area can reflect the law-and-order situation. The current study will attempt to create societal awareness, thereby improving the prevailing situation.

Keywords: *Accident; homicide; suicide; unnatural female deaths*

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INTRODUCTION

Death can be an outcome of any natural disease or unnatural causes. Unnatural deaths include those due to road traffic accidents (RTA), poisoning, burns, assault, hanging, electrocution, drowning, falling from a height, strangulation, lightning, etc. Unnatural deaths affect the family and community both psychologically and socially[1]. Despite the increasing liberalisation of women's rights over the past two decades, crimes against women are also on the rise. Especially in a male-driven society, females have always been the victims. This prevails in every country regardless of

social standing or class[2]. In the modern era, more and more women from different parts of society are coming out of the confines of their homes for studies, jobs, and social work, which in turn could have contributed to the recent phenomenal spurt in crimes against women. This has become a staggering problem for today's society, law enforcement authorities, and the judiciary of the country. This study attempted to investigate the percentage of unnatural deaths among women in our region to develop preventive strategies to minimize such cases in the future[3]. The unnatural death of a female usually affects the lives of her family. The reporting of injuries due to trauma among females is inadequate worldwide, and there are very few studies conducted in this area[4].

Mortality trends among women reflect the region's dominant social structure and mental health status. Many cultural and socioeconomic factors in a country are often implicated in the causes of women's death. Data on women's deaths in a particular geographical region can reflect its law and order[5]. Through this research, we can know the various influencing factors involved in women's deaths and what percentage of deaths in women are due to unnatural causes.

METHODS

This study was a single-centered, retrospective study of unnatural female deaths that was presented to one of the two government tertiary healthcare centers in the city of Maharashtra, India, from January 2017 to December 2018. All cases of unnatural female deaths subjected to autopsy in our center during the period from January 2017 to December 2018 were considered for the study. Bodies with advanced decomposition were excluded from the study. A total sample of 204 deaths were included in this study.

A standardized proforma was used for the collection of data during the postmortem. Details regarding the history of the incident, the deceased's age, socio-economic background, level of education, occupation, marital status, and rural/urban residence status were collected. Information was obtained from the investigating officials and relatives/friends of the deceased. Data analysis was done using Microsoft Excel version 2019 and Open Epi info version 7.2.2. Ethical committee clearance was granted by the Institutional Ethics Committee (IEC), Department of Pharmacology, Government Medical College, Nagpur, India. Confidentiality was maintained.

RESULTS

Distribution of cases according to the age of victims

Table 1: Distribution of cases according to the age of victims

Age Group	No. of Cases	Percentage
0-10	5	2.45
11-20	21	10.29
21-30	49	24.02
31-40	46	22.55
41-50	37	18.14
51-60	23	11.27
61-70	13	6.37
71-80	5	2.45
81-90	4	1.96
91-100	1	0.49
Total	**204**	**100.00**

The majority of the deaths were from the 21-30 years age group (n=49, 24.02%) including 5 cases (2.45%) from the 0-10 years age group. A single case was observed in the 91-100 years age group. (Table 1).

Distribution of cases according to marital status and duration

The majority of the deceased were married (n=149, 73.04 %), with most of them (n=80, 39%) being married for more than 15 years, followed by 22% for 0-7 years and 20% for 8-14 years.

Among the study population, 19.12% had been unmarried (n=39), 6.86 % widowed (n=14), and 0.98% divorced (n=2).

Distribution of cases according to the area of residence

The majority of the deceased (n=109, 53.43%) were from urban areas, whereas 95 (46.57%) had resided in rural areas.

Distribution of cases as per the socioeconomic strata

Most of the deceased had belonged to the upper lower class (n=87, 42.67%) followed by the lower class (n=46, 22.55%), lower middle class (n=40 19.61%) and upper middle class (n=23, 11.27%). Only a very few of the deceased in the study population were from the upper class (n=8, 3.92%).

Distribution of cases according to the literacy

The majority of the deceased (n=88, 43.14%) had obtained primary education, whereas 72 (35.29%) had obtained secondary education, 28 (13.73%) were graduates and 3 (1.47%) were postgraduates. However, 13 (6.37%) of the deceased had been illiterate.

Distribution of cases according to the occupation

The majority of the deceased were housewives (n=91, 44.61%). 26.96% of the deceased (n=55) were employed, 14.22% (n=29) were farmers, and 12.25% (n=25) were students. The occupation status of 4 (1.96%) females was not known.

Distribution of cases according to the manner of death

Accidental deaths were more common (n=120, 59%), followed by suicide (n=67, 33%) and homicide (n=17, 8%).

Table 2: Distribution of cases depending on the type of accidental death

Type of Accident	No. of Cases	Percentage
Road traffic accident (RTA)	81	67.50
Burn	24	20.00
Trauma other than RTA	4	3.33
Poisoning	4	3.33
Animal Bite	3	2.50
Drowning	2	1.67
Electrocution	1	0.83
Choking	1	0.83
Total	120	100.00

Amongst accidental deaths, RTA (n=81, 39.71%) was the most common, followed by burns (n=41, 20.10%). Poisoning and trauma other than RTA, like falls from height, were reported in 4 cases (3.33%). Other causes of accidental deaths were animal bite (n=3, 2.5%), drowning (n=2, 1.67%), electrocution (n=1,0.83%), and choking (n=1, 0.83%) (Table 2).

Table 3: Distribution of cases depending on the type of suicidal death

Type of Suicide	No. of Cases	Percentage
Poisoning	30	44.78
Hanging	19	28.36
Burning	14	20.90
Drowning	4	5.97
Total	**67**	**100.00**

Amongst suicidal deaths, poisoning (n=30, 44.78%) was the most common method of suicide, followed by hanging (n=19, 28.36%), burning (n=14, 20.9%), and drowning (n=4, 5.97%) (Table 3).

Table 4: Distribution of cases depending on the type of homicidal death

Type of Homicide	No. of Cases	Percentage
Assault by blunt weapon	8	47.06
Assault by sharp weapon	5	29.41
Burn	3	17.65
Neck compression	1	5.88
Total	**17**	**100.00**

Amongst homicidal deaths, the most common method employed was assault with a blunt weapon (n=8, 47.06%), followed by sharp weapon (n=5, 29.41%), burning (n=3, 17.65%), and neck compression (n=1, 5.88%) (Table 4).

Reasons attributed to suicide and homicide

The most common reason for suicide was a family dispute (n=21, 31.34%), illness (n=14, 20.9%), conflicts in a love affair (n=10, 14.93%), rage (n=3, 4.48%), and extramarital affair (n=1, 1.49%). In 26.87% of the cases, no reason was known (n=18).

The most common reason for homicide was again family dispute (n=8, 47.06%) followed by rage (n=7, 41.18%), extramarital affair, and quarrel with another person (n=1, 5.88%). The husband was the perpetrator in the majority of cases of homicide (n=11, 64.71%), followed by the father (n=2, 11.76%), brother-in-law, mother, and acquaintance (n=1 each, 5.88%).

DISCUSSION

Mortality among women has long been a concern for policymakers and health organizations. Greater emphasis is generally given to maternal mortality, which has been linked to development indices that are used to assess the level of development of countries[6]. The present study shows the maximum percentage of unnatural female deaths in the 3rd decade, i.e., 49 cases (24.02%). Similarly, findings of the study by Kumar TS et al. (2004)[7] showed that the maximum number of cases of unnatural deaths occurred in the 3rd decade. However, in some studies, 21-30 years was the most commonly involved age group[3,8].

In the present study, the majority of females (n=149, 73.04%) were married as compared to unmarried females (n=14, 6.86%). This finding is consistent with other studies in the literature[9,10,11].

The present study shows that a maximum number of females (n=80, 39%) belonged to the group with a marital duration of above 15 years, followed by the group with a marital duration of 0-7 years (n=44, 22%). This is in contradiction with other studies where the majority of married females died within the first 7 years of their marriage[9,12]. The reason for this may be the trend of dowry death, which is reducing in the modern demography that is reflected in the present study.

The present study shows that the maximum number of cases of unnatural female death were from urban areas (n=109, 53.43%). This finding is in contradiction with other studies[8,12,13,14]. The reason may be due to the present study being conducted in a metropolitan area where more and more people are coming with their families for a better chance of job opportunities and a better life.

The present study shows that the maximum number of cases were from the upper lower class of socioeconomic status followed by the lower class. These findings are comparable with other studies[8,15].

According to the present study, 43.14% of female victims had primary education, 39.29% of female victims had secondary education, 13.73% of females had graduated, and 1.47% were post-graduated. It is clearly shown in this study that as the educational status of females increases, the death rate decreases. This finding is comparable with other studies[5,8,11,12].

In the present study, housewives formed the maximum number of victims, which is 44.61%; 26.96% of females were employed, and 12.25%

of females were students. This finding coincides with the other studies[8,11,12,16].

As per our study, the most common manner of death is accidental, followed by suicidal deaths, and homicidal deaths are the least common, which is comparable with the other studies[3,4,8,9,12].

The most common cause of death was RTA-related trauma, followed by burns. This is consistent with other studies[11,17]. Few studies reported burns as the most common cause of death[3,8,14] followed by RTA-related trauma in unnatural female deaths.

In our study, RTA-related trauma was the most common type of accidental death, followed by burns. This is consistent with other statistics and studies[4,11]. One of the studies reported burn as the most common cause of accidental death, the reason for which may be attributed to demographic variations[12].

Poisoning was the most common means of suicidal death, followed by hanging and burns, which is comparable with other studies[18,19]. Easy accessibility and availability of different types of poisons may be the main reason for poisoning to be the most common means of suicide in this population.

In the majority of homicidal deaths, hard, blunt weapons were used, followed by sharp weapons. Burning and neck compression were means employed in homicidal deaths seen in the study sample. This is in contradiction with one of the studies[4].

According to the present study, in the majority of the cases of suicide, family dispute was the main reason, which is consistent with other statistics[9] and studies[4,18,19].

Similarly, in the majority of the cases of homicide also, the family dispute was the main reason, and the husband was the perpetrator. This is consistent with another study[4].

CONCLUSIONS

Mortality in women has long been a source of concern to health policymakers and health organizations. Mortality trends among women reflect the region's dominant social structure and mental health status. Many cultural and socioeconomic factors in a country are usually related to the causation of female deaths. This study helps us to identify various factors which affect the incidence of unnatural deaths in females. The study will be useful for raising awareness among society and to improve the situation. We recommend the following actions.

1. Seek public opinion against this serious social scourge through various means, including the media and non-governmental organizations.

2. Effective coordination between non-governmental organizations, voluntary, and law enforcement agencies to prevent and curb crimes against women.

3. Promote literacy among women and make them economically independent and free employment generation.

4. Enact stricter laws against the ill-treatment of housewives by their husbands and parents-in-law.

5. Mahila Courts should be strengthened.

6. Adequate facilities should be provided to the Women's Protection Cells operating in the state to deal with deaths due to burns.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

ETHICAL ISSUES

Ethical approval was granted by the Institutional Ethics Committee (IEC), Department of Pharmacology, Government Medical College, Nagpur, India.

SOURCES OF SUPPORT

None.

AUTHOR CONTRIBUTIONS

JLB: Conception or design of the work; and final approval of the version to be published. **AKJ:** Drafting the work or revising it critically for important intellectual content; and final approval of the version to be published. **KJ:** Drafting the work or revising it critically for important intellectual content; and final approval of the version to be published.

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ORIGINAL ARTICLE

ESTIMATION OF AGE BY RADIOLOGICAL EXAMINATION OF THE ILIAC CREST: A STUDY ON YOUNG ADULTS

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ABSTRACT

Objective: This study aimed to estimate the age of young adults within the age group of 18-25 years using radiological examination of the iliac crest of the iliac bone. It also aimed to determine the age range with the mean within this study group. The sample size consisted of 200 participants, with equal representation of males and females.

Methods: This cross-sectional study was conducted using radiological examination of the iliac crests of the iliac bones. The study participants were aged between 18 and 25 years, with no history of significant trauma or skeletal abnormalities.

Results: The mean age of the study population was calculated. The minimum and maximum ages were determined as well. Data were analyzed separately for males and females to assess any gender-specific variations. The mean age of fusion of the iliac crest was calculated to be 22.25 ± 1.36 years, with a median age of 22.41 years for males whereas for females, the mean age was 21.96 ± 1.5 years, with a median age of 22.04 years. The fusion started at the earliest 19-<20 years in males and 18-<19 years in females.

Conclusion: Radiological examination of the iliac bone is a reliable method for estimating the age of young adults within the age group of 18-25 years. This study provides valuable information on the mean age, minimum age, and maximum age within this age group, which can contribute to forensic investigations, medical assessments, and population studies. Further research should focus on expanding the age range and including larger sample sizes to enhance the accuracy and generalizability of age estimation techniques.

Keywords: *Age estimation, iliac bone, radiological age*

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INTRODUCTION

Determining the age of an individual, whether they are alive or deceased, at various stages of decomposition poses a challenge for medical experts in both civil and criminal cases[1]. It is a crucial aspect of forensic examinations in medicolegal practice. Numerous researchers have studied this process, aiming to comprehend its origins, development, consequences, and potential countermeasures[2]. The fusion of the iliac crest, which typically occurs around 18-21 years of age, plays a significant role in determining

several factors such as the appropriate age for marriage, attaining legal adulthood, voting rights, eligibility to contest elections, judicial sentencing, cases of kidnapping (as defined by section 361 of the Indian Penal Code)[3], consent for participating in hazardous sports (as outlined under section 87 of the Indian Penal Code)[4], and establishing personal identification in India. The present study aims to investigate the fusion of the epiphysis of the iliac crest to provide an estimated age range.

METHODS

This cross-sectional, observational study was conducted at the University College of Medical Sciences and Guru Teg Bahadur Hospital, Delhi, India, from Nov 2019 to April 2021. This institute caters to the north Indian population from Himachal Pradesh, Uttarakhand, Punjab, Haryana, Uttar Pradesh & Rajasthan, and Union territory of Chandigarh, Ladakh. The study participants were aged between 18 and 25 years. A total of 200 participants, with the age and sex known, were selected using random sampling (100 male and 100 female). Official documents like Aadhar Cards, voter identity cards (IDs), and school certificates were used to verify their age and native residence. Individuals without a documented age, having metabolic diseases that could affect bone age, history of fractures of the pelvis and clavicle, those with systemic diseases or drug use affecting skeletal development, non-natives of North India, pregnant women, and individuals of sexes other than male or female were excluded from this study. Ethical clearance was obtained from the Institutional Ethics Committee of the institute before the start of the study via the letter no HR/2019/41/36 dated 16/10/2019. Informed written consent was obtained from the participants. Digital radiographs of the antero-posterior (AP) view of the pelvis were taken and examined by the principal investigator to assess the degree of ossification of the iliac crest. The positioning for the AP view involved the subject lying supine, with adjustments made to align the median sagittal plane with the couch's central longitudinal axis. The anterior superior iliac spines were ensured to be equidistant from the top of the couch using non-opaque pads. Foam pads were placed under the knees for comfort, and the heels were separated while rotating the limbs inward. Sandbags were used to maintain limb position. The X-ray beam was centered in the midline between the anterior superior iliac spines and the superior border of the symphysis pubis, with the central ray perpendicular to the film. The X-ray was performed with a General Electric X-ray machine. The estimated ages were presented as a range with a mean ± standard deviation and median also calculated.

RESULTS

A total of 200 radiographs, with 100 male and 100 female subjects, depicting the AP view of the pelvis were analysed. The subjects were within the age range of 18 to 25 years. To further analyse the data, the entire population was divided into specific age groups: 18 to less than 19 (group 1), 19 to less than 20 (group 2), 20 to less than 21 (group 3), 21 to less than 22 (group 4), 22 to less than 23 (group 5), 23 to less than 24 (group 6), and 24 to less than 25 years (group 7). The statistical analysis was performed using SPSS 20.0 software.

The findings of the study revealed that among the 17 male candidates in group (1), the epiphysis of the AP view of the iliac crest was unfused in all cases. In the group (2), only 3 out of the 16 male candidates (18.75%) demonstrated complete epiphyseal fusion. In the group (3), 12 out of the 15 male candidates (80%) showed complete epiphyseal fusion. In the group (4), 10 out of the 12 male candidates (83.34%) exhibited complete epiphyseal fusion. Among the subjects of the group (5), 17 out of the 18 male subjects (94.44%) demonstrated complete epiphyseal fusion. Above the age of 23 years, all 39 male candidates in groups (6) and (7) displayed complete epiphyseal fusion.

In males, the fusion of the epiphysis of the iliac crest' commenced at the age of 19 years and was completed by the age of 24 years. The mean age of fusion was calculated to be 22.25 ± 1.36 years, with a median age of 22.41 years (Table 1).

Table 1: Epiphyseal fusion of the iliac crest in males

Age group (years)	Cases showed complete fusion	Total cases
18-<19 (Group 1)	0	17
19-<20 (Group 2)	3	16
20-<21 (Group 3)	12	15
21-<22 (Group 4)	10	12
22-<23 (Group 5)	17	18
23-<24 (Group 6)	17	17
24-<25 (Group 7)	5	5

We observed that among the 23 female participants in group (1), only one individual (4.3%) showed fused epiphysis of the iliac crest. In group (2), 8 out of the 16 female participants (50%) displayed complete epiphyseal fusion. In group (3), 10 out of the 11 female participants (90.9%) exhibited complete epiphyseal fusion. Remarkably, in group (4), all 15 female participants (100%) showed complete epiphyseal fusion. Above the age of 22 years, all 35 female participants in groups (5), (6), and (7) demonstrated complete epiphyseal fusion of the iliac crest.

In females, the fusion of the epiphysis of the iliac crest began at the age of 18 years and was completed by the age of 23 years. The mean age of fusion was calculated to be 21.96 ± 1.5 years, with a median age of 22.04 years (Table 2).

Table 2: Epiphyseal fusion of iliac crest in females

Age group (years)	Cases showed complete fusion	Total cases
18-<19 (Group 1)	1	23
19-<20 (Group 2)	8	16
20-<21 (Group 3)	10	11
21-<22 (Group 4)	15	15
22-<23 (Group 5)	11	11
23-<24 (Group 6)	22	22
24-<25 (Group 7)	2	2

Figure 1 depicts an X-ray of the pelvis of a subject from the group (5), demonstrating an unfused epiphysis of the iliac crest. Figure 2 illustrates an X-ray of the pelvis of a subject from the group (6), showing a fused epiphysis of the iliac crest.

Figure 1: X-ray of the pelvis of a subject from the group (5) showing unfused epiphysis of the iliac crest.

Figure 2: X-ray of the pelvis of a subject from the group (6) showing fused epiphysis of the iliac crest.

DISCUSSION

According to this study, the complete fusion of the epiphysis of the iliac crest occurred at an average age of 22.25 ± 1.35 years in males and 21.96 ± 1.5 years in females. Importantly, there was no statistically significant difference observed in the age of fusion between males and females, indicating a similarity in the timing of this developmental milestone.

According to other studies conducted in India and the rest of the world, regional variations in the age of iliac crest fusion were observed. Therefore, it is crucial to consider the most up-

to-date data specific to a given for a more accurate estimation of age.

These findings are consistent with the findings of other Indian researchers, such as Singh P *et al.* (Punjab), Parikh *et al*. (Delhi), and Sankhyn *et al*. (Himachal Pradesh). All of these studies were performed in the Indian subcontinent, which has a similar nutritional status and environment.

Table 3: Comparison of the age of complete fusion of iliac crest with other studies conducted in India.

Author	Place of study	Age of males (years)	Age of females (years)
Singh P *et al.*[5]	Punjab	23-24	22-23
Parikh *et al.*[6]	Delhi	20-21	20-21
Sankhya S *et al.*[7]	Himachal Pradesh	21.5	21.5
Present study	Delhi	23-24 (Mean age 22.25±1.35)	21-22 (Mean age 21.96±1.50)

To further explore the global perspective, we compared our findings with studies conducted outside India. The results were similar to studies conducted in the Eastern region of the Indian subcontinent as well as in Europe. Similar researches were conducted by Bartolini et al.[8] in Germany, Wittschieber D *et al*.[9] in Europe, and Ekizoglu O et al. in Turkey. All three studies reported the age at which fusion was complete as 21.74 years, 20.8 years, and 23.11 years in males, and 21.59 years, 20.8 years, and 22.88 years in females, respectively.

Table 4: Comparison of the age at which fusion of the epiphysis of the iliac crest was complete with other studies conducted in the world.

Author	Place of study	Age of males (years)	Age of females (years)
Bartolini V *et al.*[8]	Germany	21.74	21.59
Wittschieber D *et al.*[9]	Europe	20.8	20.8
Ekizoglu O *et al.*[10]	Turkey	23.11	22.88
Present study	India	22.25±1.35	21.96±1.50

CONCLUSION

Radiological assessment of the pelvis can serve as a reliable method for estimating an individual's age during their second and third decades of life. This modality is preferred due to its quick, non-invasive nature and ease of performing and assessing the fusion. However, further research is needed to effectively apply this method to populations from different geographical locations.

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The author declared no conflicts of interest.

ETHICAL ISSUES

The study was conducted after obtaining approval from the Institutional Ethics Committee of the University College of Medical Sciences, University of Delhi, via letter no. IEC-HR/2019/41/36.

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AUTHOR CONTRIBUTIONS

NV: Drafting the work and revising it critically for important intellectual content; final approval of the version to be published. **H:** Acquisition of data for the work and final approval of the version to be published. **JVS:** Revising the work critically for important intellectual content; final approval of the version to be published. **PD:** Revising the work critically for important intellectual content; final approval of the version to be published.

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CASE REPORT

FORENSIC INVESTIGATION OF EXPLOSION IN A PLASTIC RECYCLING PLANT

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ABSTRACT

Introduction: Plastics have woven themselves intricately into the fabric of human existence, manifesting in myriad forms across daily life. From the convenience of single-use items like bags and bottles to the structural integrity of complex machinery components, plastics have no doubt revolutionized industries and consumer habits, rendering them indispensable in multiple sectors, especially routine household items, kid's toys, and healthcare, where they enable sterile packaging and life-saving medical devices. Their omnipresence has also generated environmental challenges; hence, reuse-recycling is encouraged. Plastic recycling plants have grown like mushrooms in the industrial belts of Delhi, the capital city of India, too. An accidental explosion in one such plant was life-threatening to three people and injured six. Cases of such demystifying explosions are rare, and therefore, forensic investigation into the incident is of utmost importance to understand the origin and cause of the explosion.

Case History: This case report details an atypical incident involving a sudden blast within a manufacturing facility in a plastic recycling unit. Forensic scene of crime examination, conducted meticulously and comprehensively, revealed no indications of external ignition sources or any incendiary materials. Chemical analysis of exhibits performed at a forensic laboratory confirmed the presence of butane, consistent with findings from cigarette lighter's fuel, using HS-GC-MS instrumentation.

Conclusion: The clear resolution of this enigmatic explosion was achieved by forensic investigators through a thorough scene of crime investigation, careful co-relation of all pertinent evidence, and applying the basic scientific principles of physics and chemistry. Instances of malpractice, lack of awareness, and negligence in recycling procedures have posed significant risks to individuals present in the vicinity of factory premises.

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INTRODUCTION

Accidental explosions are a cause of concern, especially resulting from the ignition of volatile flammable gases in industrial plants. The case becomes a serious hazard when it occurs in a small recycling industrial factory. The surrounding areas of Delhi, India, have a large number of small recycling units running in various designated industrial sectors. These

incidents underscore the critical importance of understanding and effectively managing the risks associated with handling such hazardous materials, as often the explosions are sudden, providing very few opportunities to act on safety measures. The intersection of accidental explosions caused by the ignition of volatile inflammable gases always presents a compelling case study for forensic scientists to explore the intricate relationship between these unexplained explosions and the scientific methods employed for investigation and analysis. Understanding the dynamics and causes of such incidents is a crucial part for forensic investigators. While explosion injuries resulting from terrorist attacks or combat incidents or burns associated with inhalant abuse have been extensively documented, there is limited literature on sudden explosions due to volatile inflammable gases in industrial settings[1,2]. The investigation of volatile explosions is complex, necessitating a multidisciplinary approach, and requires a comprehensive analysis that encompasses various scientific principles and methodologies for understanding the mechanisms and consequences of such explosions. Explosion involves rapid chemical reactions that produce gases and heat, leading to a shockwave. Principles of physics help to explain the dynamics of shockwaves, while chemistry provides insights into the reactive materials and the specific reactions that occur during an explosion. In the aftermath of an explosion, forensic experts need to determine the cause where chemistry plays a key role in identifying residues and explosive compounds, while physics aids in reconstructing the event through blast wave analysis. This collaboration proves vital for understanding this phenomenon and helps law enforcement and regulatory bodies in their investigations. The authors, therefore, felt the need to write this article keeping in mind the forensic community.

CASE HISTORY

An explosion was reported at a plastic recycling facility situated in Delhi's Industrial Area, India, at approximately 5.10 pm. The blast transpired during the production phase involving the conversion of plastic scrap material, notably including plastic tubes, disposed of syringes and bottles, cannula, discarded cigarette lighters, etc., into small plastic granules. The explosion resulted in severe injury to six individuals, and three people succumbed to death. Notably, all individuals affected by the explosion were employed as daily wage labourers at the facility. Subsequent investigation disclosed that the factory obtained its raw materials from various sources, including hospital waste, general waste, and scrap materials, which were further processed to manufacture recycled plastic goods.

SCENE OF CRIME OBSERVATIONS

Information for the forensic scene of crime examination was received about the factory where the sudden blast took place, and explosion effects were visible when the team reached the spot approximately one hour after the incident (Fig. 1). The half portion of the metallic entrance gate was found broken and one meter apart from the entrance point which clearly depicted the intensity of the explosion (Fig. 1). It was a large plastic recycling factory with working units inside. The recyclable plastic items were segregated manually into different types and then subjected to the recycling process. Many plastic items like pipes, medical disposable bottles, syringes, cigarette lighters, etc., were observed lying in various places (Fig. 2). The walls, ceiling, and machines in the workshop had black shoot deposits on them (Fig. 3). The walls, fans, and other surrounding areas displayed burning and heat effects. The death of three persons working on the premises of the workshop was reported by investigating agencies. Initial inquiries by investigating authorities suspected the death was due to injuries from the sudden unexplained explosion as everyone in the factory was busy with their assigned duties and, therefore, did not pay attention to what had happened. It was also observed that the workshop lacked proper ventilation. Detailed investigation revealed that the explosion did not occur due to any added inflammable substance or electric short circuit. A thorough inspection of the area and waste garbage and raw material revealed some unused plastic bottles and some liquid inside mainly the broken used and unused cigarette lighters (Fig. 4). This raised some suspicion, and the samples

were sent to the forensic science laboratory for detailed analysis. The autopsy samples of the three deceased, along with the scene of crime exhibits, were received at the Forensic Science Laboratory (FSL) for detailed chemical analysis.

Fig. 1: Photograph of the explosion at the scrap factory where the blast took place showing the broken metallic gate (arrow).

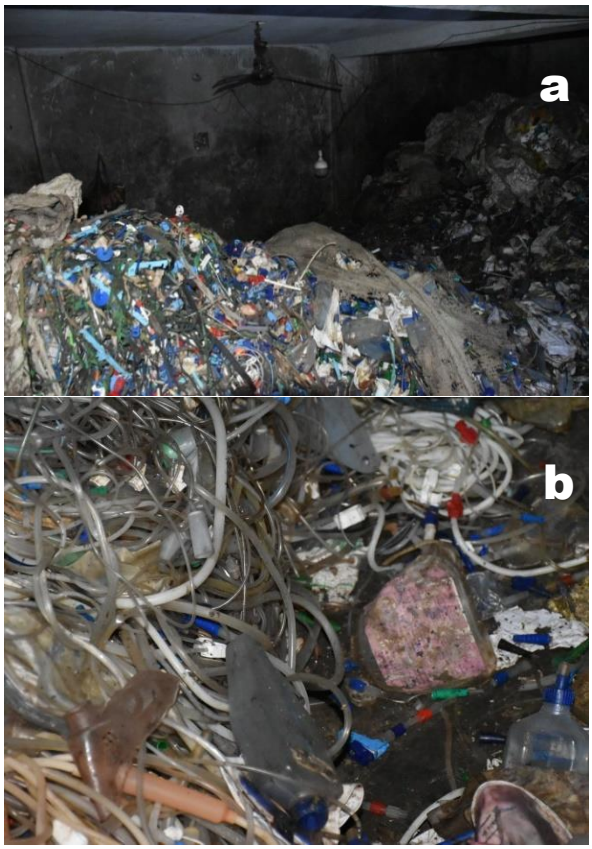

Fig. 2: Photograph showing various waste plastic items found inside the recycling factory (a) with a close-up view (b) showing different types of plastic waste.

Fig. 3: Photographs showing the cascading burnt impressions on walls in the factory.

Fig. 4: Photograph showing partly filled and empty lighters found at the scene of the crime (a) and a close-up view (b).

ANALYSIS METHODS

Samples: Scene of crime exhibits (six lighters with liquid inside), visceral samples, and fresh lighter (procured as working standard).

Instrument: Head Space Gas Chromatography Mass Spectrometry (HS-GC-MS)

Parameters: HS-GC-MS (make Thermofisher Scientific) was used in HS-GC-FID/MS configuration comprising of a GC (Trace 1610) fitted with a FID and MS detector (ISQ 7610) coupled to HS sampler (TriPlus RSH SMART). The split ratio was 1:1 for FID and MS using restrictors. Gas chromatography separation of analytes was carried out using TG Wax MS column (polyethylene glycol, 30m × 0.25 mm × 0.25 µm, make Thermofisher Scientific). The MSD was operated under EI mode. The HS parameters were as follows: oven temperature was maintained at 50°C, agitator speed 250 rpm, and sample drawn was 0.8µl. The sample vials were incubated for 10 min at 60 °C before injection of the sample. The injection port temperature was at 150 °C and operated in split mode with a split ratio of 20:1, a pressure of 9.7 psi, and a septum purge flow of 5 ml/min. The GC was programmed with an initial oven temperature of 45°C which was held for 6 min and then increased linearly to 100°C at a rate of 20°C/min with a 0.5 min hold time and then further increased to 220°C at a rate of 45°C/min. The FID detector temperature was at 250°C. The flow rates of hydrogen gas 35.0/min flow rate with Air 350.0 mL/min and makeup gas Nitrogen 25.0 mL/min for FID. The nitrogen flow rate was maintained at a constant 15 psi. Helium carrier gas (with purity 99.999%) was set to flow at a rate of 0.6 mL/min for MS. MSD temperature was at 300°C, ion source temperature was 280°C, the ionization energy in mass was 70 eV, and scanning was carried out from 14 to 200 amu at a rate of 3.0 scans/s. The total run time for HS-GC-FID/MS was 11.917 minutes per sample. Chromeleon Data Analysis software (Version 7.3.2.10759) was used for data analysis, record, and analysis, and NIST database 2020 was used to interpret the spectra. Identification of the compound was determined by the retention time.

RESULTS

HS-GC-MS is a powerful analytical technique used extensively in the identification of volatile substances. The combination of GC and MS allows for the separation and identification of complex mixtures, providing specific data on the molecular structure of each substance, making it highly sensitive even for detecting low concentrations of volatile compounds. Moreover, it enables rapid sample analysis with less or no sample preparation process, providing qualitative and quantitative analysis identification of volatile substances. A minimal sample preparation process reduces the risk of contamination and loss of volatile compounds, improving efficiency, which is particularly beneficial while analysing sensitive samples where preserving the integrity of the volatile components is critical. HS-GC-MS plays a crucial role in the identification of volatile substances across multiple sectors. Its sensitivity, speed, and versatility make it an indispensable tool for scientists and analysts working to ensure

safety, compliance, and quality in their respective fields. HS-GC-MS analysis identified the presence of butane, and confirmation of ions of butane was detected with m/z values 43, 29, 27, and 57, respectively[3] in the liquid obtained from all the lighters collected from the scene of the crime (Fig. 4a and 4b) and Fig. 5a, 5b and 5c illustrates the result of only one lighter fluid sample along with the standard. All the samples gave similar results. A diagrammatic representation of the whole case is presented in Fig. 6.

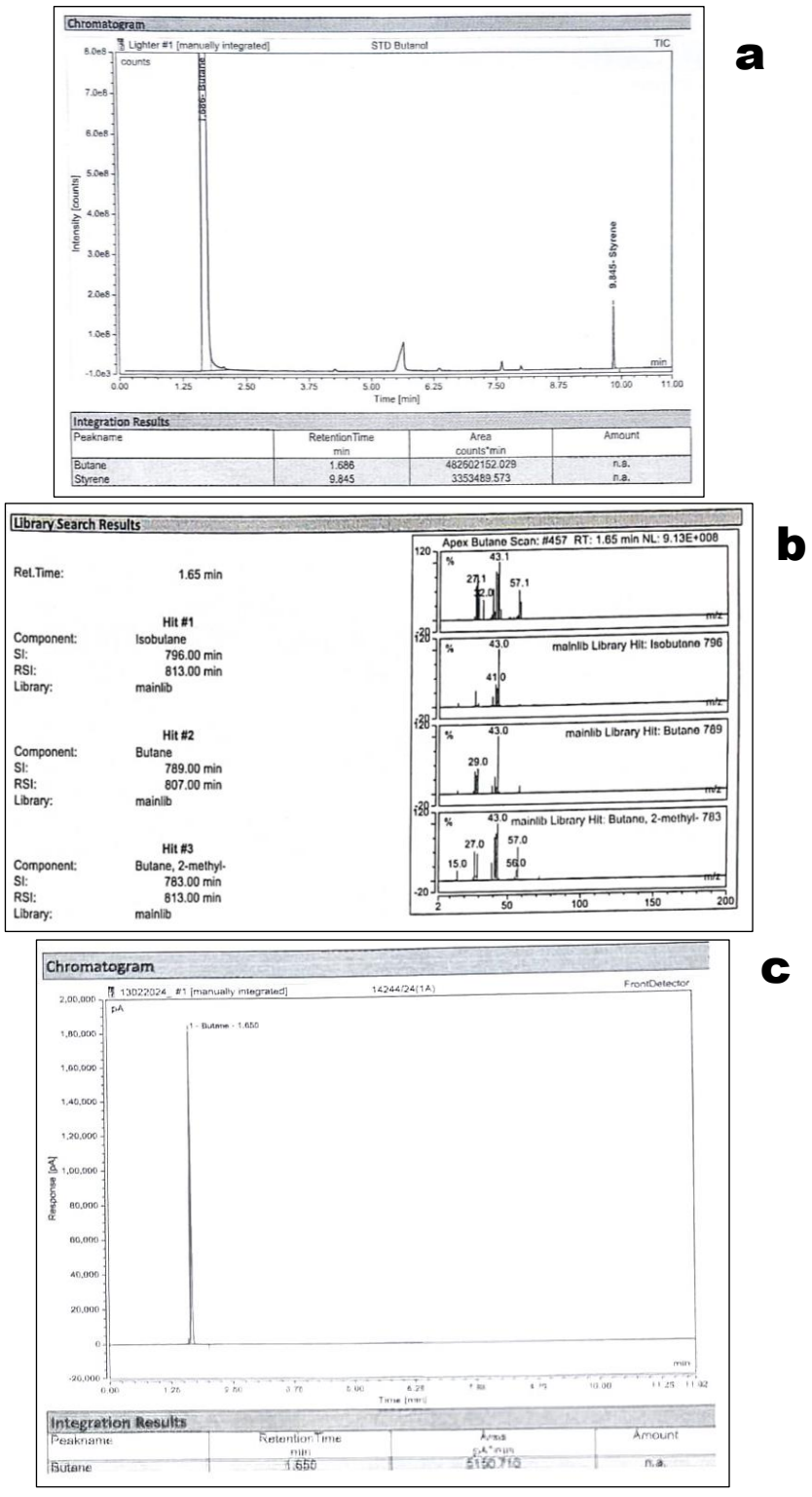

Fig. 5: Total Ion Chromatogram of Standard Liquid Butane (a), m/z values (b), and sample analysis liquid obtained from lighters in instrument GC-HC-MS (c).

Fig. 6: Diagrammatic representation of the analysed case study

DISCUSSION

Accidental explosions attributed to butane gas are a rare phenomenon, although forensic reports on butane gas toxicity and inhalant abuse have been reported earlier. Butane is a highly flammable gas, which ignites quickly in the air if exposed to a static charge or a spark and is therefore used as a basic fuel in lighters. The presence of styrene was also detected in working standards, which is unexplained. Although styrene in gaseous form also has explosive and flammable properties, it was not identified in case exhibits, hence, it is not discussed here. During s, subsequent toxicological analysis, no other toxic chemicals, drugs, or any other pharmaceutical products were found to be present in the visceral tissues and blood of the three victims who died during the fatal accident. The post-mortem report suggested cranio-cerebral injuries as the cause of death. Thus, from the circumstantial evidence, autopsy findings, and results of the toxicological investigations, forensic scientists were clear that the cause of death of these victims was not remotely related to the presence of butane in the body tissues or blood sample.

Butane and isobutane are the primary volatile components of cigarette lighter fluid. Butane gas is used in many applications like fuel for cooking, lighter fluid, refrigerant, deodorant propellant, and industrial applications[1]. Butane, an aliphatic hydrocarbon derived from petroleum, is a highly flammable, odourless, colourless, non-halogenated gas[4]. Incidents involving butane gas typically stem from camping gas explosions, accidents during motor vehicle refuelling, or abusive inhalation[1]. While speaking to individuals in the factory, it was gathered that the collected lighters were first segregated based on their colours, and then their metal part was removed. Later, the lighters were broken into large pieces, and the inner liquid Butane was discarded carelessly or spilled into the nearby surroundings. Sometimes, the discarded plastic containers may be full or have some leftover contents in them. It is very important for individuals working in recycling units to know the contents that were stored in such containers and safely discard them before processing or breaking such containers. Butane, being an odourless gas, no foul smell must have been identified by individuals working on the premises, potentially leading to unnoticed accumulations. It is also important to mention here that there was no gas detector in the factory, which should be one of the prime requirements while establishing any factory. The boiling point of Butane gas is -0.5°C, suggesting its existence in gaseous form at normal temperature and pressure[5]. Low boiling point liquid Butane ensured rapid evaporation in the high summer temperature of Delhi and thus minimized workplace contamination where it was spilled during the recycling process. Therefore, no urgent need was felt by either the factory owner or the workers to make any appropriate arrangement for the proper removal of the discarded liquid. Delhi's warm summer climate gave enough time for the gas to accumulate in large volumes without getting noticed. However, the accumulation of inflammable butane vapours, imperceptible to smell, can pose significant risks. It is readily visible how butane gas settled in the routine process through heating effects observed on the ceiling, the fans, and the upper parts of the walls (Fig. 3) after the explosion in the recycling factory. In an enclosed space, these volatile, inflammable vapours become extremely explosive when an ignition source is introduced and is sufficient to create an explosion[1]. The ignition source may not be deliberate, but an invisible spark in the factory machine or at a plug point, which under normal conditions may not cause any harm, is, in fact, sufficient to cause an explosion. The investigation revealed that everyone was working during the incident, so the machines were in running condition. However, inquiries during the scene of crime investigation ruled out any possibility of intentional fire or observation of any spark in the premises. It is pertinent to mention here that the mere presence of an inflammable fuel in the vicinity of an ignition source will not in itself guarantee combustion, but the flammable range of that fuel must also be reached, above or below which combustion will not be sustained. Butane forms an explosive mixture with air when it is found in concentrations between 1.8 and 8.5%[5]. When such an inflammable mixture is ignited, a rapid, exothermic combustion reaction occurs. The resulting products of

combustion, carbon dioxide, and water vapour, undergo a rapid increase in temperature, pressure, and volume. The destructive nature of this ignition will depend on two important factors. Firstly, the volume of the fugitive gas (here Butane) available for ignition will determine the amount of energy available for release. Secondly, the degree of confinement of the fugitive gas will determine the extent to which products of combustion will be able to expand, i.e., the force created. It is this destructive force of the gaseous explosion that caused the greatest damage in the plastic recycling plant but caused no fire because all the gaseous fuel was consumed in the explosion. Such explosions result in a short-term high-heat release that is too short in duration to ignite structural or other large components in the vicinity. The important point in any forensic analysis of such an unexplained explosion is the confinement of the inflammable mixture, its movement, and its spread. Upon re-analysis of the scene of the crime, it was evident that major prerequisites for combustion must have been fulfilled due to the very high possibility of the release of butane and its accumulation in sufficient quantity in the closed work area. Further, any ignition source or spark must have led to rapid combustion, creating a high pressure with subsequent explosion.

CONCLUSIONS

This interesting case of an accidental explosion is of forensic importance as the explosive potential of butane, a volatile and inflammable gas, is largely unknown. Plastic waste recycling is a specialized process including sorting, cleaning, and processing of plastic waste through methods like shredding and melting to produce raw materials suitable for manufacturing new plastic products. It is, therefore, pertinent to mention here that recycling plant owners and workers must have proper awareness regarding safe handling and accident prevention. While plastic scrap recycling significantly aids in mitigating environmental pollution and resource conservation by diverting waste from landfills and incinerators, any oversight or negligence can lead to tragic and inexplicable fatalities, as evidenced by the unfortunate loss of three lives in this instance.

LIST OF ABBREVIATIONS:

HS - Headspace
GC - Gas Chromatography
FID - Flame Ion Detector
MS - Mass Spectrometry
EI - Electron Impact Ionization

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CONFLICTS OF INTEREST

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AUTHOR CONTRIBUTIONS

SS: Study conception and design, analysis, presentation, interpretation of data critical review of the draft; and final approval of the version to be published. **PP:** Scene of crime observation and final approval of the version to be published. **VK:** Data analysis and interpretation and final approval of the version to be published. **MK:** Instrumentation and interpretation; final approval of the version to be published. **YCP:** Critical review of draft and presentation and final approval of the version to be published.

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CASE REPORT

A COCAINE AND HEROIN-RELATED SUDDEN DEATH IN SRI LANKA: TOXICOLOGICAL EVALUATION

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ABSTRACT

Cocaine is a prominent illicit substance associated with sudden mortality in individuals engaging in poly-drug use. We are presenting a case of a sudden death of a 37-year-old male. The autopsy failed to reveal the pathological cause of death, and the toxicological analysis of post-mortem samples was carried out. Quantitative analysis of ethanol was carried out by headspace gas chromatography with a flame ionization detector (FID). Solid-phase extraction was carried out to extract drugs and their metabolites from biological samples. After derivatization, these drugs and metabolites were then quantitatively analysed using gas chromatography-mass spectrometry. The analytical methods were validated before analysing the samples.

In the toxicology results, all biological samples, including blood, bile urine, and stomach contents, contained morphine, with concentrations ranging from 12 µg/mL to 55 µg/mL. 6-Monoacetylmorphine was detected in urine at a concentration of 8 µg/mL and in stomach contents at a concentration of 60 µg/mL. The concentrations of cocaine were detected in bile, urine, and stomach contents at 727 µg/mL, 202 µg/mL, and 39 µg/mL, respectively. Benzoylecgonine was detected in blood, urine, and stomach contents at concentrations of 6 µg/mL, 227 µg/mL, and 7 µg/mL, respectively. Additionally, ecgonine methyl ester was identified in urine at a concentration of 123 µg/mL. Furthermore, ethanol concentrations of 109 mg/100 mL in blood and 102 mg/100 mL in urine were also detected.

The presence of cocaethylene in the stomach contents and urine samples confirmed that cocaine and ethanol were co-administered, leading to a more pronounced effect. The presence of cocaine, its metabolites, ethanol, cocaethylene, and heroin metabolites in the biological samples reveals the simultaneous use of cocaine, heroin, and ethanol. This drug combination likely led to acute toxicity. Therefore, these findings provide a well-defined outline for the cause of death.

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INTRODUCTION

Forensic toxicology analysis involves evaluating toxicological data to understand its implications for legal and medical investigations[1]. Forensic toxicology qualitative analysis identifies the specific drugs or chemicals present, while quantitative analysis measures their concentrations[1]. Together, these methods provide crucial information on whether a substance could have contributed to a person's

death or impairment, aiding in the reconstruction of events and supporting legal decisions in cases such as overdose, poisoning, or substance-related incidents[1-4]. Furthermore, toxicological analysis revealed that the deaths were caused by overdoses of illicit drugs, with some cases involving the use of multiple drugs simultaneously[2-4]. These findings highlight the significant role of drug abuse, both singularly and in combination, in contributing to the fatalities[2-4].

In the literature, Joaquín Lucena *et al*. found that out of 668 cases of sudden death, 21 were related to cocaine use[2]. Additionally, the study reported that 62% of the sudden deaths were due to cardiovascular causes, while 14% were attributed to cerebrovascular causes. In a two-year toxicology study by Candia *et al*., 136 cases were analysed[3]. The results showed that 74.3% of the cases tested positive for substances, which included illicit drugs such as cocaine and morphine, along with ethanol. Furthermore, Rooney *et al*. stated that a significant risk of cocaine overdose occurs in cases of polydrug use, particularly when combined with opiates and/or alcohol[4].

Cocaine is one of the most common illicit drugs of abuse in many countries[4-7]. Heroin is a potent opioid that, when used concurrently with other substances like cocaine, increases the risk of adverse cardiovascular and respiratory events, often leading to fatal outcomes[8].

The World Drug Report 2022 by the United Nations Office on Drugs and Crime (UNODC) showed that the annual prevalence of cocaine and heroin use at the global level is approximately 0.45% and 1.15% of the general population, respectively. Cocaine is a central nervous system stimulant, and it blocks the re-uptake of neurotransmitters such as norepinephrine, dopamine, and serotonin[1,9]. Consumption of cocaine together with ethanol results in the formation of a pharmacologically active metabolite, cocaethylene[1,9-11]. Cocaine and cocaethylene structurally differ only in the substitution of an ethyl group in place of the methyl ester of cocaine however, it has stronger physiological effects compared to cocaine[12-13]. Cocaine is metabolized primarily into two major metabolites, biologically active benzoylecgonine and biologically inactive ecgonine methyl ester (EME) by plasma and liver enzymes[14]. In this study, we present a case of a sudden and tragic death of a male individual who ingested a combination of cocaine and heroin in conjunction with alcohol, which is reported in the literature for the first time in Sri Lanka.

CASE HISTORY

A 37-year-old male was found suddenly unresponsive at a party. There is evidence that the deceased used alcohol at the party, along with others. Post-mortem samples, including blood, urine, bile, vitreous humour, and stomach contents, were sent to the forensic toxicology laboratory at the Government Analyst's Department, Sri Lanka, for toxicology analysis. Used vodka bottles, food, and beverage samples from the scene were also sent to the said department. All samples were stored and preserved in a cold room at 2-8°C.

METHOD OF ANALYSIS

Reference standards of ethanol, benzoylecgonine, cocaine, 6-monoacetylmorphine (6-MAM), morphine, and ecgonine methyl ester were purchased from Lipomed (Switzerland). Solid phase extraction (SPE) cartridges (Bond Elute Certify Columns 10 mg) were purchased from Agilent Technologies (USA). Other common chemicals: methanol (99.5%), hydrochloric acid (HCl 37%), dichloromethane (98%), isopropyl alcohol (99.5%), n-propanol (99.8%), ammonium hydroxide (25%), ethyl acetate (99.5%) and phosphoric acid (88%); all were analytical grade and purchased from Sigma-Aldrich Laborchemikalien GMBH, Germany. The two derivatization agents, N,O-Bis(trimethylsilyl)trifluoroacetamide (BSTFA) and Trimethylchlorosilane (TMCS), were also purchased from Sigma-Aldrich Laborchemikalien GMBH, Germany.

The analysis of ethanol and methanol in blood, urine, and vitreous humour was conducted

using n-propanol as an internal standard, employing headspace gas chromatography with a flame ionization detector (HS-GC/FID). A bond Elute certify column (10 mg) was used for solid-phase extraction (SPE) to extract benzoylecgonine, ecgonine methyl ester, cocaine, 6-monoacetylmorphine (6-MAM), and morphine from biological samples. These drugs and metabolites were then quantitatively analysed using gas chromatography-mass spectrometry (GC-MS) after derivatization.

Alcohol analysis- HS-GC/FID apparatus and conditions

HS-GC/FID analysis was performed on a headspace autosampler, Thermo Scientific Triplus 300, and Thermo Scientific Trace 1300 GC with flame-ionization detector (FID). The analysis was carried out using Restek Rtx -BAC 1 capillary column (30 m x 0.32 mm ID x 1.8 µm gf).

Blood/urine/vitreous humor samples were prepared by adding a sample (0.1 mL) and internal standard (0.02% n-propanol, 0.7 mL) into a headspace vial and rapidly sealed with a septum and an aluminium crimp cap to prevent any loss of alcohols. The sealed vials were introduced to the Triplus 300 headspace auto-sampling system for volatilization (70 ^{0}C for 13 min) and GC cycle time of 30 min. The transfer line temperature was set to 200 ^{0}C, and the carrier gas flow rate was 3 mL/min. Split mode injection was done with a split ratio of 10:1, and the front inlet temperature was set to 200 ^{0}C, pressure 12.1 psi. The oven temperature was held at 70 ^{0}C. The total run time for gas chromatography was 7 min. Quantification of ethanol was performed using a calibration plot of the area ratio of ethanol to the internal standard versus ethanol concentrations.

Solid phase extraction[15]

0.1 M potassium phosphate buffer (5 mL) was added to the autopsy urine/bile sample (1 mL) followed by the addition of phosphoric acid till the pH of the sample was around 5.8-6.0. The sample was then subjected to SPE. The cartridges were activated with methanol (2 mL) and 0.1 M potassium phosphate buffer (2 mL) before use. Then the above prepared sample was applied to the SPE cartridge and slowly passed through it. The cartridges were rinsed with de-ionized water (6 mL), 0.1 M HCl (3 mL), methanol (9 mL) and vacuum-dried for 5 min. The retained drugs of abuse were eluted with a mixture of dichloromethane, isopropyl alcohol, and ammonium hydroxide (78.4:19.6:2) (2.5 mL) under gravity. Each elute was evaporated to dryness under a stream of nitrogen using a nitrogen evaporator.

For autopsy samples of blood (1 mL) and stomach contents (1 g), preparation of the samples was needed. Methanol (5 mL) was added to autopsy blood/ stomach contents, and the sample mixture was vortexed. This was centrifuged for 15 minutes at 5000 rpm. The above steps were repeated for the infranatant, and the resulting supernatants were combined. The combined supernatants from the above centrifugations were evaporated to 1 mL and followed by the above-mentioned procedure, which was used for urine/bile.

Derivatization[16]

For the GC-MS analysis, extracted samples were derivatized using a mixture of the derivatizing agents BSTFA and TMCS (99:1, 50 µL). As the final step, ethyl acetate (50 µL) was added, followed by 15 minutes in the oven at 90 °C. This was then injected into GC-MS.

GC-MS apparatus and conditions

GC-MS analysis was performed on Agilent Technologies, USA 8890-GC with Agilent 5977B-MS. The analysis was carried out using a capillary column HP-5 MS (30 m x 0.250 mm x 0.25µm). The oven temperature program had an initial temperature of 150°C held for 1 min, then 10°C/min to 270 °C held for 4 mins. The final temperature was held for 12 min. Helium was used as the carrier gas at a flow rate of 0.6 ml/min. The GC injector and transfer line temperatures were set at 270°C and 280 °C, respectively. The mass spectrophotometer was operated in the electron impact ionization (EI)

mode. The mass detector was linked to a data handling system with Agilent MSD Chem-Station integration software (E.02.02.1431) for data acquisition.

RESULTS, INTERPRETATION AND DISCUSSION

The gas chromatography detection process had a total run time of 17 minutes. The method was validated according to Eurochem guidelines, and all validated parameters fell within the accepted range of the validating method. (Table 1)

Table 1: Method validation parameters for 6-MAM, morphine, cocaine, benzoylecgonine and ecgonine methyl ester

Sample	RT (mins)	Calibration Range (µg/mL)	R^2	LOD (µg/mL)	LOQ (µg/mL)
6-MAM	15.123	5-100	0.9976	1.5	2.0
Morphine	14.407	10-100	0.9936	1.1	1.3
Cocaine	11.76	10-100	0.9957	1.1	1.3
Benzoylecgonine	12.31	5-100	0.9996	1.2	1.6
Ecgonine methyl ester	5.52	5-100	0.9975	1.2	1.6

RT- Retention Time LOD-Limit of detection; S/N=3 LOQ- Limit of quantification; S/N=10

According to the toxicology results (Table 2), all biological samples contained morphine, with concentrations ranging from 12 µg/mL to 55 µg/mL. Further, the post-mortem urine and stomach contents contained 8 µg/mL and 60 µg/mL, respectively. Diacetylmorphine (heroin) is rapidly metabolized to 6-MAM and then to morphine after administration[4]. 6-MAM is a biomarker for heroin use; therefore, the presence of 6-MAM in urine and stomach contents and morphine in the deceased's blood, bile, urine, and stomach contents confirmed the use of heroin[17].

Baselt R *et al* in 2008 reported that morphine concentrations in blood ranged from 0.2 µg/mL to 2.3 µg/mL, with an average of 0.7 µg/mL, and in urine from 14 µg/mL to 81 µg/mL, with an average of 52 µg/mL in fatal cases[18]. Furthermore, Poklis *et al* in 1995 found concentrations of 0.128 µg/mL, 135 µg/mL, and 16 µg/mL in the blood, bile, and stomach contents, respectively in a fatal case of morphine overdose[19]. Hence, it is evident that the morphine levels found in the post-mortem samples in our case have exceeded those reported in the literature.

Table 2: Toxicological results

Alcohol detection						
Blood	Ethyl alcohol-109 mg/100 mL					
Urine	Ethyl alcohol-102 mg/100 mL					
Vitreous humor	Ethyl alcohol- Not detected					
Drugs/metabolite concentration (µg/mL)						
	6-MAM	Morphine	Cocaine	Benzoylecgonine	Ecgonine methyl ester	Cocaethylene
Blood	N/D	55	N/D	6	N/D	N/D
Bile	N/D	46	727	N/D	N/D	N/D
Urine	8	12	202	227	123	Detected
Stomach content	60	42	39	7	N/D	Detected

The analytical results revealed the presence of cocaine in bile, urine, and stomach contents at concentrations of 727 µg/mL, 202 µg/mL, and 39 µg/mL, respectively. Cocaine metabolites, including benzoylecgonine were detected in the blood, urine, and stomach contents at concentrations of 6 µg/mL, 227 µg/mL, and 7 µg/mL, respectively. Ecgonine methyl ester was also detected in the urine at a concentration of 123 µg/mL. The above results confirmed that the deceased used cocaine along with heroin, which resulted in a fatal outcome. This is confirmed by the literature, where Rooney *et al*. in 2003 found that cases of morphine-cocaine co-administration had the highest proportion of fatalities during their research period from 2000 to 2019 in England[4].

Di Candia *et al*. in 2022 reported at the Bureau of Legal Medicine of the University of Milan in Italy that the most common drug detected in drug-related deaths was cocaine, with concentrations ranging from 0.33 µg/mL to 19.8 µg/mL in cardiac blood and 0.49 µg/mL to 18.78 µg/mL in femoral blood[3]. According to these data, the minimum levels detected are 0.33 µg/mL and 0.49 µg/mL in blood samples from different sites of the body. These values are below the limit of detection of the method used, which may explain the failure to detect cocaine in blood samples in our study.

Furthermore, the concentrations of ethanol in the blood and urine, which were 109 mg/100 ml and 102 mg/100 ml, respectively, indicate ethanol consumption by the deceased. Cocaethylene was detected in the urine and stomach contents samples; however, we were unable to quantify it due to the unavailability of reference standard material. The presence of cocaethylene indicates the co-administration of cocaine and ethanol, which resulted in a cumulative effect with a fatal outcome.

Cocaine use carries a significant overdose risk, particularly when consumed in large amounts or in combination with other substances, like opioids or alcohol. It can have a serious impact on the cardiovascular system, with elevation of the heart rate and blood pressure. With higher doses or more frequent use, there can be dangerous complications like seizures, strokes, and heart attacks. Chronic use may cause lasting damage to the heart, including conditions like cardiomyopathy and arrhythmias. Users of cocaine are also more prone to develop mental health issues, such as depression and suicidal thoughts[4]. When mixed with potent opioids like heroin, which has a quick action, the risk of respiratory depression and overdose is significantly heightened, even for those not regularly using opioids[20]. Additionally, cocaethylene, which is the toxic by-product of alcohol and cocaine, leads to an even greater increase in heart rate and cardiac toxicity than cocaine alone[4].

The observed variations in results can be attributed to the pharmacokinetics of the drugs, which are influenced by multiple factors. These factors may be related to the drug itself, such as the postmortem interval, route of administration, postmortem stability, redistribution, and concomitant use of other substances. Additionally, individual-specific factors, including body mass index (BMI), acute or chronic use, underlying health conditions, age, and sex, also play a significant role.

CONCLUSIONS

This case highlights a trend of polydrug abuse in Sri Lanka, especially for recreational purposes, where cocaine may be used combined with other substances. Therefore, medical professionals need to have awareness and vigilance when handling patients with sudden unconsciousness/ death.

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LETTER TO THE EDITOR

THE ELUSIVE PATH TO VIRTUAL AUTOPSY IN DEVELOPING COUNTRIES

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I read with interest the "Contentious Issues" article on the need for incorporating imaging modalities into autopsy work[1]. I congratulate the authors on their significant contribution to the field of forensic radiology and its application in day-to-day practice. There's always a discord between tradition and innovation, with some old-school pathologists viewing 'virtopsy' as mere 'shadow play' compared to the 'reality' of conventional dissection. I do not wish to delve into that debate, but some practical concerns are worth discussing. While the article candidly explains the methods to adopt imaging into forensic pathology practice, the key elements to consider are the skills gap for forensic pathologists in reporting scans and the significant question of the costs involved in establishing a virtual autopsy centre.

The article mentions that numerous postmortem artifacts complicate interpretation even for trained professionals. Therefore, introducing virtual autopsy in any jurisdiction requires carefully planned training, taking into consideration the varied learning curves of pathologists of different ages and experiences. Comprehensive training is essential to ensure accuracy before transitioning away from traditional 'open autopsy'. One advantage of digital autopsy is the ability to retain data for interpretation at any time. However, it's crucial to implement robust digital archival systems to prevent data breaches or theft[2].

From the perspective of the global south, the initial costs associated with setting up imaging technologies can be overwhelmingly high. Even the ongoing expenses such as software add-ons, license renewals, and facility maintenance to meet regulatory standards pose significant challenges. Countries proficient in virtopsy technology should support developing nations through technology transfer and expertise sharing at no cost. The commercialization of the non-invasive autopsy model poses a significant barrier to its adoption in these regions, as several companies have entered this domain and are targeting Asian countries due to the high volume of autopsies conducted there.

It's unfortunate but true that mortuaries in some developing countries lack basic infrastructure such as proper cold storage, dissection tools, and body packing materials. This often makes me question whether we should prioritize addressing these fundamental needs before introducing novel technologies into our setting. While I agree with the importance of evolving with technology and respecting the wishes of the deceased's next of kin, the reality in many third-world countries is that some tertiary care institutions lack CT/MRI facilities crucial for diagnostics and emergency care. This raises a valid concern: is

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it fair to prioritize imaging technology for autopsy services when basic imaging services are unavailable for saving lives in critical situations?

But at the same time, the crucial question arises: why must the deceased endure the whole dissection of their body to determine the cause of death when a more humane and palatable alternative is available? Is it not the right of an individual to decide beforehand how their body should be handled in the event of an unnatural death? The outdated concept that the state owns the dead body is undoubtedly 'barbaric'. I strongly believe that human rights charters should advocate for dignified handling of mortal remains and recognize choosing the type of autopsy as a fundamental human right under the Charter of Human Rights. While there is no issue of consent in a medico-legal autopsy, as the deceased was wronged and their death needs investigation, should we not explain and seek consent when there are two equally standardized alternatives? Is this not a fundamental part of medical ethics?

From a broader perspective, it is undeniable that keeping pace with technology and adapting our work systems to meet the needs of our clientele are necessary steps. In my view, virtopsy should become accessible to all humankind rather than a luxury for the few. It is time for a consensus on this matter across jurisdictions, with the hope that governments are prepared to invest in this domain.

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RESPONSE TO LETTER TO THE EDITOR

RESPONSE TO LETTER TO THE EDITOR: THE ELUSIVE PATH TO VIRTUAL AUTOPSY IN DEVELOPING COUNTRIES

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Dear Editor,

I appreciate the thoughtful and detailed response from the author of the letter titled "The Elusive Path to Virtual Autopsy in Developing Countries," which raises pertinent questions and reflections on the challenges associated with implementing virtopsy technology, particularly in resource-constrained settings.

The letter highlights the discord between conventional dissection-based autopsies and the emerging, less invasive virtopsy approaches. This debate is longstanding, with strong opinions on both sides. While traditional autopsy remains the "gold standard" due to its established reliability and accessibility, virtopsy holds immense potential for enhancing forensic investigations, particularly in preserving the dignity of the deceased and providing non-invasive alternatives for next of kin[1,2,3].

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The concern regarding the skill gap among pathologists in interpreting imaging data is valid. Postmortem imaging introduces challenges, such as artifacts, that can complicate interpretation. Therefore, structured and comprehensive training programs for forensic pathologists are critical, and these programs must be tailored to varying levels of experience. The development of hybrid models that combine traditional and virtual autopsies could bridge the gap during this transition, allowing the advantages of both methods to be utilized effectively[2,4].

As for the costs associated with setting up virtopsy centres, I concur that high initial investments and ongoing expenses related to software updates and maintenance can be significant barriers, particularly in developing countries. Prioritizing virtopsy in regions lacking even basic imaging modalities may seem incongruous. Many tertiary institutions in developing countries face infrastructural deficiencies, and addressing these fundamental needs should be paramount before venturing into postmortem imaging technologies[5]. Nevertheless, given the proper infrastructure and investments, virtopsy could become an essential complement to diagnostic tools in the future.

The ethical dimension of offering families a dignified alternative to traditional autopsy is particularly compelling. Although medico-legal autopsies may not require consent, your argument for offering more humane and less invasive alternatives to the decedent's families aligns with evolving perspectives on human rights. Integrating virtopsy as an option, where

feasible, acknowledges the emotional and ethical considerations surrounding death and postmortem procedures.

Finally, I strongly support your call for global collaboration to make virtopsy technologies more accessible and less commercialized, particularly in lower-income regions. Technology transfer and knowledge sharing between nations could facilitate the adoption of virtopsy worldwide[6]. Virtopsy should not be a luxury reserved for high-income countries but rather an accessible tool that aligns with the evolving needs of forensic pathology globally.

In conclusion, the integration of virtopsy into forensic practice presents both challenges and opportunities. As we navigate this transition, it is essential to focus on training, infrastructure development, and ethical considerations. While virtopsy may not be feasible in all settings, it is a valuable tool worth pursuing through careful planning and international cooperation.

Thank you once again for your insightful contribution to this vital discussion.

Sincerely,

Herath JC, Herath UR
Authors of "*Are invasive postmortem examinations still the 'gold standard' in diagnosing the cause of death?"*

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INVITED ARTICLE

RESPONSE OF AUSTRALIA'S FORENSIC MORTUARIES TO THE COVID-19 PANDEMIC

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ABSTRACT

The COVID-19 pandemic had an impact on health services, including forensic pathology services, throughout the world. Throughout the COVID-19 pandemic, forensic mortuaries in various Australian jurisdictions developed and implemented local guidelines and procedures to ensure the safe continuation of providing their essential services. The jurisdictional responses are outlined in this article.

Keywords: *Autopsy; COVID-19; forensic; post-mortem examination*

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INTRODUCTION

From the outset, it was thought that in most Australian jurisdictions, forensic pathologists undertaking work for coroners would have limited engagement with COVID-19 cases as they would be considered natural deaths and would not fall under the jurisdiction of the coroner. However, in certain instances, such as a person dying an unnatural death or the diagnosis not being known before death, COVID-19 autopsies would need to be performed.

Australia reported its first cases of COVID-19 on 25 January 2020, its first death on 1st of March 2020, and the first recorded case of community transmission was reported the following day.

The Royal College of Pathologists of Australasia (RCPA) was consulted about guidelines for undertaking autopsies early in 2020. At this stage, there had been much larger outbreaks elsewhere in the world and some autopsy information was available. It was deemed that it was safe and important from a disease progression point of view to perform autopsies on these cases where required. Advice on the Handling of Anatomical Specimens and Autopsy was published on the RCPA website in April 2020 with reference to guidelines for autopsy practice in the USA and UK[1,2,3].

Differing guidelines and testing procedures were implemented across Australian states and territories, and the jurisdictional responses and experiences are outlined in this paper.

JURISDICTIONAL APPROACHES

Queensland

From April to October 2020 the department was divided into two teams, with no cross-over between the teams. This was done to maintain continuity of service as workplace contacts of COVID-19 positive cases were required to quarantine at the time. Staff leave was minimal, enabling this system to work reasonably well. In October 2020, staff regrouped into a single department and followed the Queensland Health mandate for COVID-19 vaccinations. Required isolation periods did, at times, cause some staffing shortages. However, work-from-home arrangements meant otherwise well staff could continue to work while isolated.

Initially, it was decided to perform combined oropharyngeal/nasopharyngeal COVID-19 swabs on cases with a history of fever/upper respiratory tract infection/COVID-19-like symptoms prior to death and await the results before performing an autopsy. There were rare positive cases received through the department.

Following a multi-department consultation process in 2021 (including microbiology, virology, and forensic pathology) and discussion with other forensic departments, a formal guideline was developed called "Guideline for Management of Suspected PM COVID testing at Forensic Scientific Service (FSS)". This guideline outlined an approach to triaging and handling potentially positive COVID-19 cases arriving at FSS. Testing for COVID-19 continued for cases with a history suspicious of fever or respiratory illness.

Cases requiring autopsy with COVID-19 were preferably performed in the negative pressure special dissection theatre.

External visitors were stopped, including viewings of deceased bodies, as this area of the department did not have sufficient size for required social distancing measures.

Personal protective equipment (PPE) masks utilized within the autopsy theatre were changed to N95 masks only, with mask fit tests required.

Around mid-2020 mask supply issues led to participation in a COVID-19 surety PPE supply program to ensure adequate PPE supplies, set aside by Queensland Health.

Northern Territory (NT)

Very low case numbers of COVID-19 were reported in the NT from the start of the pandemic until the end of 2021, with the first case of community transmission identified in November 2021 followed by the first COVID-related death reported in December 2021.

No routine COVID-19 screening of deceased bodies was conducted upon mortuary admission, with COVID-19 testing (nasopharyngeal swab) only performed in cases with a reported history of respiratory symptoms, fever, a history of traveling prior to death, and/or pathological evidence of respiratory infection observed during macroscopic examination. Additionally, COVID-19 screening was performed on bodies that required interstate or international repatriation. Any COVID-19 positive cases were reported to the NT Centre for Disease Control.

The procedures for the management of COVID-19 positive deceased bodies in the mortuary were in line with international and national guidelines, which included the correct use of appropriate PPE and limited handling of the

bodies (including no viewing to reduce the risk of spreading between visitors). The NT coroner did not investigate COVID-19 related deaths where the cause of death was clear, unless there were any reportable aspects. Full autopsies were performed as required. The usual body storage capacity issues were aggravated during the pandemic as a result of a reduction in the number of funeral and burial ceremonies due to imposed restrictions.

Vaccinations were available and were considered mandatory to all mortuary staff and pathologists during Australia's phase 1A of the vaccine roll-out program.

New South Wales (NSW)

On 17 March 2020, the NSW State Coroner published in the State Coroner's Bulletin No. 11 that deaths as a result of COVID-19 are regarded as natural deaths and that the expectations are that in most deaths due to COVID-19 a Medical Certificate Cause of Death ("Death Certificate") (MCCD) will be issued. Death following contact with a suspected or confirmed patient with COVID-19 was therefore not necessarily referable to the coroner unless it was a reportable as defined within Section 6(1) of the NSW Coroners Act 2009[4].

A risk assessment tool was developed by Forensic Medicine in collaboration with the NSW Ministry of Health, NSW Police, and the Office of the State Coroner. The risk assessment tool was completed by NSW Police at the death scene, and it contained questions related specifically to exposure risk and clinical symptoms related to COVID-19 experienced by the deceased prior to death. The checklist was submitted together with the NSW Police Coronial referral documents to the relevant Forensic Medicine facility. Responses noted were used by the Duty Pathologist (DP) and/or Clinical Nurse Consultant (CNC), together with other available clinical information to determine whether the deceased person should be tested for COVID-19 with a post-mortem nasopharyngeal swab.

Changes to the NSW Coroners Act, Section 88A (preliminary examination) came into effect on 20th January 2020 allowing Forensic Pathologists to collect these samples without obtaining consent from the NSW Coroner. Once a swab was collected, a recommendation was only made to the coroner after receipt of the results. The Coronial Direction decision is based on the guiding principle of the NSW Coroners Act to determine the cause of death in the least invasive manner. Where a deceased was believed to have died from COVID-19, no post-mortem examination was performed as the death was due to natural causes.

No post-mortem screening was available for regional cases not directly admitted to a forensic medicine facility. For these deaths, a decision regarding a potential natural cause of death (including COVID) was made based on available clinical information and information provided by NSW Police on the COVID risk assessment tool.

The Forensic Medicine approach to the management of deaths associated with COVID-19 was documented in a COVID-19 Post-mortem Procedure document providing clear guidelines to all teams. The procedure was continuously updated as the pandemic situation evolved, and immunizations were introduced. The COVID risk assessment tool is no longer used to assess risk at the death scene.

Western Australia (WA)

Similar to the Northern Territory, Western Australia (WA) was delayed in experiencing community spread of COVID-19 infection compared to other parts of Australia, due to firm border restrictions put in place by the State Government. However, community spread was unable to be contained in March of 2022. Following this, additional procedures were implemented, which had been prepared as part of Emergency COVID-19 planning.

For example, whilst in the mortuary, laboratory, and any shared workplace, masks were always worn, specifically surgical masks in office spaces and N95/P2 respirators in the mortuary setting. This was an ongoing procedure, whilst some other measures were stepped down in July and August of 2022.

There was a lag of several weeks between the initial community spread and the arrival of

COVID-19 positive cases at the State Mortuary. All cases were screened upon mortuary admission via throat and nasal swabs sent for PCR analysis. Some cases were precluded, i.e., severe traumatic head injury with marked anatomical disruption or advanced decomposition. Screening for COVID-19 infection on admission was first implemented in March 2020. If a case was identified as being COVID-19 positive, the laboratory notified the mortuary manager and duty pathologist in charge of allocating cases.

If deemed appropriate after evaluation of the case details, COVID-19 positive cases had an external examination to minimize exposure risk at the discretion of the pathologist and coroner. All staff involved in dealing with a COVID-19 positive case, even if just for external examination and sampling, donned PPE, which included a disposable gown, apron, at least two layers of surgical gloves, goggles, N95/P2 respirator, and a disposable face shield. After exposing the body, an N95/P2 respirator was placed over the mouth and nose of the body, and the body was sprayed down with disinfectant several minutes before handling the body. The respirator was briefly removed for examination of the mouth and nose and/or photography. At the end of the examination, the body bag was zipped shut and sprayed down again with disinfectant several minutes before returning the body to the fridge. All staff then appropriately doffed their PPE, as advised by the WHO, to avoid personal contamination. Use of hand sanitizer in between several steps of doffing PPE, particularly between removals of layers of gloves, was advised. COVID-19 positive cases which required full autopsy were performed in the infectious mortuary theatre to limit exposure. Where possible, procedures likely to create aerosols were avoided or kept to a minimum. Manual clippers were used for chest plate removal and an electric saw covered by a clear plastic bag was used for sawing of the head. If a post-mortem CT scan (PMCT) showed no cranial abnormality and there was no indication, internal examination of the head was not performed.

As part of public health tracking of COVID-19 spread, Forensic Pathologists were obligated to report positive cases using a WA Department of Health Infectious and Related Diseases Notification Form sent via email to the relevant authorities. An in-house record of positive cases is kept via an electronic spreadsheet completed by the examining pathologist.

South Australia (SA)

In SA in late February 2020, as the potential risk from COVID-19 in Australia became clear, the State Coroner convened a meeting with SA Police, SA Health (communicable diseases control branch), and Pathology at Forensic Science SA (FSSA). It was agreed to initiate COVID-19 testing by PCR of a nasopharyngeal swab on every admission to the mortuary. This policy was continued until April 2022. FSSA did not identify a definite positive swab until early 2022. Turnaround time for PCR testing varied depending on demand overall within the State but was typically 24 hours. PPE for pre-autopsy testing was as per the SA Health guidelines for clinical sampling.

An additional form to be completed by SA Police (SAPOL) officers reporting deaths to the coroner was initiated to specifically capture information regarding symptoms, contacts, and travel history for additional risk assessment. This form was subsequently updated to include vaccination details.

FSSA uprated the minimum PPE requirements in the mortuary to P2/N95 mask, with most choosing to wear a P3 vented hood with an electrically driven air supply, in addition to the pre-existing PPE requirements. Disposable gowns were also available for positive or potentially positive cases. All positive cases were to be examined in the high-risk autopsy suite.

Masks, gowns, and hand sanitizer were made available in the admission/release bay for funeral directors. Hand sanitizers were made available within non-clinical areas.

No post-mortems were carried out until receipt of the nasopharyngeal swab results, except for suspicious cases that needed to be performed without delay. These were managed in the high-risk suite and assumed to be positive.

No viewings were permitted without the COVID-19 status being known.

No deceased person was released to a funeral director without the COVID-19 status being known. Before the pandemic, a service was offered in cases from rural and regional areas where the autopsy was performed within a day, allowing admission and release to the funeral director within the working day. This was ceased due to the requirement for a COVID-19 result to be known prior to the autopsy and release.

An in-house CT scanner was put out for tender, sourced, and installed/commissioned by July 2020. This had been planned pre-COVID-19. However, its rapid installation before the end of the financial year assisted with our response and created an additional element of pre-autopsy screening with the avoidance of internal examination when appropriate.

Pathologists and mortuary staff in SA did not automatically qualify for vaccinations as healthcare workers. Forensic Pathologists and mortuary staff in SA are employed by the Attorney General's Department and not SA Health. The employer had to specifically engage with SA Heath so that at-risk staff could receive vaccines in group 1b along with healthcare workers.

Vaccinations were made mandatory for all staff by direction from the (Chief Executive Officer) CEO in November 2021 and for staff and visitors to FSSA on 15th December 2021 by Emergency Management Direction. This was modified in January 2022 to include the booster. This remained in place until late 2022.

It was not possible for the pathologists and technical staff to split into teams due to insufficient staff numbers to allow this. However, a rota was initiated where one pathologist was working from home or otherwise isolated from colleagues, to at least maintain the on-call service if there were an outbreak in the workplace requiring mandatory isolation.

Meetings were moved online or with restricted numbers, masks, and social distancing.

Rotation of Anatomical Pathology trainees from SA Pathology and medical student placements were postponed.

Positive cases were reported to the SA Health Communicable Diseases Control branch.

FSSA provided advice to the State Coroner in June 2021 regarding the management of suspected vaccination complications (based on THANZ clinical guidelines[5]).

Victoria

At the start of the pandemic, three goals were set: protection of the health of the staff, maintenance of essential services, and contribution to community efforts to slow the spread of COVID-19.

From the end of March 2020, most of the Victorian Institute of Forensic Medicine (VIFM) staff were working from home where possible. All staff on site were required to wear masks, and those staff working in the mortuary were equipped with full PPE. Group meetings and case discussions were held virtually.

During the first wave, COVID-19 testing was performed only on suggestive history, as testing capacity at the beginning of the pandemic was limited. During the Victorian second wave, nasopharyngeal swabs were performed on all cases on admission where possible. A COVID-19 screening working group was created to document and communicate results (including reporting to the Department of Health). Across the board screening was discontinued in November 2020, and between November 2020 and the 3rd wave, testing was performed only based on suggestive history, imaging, or autopsy findings.

During the delta-driven third wave, screening all VIFM admissions was re-instituted in August 2021 and subsequently de-escalated to a targeted screening approach in November 2021 as the incidence of COVID-19 in the community became very high (with increasing detection of asymptomatic and historic cases on testing). This approach remains in place.

On-site temporary body storage facilities were deployed at varying stages of the pandemic,

largely due to the cumulative delays in funerary processes. Vaccination against COVID-19 was made mandatory for all VIFM staff in accordance with the Victorian state government directives.

Autopsies on suspected and known COVID-19 positive decedents were performed at all stages throughout the pandemic, where it was deemed necessary for the determination of the cause or manner of death. During the second wave, with the family's consent, Victorian post-mortem tissue samples were used for an international study on the effects of SARS-CoV-2 on lung tissue. During the third wave, autopsy findings of home deaths due to COVID-19 were useful to reflect the management of COVID-19 outside the hospital setting. The correlation of post-mortem CT imaging findings with autopsy data informed a study of the utility of post-mortem CT imaging in suspected COVID-19 cases[6]. SARS-CoV-2 infection caused no impediment to autopsy examinations, and autopsies continued to be performed where there was a demonstrable need.

Tasmania

Tasmania had a unique geographical advantage during the pandemic as an island offshore to another island, compared to the mainland Australian States and Territories with their respective land borders. The rapidly evolving nature of the pandemic required continued vigilance and flexibility in the approach taken by the state.

In March 2020, State wide Forensic Medical Services (SFMS) had discussions with the Tasmania Magistrate's Court Coronial Division about mortuary procedures during the pandemic.

Deaths of individuals investigated, diagnosed, confirmed to have COVID-19, and treated and then dying in hospital from pneumonia/ complications were not reportable to the coroner. The manner and cause of death was known to be natural. A separate concern was raised regarding deaths in the community where reliable information was not available or revealed "*a recent flu-like illness*", a scenario encountered during every flu season. Suspicious cases of this type would ideally undergo a PMCT with the body remaining in the sealed body bag, followed by acquiring a swab for respiratory virus testing, including COVID-19.

Closing of international and domestic interstate and territory borders initially reduced forensic case numbers. This allowed SFMS to adopt respiratory virus PCR screening for all cases reported to and as agreed by the coroner. The final decision about the scope (nature and degree) of external and internal post-mortem examination was deferred until screening results were available. SFMS accepted the Advice *for handling of anatomical specimens and Autopsy* published on the RCPA website in April 2020 and adopted, when applicable, guidelines for autopsy practice from the USA and UK.[1-3]

SFMS obtained increased stocks of N95 masks and purchased advanced PPE masks with filters, hoods, and headgear.

When screening revealed relevant COVID-19 nucleic acids on PCR testing in the context of sudden natural death, a limited autopsy was performed for the purposes of issuing a report to the coroner to make findings for those purposes.

Where PCR testing detected COVID-19 nucleic acids in reportable cases where the circumstances of death were suspicious, traumatic, or otherwise unnatural, the proportionate extent of autopsy examination and use of appropriate PPE was determined accordingly.

This approach was complicated in the autumn of 2020 by an outbreak in the Northwest of the state linked to patients, who were previously passengers that had disembarked in Sydney from the Ruby Princess Cruise ship on which there had been an outbreak. The coroner regarded fatal cases linked to this outbreak as potentially reportable under the Coroners' Act 1995[7]. There was also initial concern at this early stage of the COVID-19 pandemic that a mass fatality situation would arise. In early 2020, permanent mortuary storage capacity was increased at the Royal Hobart Hospital. This capacity was further increased temporarily

with a rigid container facility. This additional refrigerated storage was consistent with the State mass fatality/ disaster plan. However, the Northwest Tasmania outbreak was limited, controlled, and investigated by the Public Health Service. Thereafter, case numbers were reduced to almost negligible numbers by December 2021.

The Northwest Tasmania outbreak investigation made recommendations, in support of actions already taken, to reduce or eliminate face-to-face meetings and replace them with online meetings. SFMS adopted an online platform for all forensic meetings with the police and case management reviews with the court and other agencies. Only the duty pathologist attended the mortuary. Microscopy was performed in separate offices within the department. Reports were completed online, working remotely if possible.

Case numbers suddenly increased when Tasmania reopened its borders in line with the mainland states and territories in December 2021. With increased numbers came increased requests from public health services to gather further information about the primary cause of death in reportable death cases in which pre-autopsy PCR screening had detected COVID-19 nuclei acids. COVID-19 is a notifiable disease, and a positive PCR test triggers obligations for the director of Public Health and public health services.

In 2021, the Federal Health Department's definition of COVID-19 related death (*COVID-19 death)* was adopted by the Public Health Service in Tasmania.

COVID-19 death

A COVID-19 death is defined for surveillance purposes as a death in a confirmed or probable COVID-19 case unless there is a clear alternative cause of death that cannot be related to COVID-19 (e.g., trauma). There should be no period of complete recovery from COVID-19 between illness and death. Where a Coroner's report is available, these findings are to be observed.

In 2020, a Public Health Emergency Operations Centre (PHEOC) was established. By December 2021, following the implementation of the vaccination program, the incidence and prevalence of COVID-19 were such that PHEOC was not concerned with contact tracing. The emphasis was upon notifiable disease obligations, including implementation of isolation strategies for positive cases and advice to and support for those infected and their close contacts.

PHEOC was notified by SFMS whether there was a "clear alternative cause of death" without revealing further details, as preliminary findings and autopsy findings are non-disclosable without the coroner's consent. This helped to maintain the integrity of the ongoing death investigation while allowing PHEOC to identify cases where there was an alternative cause of death where COVID-19 infection was probably an incidental finding. When there was no obvious alternative cause of death, then public health measures could be taken with the inference that death was due to natural causes in the context of COVID-19 infection. Determination of whether COVID-19 infection was a primary cause of death, or a significant contributory condition remained pending the completion of ancillary forensic investigations, the coroner's findings, and final Death registration.

CONCLUDING REMARKS

The COVID-19 outbreak outlined the need for forensic pathology services to be responsive and adaptable when new diseases emerge to ensure that services can continue safely, whilst still meeting legal and public health obligations. Whilst each Australian jurisdiction had somewhat differed in its response to the COVID-19 pandemic, all the centers undertook routine COVID-19 testing, and full autopsies were performed only where necessary. Performing COVID-19 autopsies with proper PPE is safe and to date, there are no known cases of COVID-19 infection contracted from the mortuary.

Many Australian jurisdictions participated in research both locally and in collaboration with international groups to study the effects of COVID-19 on the human body using autopsy and imaging findings.

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The authors declared no conflicts of interest.

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INVITED ARTICLE

THE IMPACT OF COVID-19 ON FORENSIC PATHOLOGY SERVICES IN ANTWERP, BELGIUM - PERSPECTIVES OF FORENSIC PATHOLOGISTS

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ABSTRACT

The COVID-19 pandemic, which reached Belgium in early 2020, significantly impacted the country's healthcare system, including forensic medicine. Illustrating the knowledge vacuum the medical world was working in, the first ten patients arriving in Belgium were hospitalized in a police-secured medical facility. By 2021, Belgium was among the most severely affected countries in Europe, reporting over 730,000 cases and more than 21,000 COVID-19-related deaths. In response to these unprecedented challenges, forensic medicine implemented critical reforms to enhance operational safety and maintain service continuity during the crisis. The pandemic altered practices by intensifying morgue-based examinations and relying on postmortem CT (PMCT) scans as an initial screening method. Autopsy protocols were revised to incorporate protective measures and collaboration between forensic and anatomical pathology departments. Despite a surge in domestic violence and mental health issues during the pandemic, there was no corresponding increase in forensic cases. Through close interdepartmental collaboration, forensic services maintained pre-pandemic autopsy rates, contributing valuable insights into COVID-19 pathology and strengthening future preparedness. Lessons learned emphasize the importance of resilient forensic systems in addressing public health crises and enhancing the role of forensic medicine within healthcare.

Keywords: *Belgium; COVID-19; forensic autopsy; medico-legal death investigation*

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EPIDEMIOLOGY

COVID-19 emerged in Belgium in early 2020. On February 2nd, 12 Belgian citizens were repatriated from Wuhan, arriving at Melsbroek Military Airport, and were transported for quarantine to a secured military medical facility where they were hospitalized for 14 days. The following day, on February 3rd, Belgium reported its first confirmed case of COVID-19, an asymptomatic individual from this group. A second case was identified almost a month later, on March 1st. Following spring break, the virus rapidly spread, leading to a national lockdown by mid-March[1,2]. On April 8th a peak death count of 323 deaths in 24 hours was reported[3]. In 2020 and 2021, COVID-19 became the third leading cause of death in Belgium, after neoplasms and circulatory system

diseases[4]. By the beginning of 2021, after two waves, Belgium had reported over 730,000 cases and more than 21,000 deaths, placing it among the hardest-hit European countries relative to its population size, with 17 COVID-19 deaths per 10,000 inhabitants[5,6].

Cases were defined as follows: laboratory-confirmed cases were those diagnosed through molecular testing (primarily via Polymerase Chain Reaction (PCR)), with antigen tests being accepted from February 12th, 2021. Radiologically-confirmed cases involved patients who tested negative via PCR but showed clear COVID-19 symptoms and had compatible findings on a chest computed tomography (CT) scan. Possible cases were identified by clinical symptoms, including at least one major symptom, such as cough, dyspnoea, chest pain, and anosmia, or two or more minor symptoms, like fever, fatigue, sore throat, or diarrhoea. Patients with worsening chronic respiratory issues also fell into this category. Mortality surveillance in Belgium included all cases of COVID-19, including probable cases, unless a clear alternative cause of death, such as trauma, could be definitively attributed[4].

Belgium's central location in Europe, the international significance of Brussels, and its close ties with neighbouring countries created numerous possible transmission routes. The large urban agglomeration covering most of the country, combined with a relatively small area and widespread commuting, also contributed to the rapid and extensive geographical spread of potential infections[7].

IMPACT OF COVID-19 ON FORENSIC MEDICAL SERVICES IN BELGIUM

To illustrate the impact on forensic services, it is essential to highlight that in Belgium, anatomical pathology and forensic medicine operate as two distinct departments, each with its own specialized training programs. Consequently, autopsies are typically categorized as either forensic or clinical.

Any licensed physician is authorized to officially determine death, which must be certified by completing a death certificate (Model IIIC or IIID for infants). If external causes or unnatural death are suspected, the doctor will object to burial or cremation, prompting further legal investigations, often starting with an external examination by a forensic doctor. Depending on the circumstances, this external examination can be performed at the scene of discovery or the hospital mortuary (after transportation of the body). Based on the external examination findings, the forensic doctor subsequently advises the public prosecutor whether a forensic autopsy is deemed necessary[8]. On the other hand, the forensic medicine department also conducts clinical forensic tasks, such as fitness-to-drive evaluations and victim assessments.

In the early stages of the pandemic, the Belgian government implemented a series of public health measures to contain the spread of COVID-19, frequently revising them based on the latest epidemiological data. These measures included a nationwide lockdown, remote work requirements where feasible, restrictions on non-essential travel, physical distancing of 1.5 meters, and mandatory mask-wearing in public spaces[9,10]. At our forensic facility in Antwerp, we implemented several changes in response to the evolving COVID-19 measures. The frequent and rapid adjustments to these (mostly impracticable) guidelines required us to adapt quickly, initially leading to a sense of uncertainty and anxiety. This often resulted in improvisation and an overly cautious approach in certain cases.

External examinations at the crime scene

Regarding external examinations, forensic doctors initially refrained from attending death scenes, except in evident criminal cases such as murder. Instead, deceased individuals were transported directly to the hospital for screening via nasal swabs (PCR) and postmortem CT (PMCT) scans. This approach aimed to minimize potential virus exposure in a difficult setting while still being able to conduct a thorough examination of the body to assess the cause of death. However, as the pandemic progressed and the demand for hospital imaging services became overwhelming, this approach was reevaluated. On-site examinations were resumed under strict guidelines. All cases with reported COVID-19

symptoms, such as fever, cough, dyspnoea, and anosmia, were presumed positive for COVID-19, and the deceased were immediately transferred to the hospital for nasal swabbing to confirm or rule out COVID-19 infection before external examination. When no COVID-19 symptoms were reported, forensic doctors continued performing on-site examinations. On-site examinations were performed using personal protective equipment (PPE) consisting of Tyvek® 500 Xpert (DuPont™) full-body suits, N95/FFP2 masks and safety glasses. For a brief period, surgical masks were placed on the deceased's nose and mouth during manipulation to minimize aerosol formation.

Autopsy protocols

Forensic doctors and anatomical pathologists collaborated closely on all potential COVID-19-related autopsies (both clinical and forensic). This decision was based on the forensic doctors' expertise in managing high-risk cases, including those involving chemical, biological, radiological, and nuclear (CBRN) threats, ensuring proper protection during COVID-19 autopsies. This collaboration was also important for understanding the pathological effects of COVID-19 and for gathering vital data that could inform public health responses and future forensic practices. As a result of continuing autopsy practices, we were the first to document, by autopsy, a fatal COVID-19-related myocarditis[11].

In April 2020, the government issued autopsy-specific safety guidelines, such as limiting personnel, utilizing Airborne Infection Isolation Rooms (AIIRs), and avoiding aerosol-generating tools like oscillating bone saws[12]. However, due to practical constraints, these guidelines could not always be fully implemented. Hospital-specific measures were also enacted, leading to a reprioritization of medical staff duties. Forensic doctors were required to take on additional responsibilities and provide support to critical services and COVID-19 departments.

Protective measures were significantly intensified for both forensic and clinical autopsies. Initially, autopsies were performed with the examiner closest to the body wearing fully encapsulated chemical protective suits (RESPIREX RJS 300® - Respirex™) and a self-contained breathing apparatus (SCBA), while other autopsy staff wore chemical protective suits (Tychem 2000C® - DuPont™) along with safety glasses and a full-face respirator mask. Over time, as the pathophysiology of the virus became better understood, autopsies were performed in Tyvek® full-body suits along with N95/FFP2 masks and protective glasses.

To manage suspected COVID-19 cases, nasopharyngeal swabs and PMCT scans became standard practice, adding complexity to the autopsy workflow. However, the radiology department faced significant pressure as hospital-wide demand for CT scans increased. Due to this increasing demand, the radiology department eventually requested a reduction in scan referrals to manage their clinical workload more effectively. In response, our department adopted nasopharyngeal swabs even more frequently as an alternative screening method. In cases where awaiting radiology and microbiology results was impractical, we proceeded without them, treating the case as COVID-19-positive to ensure safety.

Despite the growing global interest in minimally invasive autopsies, this approach was not adopted in our center during the pandemic. The reliance remained on conventional autopsies as the gold standard, albeit with strict safety protocols.

Damage assessments and medical expertise

Hospital admissions and consultations were reprioritized, resulting in the postponement of non-urgent care and evaluations. Consequently, certain clinical forensic activities, such as fitness-to-drive evaluations and victim assessments, were deferred to focus resources and attention on more urgent medical needs.

Trends in forensic investigations during COVID-19

While the forensic caseload remained consistent, the shift towards more morgue-based external examinations highlights how forensic practice adapted to the pandemic, prioritizing safety and infection control.

During the first wave, inter-wave period, and second wave, respectively, 20%, 8%, and 13% of all external examinations were performed in the morgue, with a prominent peak of 39% in April 2020. In comparison, the averages for previous years were 13% in 2019 and 10% in 2018. These figures demonstrate that the legal and investigative duties related to sudden, suspicious, or unexplained deaths persisted throughout the early pandemic. Furthermore, despite the limitations imposed by lockdowns and restrictions, deaths from other causes, including homicides, suicides, and accidents, continued to require forensic investigation.

Pomara, Li Volti, and Cappello (2020) emphasized the importance of autopsies in their article. They argued that comprehensive autopsies are essential to accurately identify the cause of death and to distinguish COVID-19 from other potential conditions[13]. This perspective is further supported by Geller et al. (2022), who discussed the crucial role of medicolegal autopsies in their study, which highlights the need for precise determination of COVID-19 related deaths during the pandemic's initial phase[14].

While the overall non-COVID-related crime rates in Belgium, such as petty theft and street crime, declined due to restrictions on movement and increased police presence on the streets, other forms of criminal activity surged. Prolonged confinement at home created stressful environments, leading to an increase in domestic violence, maladaptive parenting, and dysfunctional family dynamics. By April 2020, reports of domestic violence had doubled compared to April 2019. The Center for Pupil Guidance reported a 28% rise in distressing parenting cases during 2020-2021 compared to the previous year[15]. Despite the documented rise in domestic violence and distressing family situations during the pandemic, our center did not see a corresponding increase in related forensic cases.

At the same time, there was a notable increase in mental health issues such as stress, anxiety, and depression due to the pandemic[16]. The strict lockdown significantly impacted social and mental well-being, with many individuals reporting increased feelings of loneliness. Collective mental well-being, as measured by the GHQ-12 (*General Health Questionnaire*), changed proportionately with the severity of safety measures, with Belgians being most affected by stricter measures[17]. Despite this, official mortality figures for Flanders in 2020 and 2021, based on death certificates completed by the attending physicians (not forensic doctors), showed no increase in suicide deaths compared to prior years. Similarly, data from the Public Prosecutor's Office and Federal Police showed no rise in suicide attempts during this period. In 2022, suicides rose by 3.7% compared to 2020, particularly among women. This post-pandemic increase aligns with expectations, as situations stemming from the crisis, like economic insecurity and social isolation, may increase the risk of suicidal thoughts and attempts[16].

It is important to note that definitive conclusions about the pandemic's role are challenging, given that after the coronavirus pandemic, there have been other major social developments, such as the war in Ukraine and the energy crisis. The Care and Health Agency records suicide deaths based on death certificates, a complex and intensive process that delays the availability of 2022 data; thus, the full impact of COVID-19 on suicide rates remains unclear. Current mental health indicators reveal that the Belgian population is still highly destabilized and suffering from mental health problems[16-18].

Recent findings support the association between COVID-19 and an increased risk of cognitive and psychiatric outcomes after the acute phase of the disease, confirming the lasting impact of the pandemic on mental health[19].

LESSONS LEARNED: POSITIVE OUTCOMES FROM THE COVID-19 PANDEMIC

A more intensive collaboration was required not only with other medical disciplines but also with forensic services such as toxicology, police departments, and the public prosecutor’s office. Consistent communication with all parties ensured that updates on evolving work restrictions were shared regularly, allowing for

coordinated adjustments across all involved parties.

By maintaining a consistent number of autopsies, including those of COVID-19 positive individuals, and collaborating closely with anatomical pathologists, we were able to study the pathology and pathophysiology of the virus in depth. We gained valuable insights, enabling us to make important scientific contributions to the understanding of related conditions such as myocarditis and underlying pathophysiological pathways such as ferroptosis[10].

The lessons learned during the pandemic underscored the importance of maintaining high standards in forensic medicine, even in crisis situations. Moving forward, the pandemic has highlighted the need for quality-based systems and the implementation of robust frameworks in forensic medicine to ensure that future challenges, whether biological, chemical, or radiological, are met with the same level of preparedness and rigor. Building on these lessons can enhance our preparedness and response capabilities, ultimately improving public health outcomes in future crises. The COVID-19 pandemic has not only tested the resilience of forensic medicine but has also provided a unique opportunity to evolve and strengthen its role within the healthcare system.

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INVITED ARTICLE

FORENSIC AUTOPSIES DURING COVID-19 PANDEMIC IN POLAND

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ABSTRACT

COVID-19 has taken the world by storm since late 2019, so we decided to investigate whether this storm also affected forensic autopsies. The study aimed to check whether the COVID-19 pandemic influenced the number of forensic autopsies conducted in the Department of Forensic Medicine, Medical University of Lodz, Poland. For this, the monthly number of forensic autopsies performed from January 2019 to December 2023 was counted, covering the pre-pandemic (2019), pandemic (2020-2022) and post-pandemic (2023) periods in Poland. The results were compared with the monthly number of SARS-CoV-2 infections and the monthly number of deaths due to COVID-19 in Poland in the same period. The results showed that the mean monthly number of autopsies in the pre-pandemic and post-pandemic periods was similar (22.2±3.6 vs. 23.4±5.5), while the mean number during the pandemic was significantly lower (17.2±5.4). A major reason for this could have been the general slowing down in the pace of life driven by various types of lockdowns, which could have had an impact on reducing crime and, therefore, also on cases where the state prosecutor could have suspected that death had been caused by criminal means. Another reason could have been society's fear of a new, completely unknown disease. This fear may also have influenced the prosecutors and further affected their willingness to order forensic autopsies.

Keywords: *COVID-19; forensic autopsy; medico-legal death investigation; Poland*

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INTRODUCTION

The COVID-19 pandemic has had an unprecedented impact on many areas of our lives. To recall the development of events at the beginning of the pandemic, let us refer to the calendar[1,2,3].

- December 31, 2019: China informed WHO about unusual pneumonia cases in Wuhan, the capital of Hubei province, with a population of 11 million.
- January 1, 2020: First patients identified as workers at Huanan Seafood Market in Wuhan.
- January 7, 2020: WHO announced that the cause of the disease was a new virus belonging to the Corona family - nCoV.

- January 10, 2020: The first death from nCoV was reported in China.
- January 12, 2020: WHO called the nCoV virus the new coronavirus.
- January 20, 2020: WHO published reports on the coronavirus. The nCoV virus is transmitted from person to person - identified cases of infection in health care workers.
- January 30, 2020: WHO declared a global emergency.
- January 31, 2020: The beginning of virus testing in Poland.
- February 11, 2020: WHO named the disease COVID-19.
- February 14, 2020: WHO calls named the virus SARS-CoV-2.
- March 4, 2020: The first Polish patient infected with SARS-CoV-2 was identified at a hospital in Zielona Góra (Western Poland, close to the border with Germany) - he arrived by coach from Germany.
- March 5, 2020: The virus had spread to 84 countries.
- March 9, 2020: Sanitary control was introduced at the Polish borders.
- March 11, 2020: WHO declared a pandemic.
- March 12, 2020: The first death was reported in Poland. A national emergency state was declared in the United States, and flights to the European Union (EU) were suspended.
- March 13, 2020: Poland's borders were temporarily closed, and air connections were suspended.
- March 14, 2020: The Minister of Health declared a state of epidemic threat in Poland (i.e., a legal state was declared in connection with the risk of an epidemic to take preventive measures specified by law).
- March 15, 2020: The first charter flights of LOT Polish Airlines enabled Poles to return home.
- March 16, 2020: All educational institutions and universities in Poland were closed.
- March 17, 2020: EU closed borders for citizens of nonmember countries.
- March 20, 2020: The Minister of Health declared a state of the epidemic in Poland (i.e., a legal state was declared in connection with an epidemic to take anti-epidemic and preventive measures specified by law to minimize the effects of the epidemic).
- March 24, 2020: The Tokyo Olympic Games were postponed to the next year.
- March 31, 2020: Restrictions were introduced in Poland on staying in public places, including limiting access to parks, boulevards, promenades, and other areas of recreation.
- April 16, 2020: It became mandatory in Poland to cover one's nose and mouth in public places.
- April 20, 2020: The beginning of the gradual lifting of restrictions in Poland.

The European Medicines Agency (EMA) approved the first COVID-19 vaccine on December 21, 2020. It was the mRNA-based Pfizer-BioNTech vaccine sold under the brand name “Comirnaty”. The logistics of distributing and storing the vaccine was a huge challenge due to storage requiring extremely low temperatures, ranging from -90°C to -60°C[4]. Its delivery to Poland began on December 25th, 2020, and vaccinations were given from December 27th, 2020, with priority being given to medical staff[5].

COVID-19 has taken the world by storm since late 2019[6]. This study aims to investigate how this affected forensic autopsies in Poland.

AIM OF THE PAPER

To study the impact of the COVID-19 pandemic on the number of forensic autopsies conducted in the Department of Forensic Medicine, Medical University of Lodz.

METHODS

The monthly number of forensic autopsies ordered to be performed at the Department of Forensic Medicine, Medical University of Lodz by 4 district prosecutor's offices (Łódź Bałuty, Łódź Górna, Łódź Widzew, Zgierz) was counted. These were prosecutor's offices that usually outsource almost all autopsies in their area of operation to our department. The period from January 2019 to December 2023 was analyzed: 5 years (60 months) covering the pre-pandemic (2019), pandemic (2020-2022) and post-

pandemic (2023) periods in Poland. The results were presented in the form of a graph, which was compared with charts that presented the monthly number of SARS-CoV-2 infections in Poland and the monthly number of deaths due to COVID-19 in Poland during the same period[7].

RESULTS

The monthly number of forensic autopsies done in the period 2019-2023 is shown in Fig. 1. The bars show the values for each month, and the black line is the trend calculated for 3 months. It was observed that in the pre-pandemic year (2019), an average of 22.2 (SD=3,6) autopsies, in the pandemic years (2020-2022), 17.2 autopsies (SD=5,4), and in the post-pandemic year (2023) 23.4 autopsies (SD=5,5) were performed per month. The t-Student statistical test showed that the means for 2019 and 2020-2022 are statistically significantly different (p=0.0043), as are the means for 2020-2022 and 2023 (p=0.0023), whereas, in the case of the means for 2019 and 2023, there was no basis to reject the hypothesis of their equality (p=0.5160). The monthly number of SARS-CoV-2 infections and deaths due to COVID-19 in Poland in the same period are shown in Fig. 2 and Fig. 3, respectively.

DISCUSSION

The total number of clinical and forensic autopsies in Poland is systematically decreasing, both in absolute terms and as a percentage of all deaths. For example, in 1971, autopsies were performed for 16% of all deaths, but in 2023, only for 4% of all deaths autopsies were performed[8]. The most plausible reason for this almost linear downward trend is the decrease in the number of clinical autopsies, which is also the global trend[9]. However, this hypothesis cannot be verified because the official statistics in Poland do not distinguish between clinical and forensic autopsies.

We discussed the medicolegal death investigation system in Poland in detail in a previous publication[10]. Under the Polish Code of Criminal Procedures[11], if suspicious of criminal activity, an external examination of the body at the scene and a forensic autopsy shall be performed. This suspicion is the only statutory prerequisite for a forensic autopsy. According to the Code, these procedures are mandatory. These investigations are aimed at identifying the cause of death and details relevant to the circumstance of death. The decision on whether to deploy them is taken solely by the state prosecutor conducting the investigation. A mere suspicion that death has been caused by criminal means obliges the state prosecutor to order an external examination of the body at the place of its discovery and a forensic autopsy[10].

Of course, whether a given situation will be considered suspicious by a particular state prosecutor depends on their judgment. Therefore, various external circumstances can affect a prosecutor's decision. The COVID-19 pandemic could also have been such an external factor.

The research results support this hypothesis. The monthly number of autopsies in the pre-pandemic and post-pandemic periods was similar (22.2±3.6 vs. 23.4±5.5), while the number during the pandemic was significantly lower (17.2±5.4). It seems, however, that one of the reasons could have been a general slowing down in the pace of life driven by various types of lockdowns, which could have had an impact on reducing crime and, in turn, reduced the number of suspicious cases for the state prosecutor. On March 31st, 2020, restrictions on staying in public places were introduced in Poland, which included limited access to parks, boulevards, promenades, and other recreational places, and from April 20th, 2020, these restrictions were gradually lifted. In April 2020, the first significant decrease in forensic autopsies was visible. Another reason could have been society's fear of a new, completely unknown disease. It should be noted that the first wave of the pandemic in Poland in April 2020, although small compared to the subsequent waves, resulted in up to 610 deaths. This fear may also have influenced prosecutors and further affected their

decisions. With time, the number of autopsies increased almost to the pre-pandemic level. This could be explained by the easing of restrictions and the society becoming accustomed to the new situation. However, in the following period (summer 2021 and summer 2022), further large declines were observed, which were not at all correlated with the number of infections or deaths. Explaining why this happened would require more extensive research.

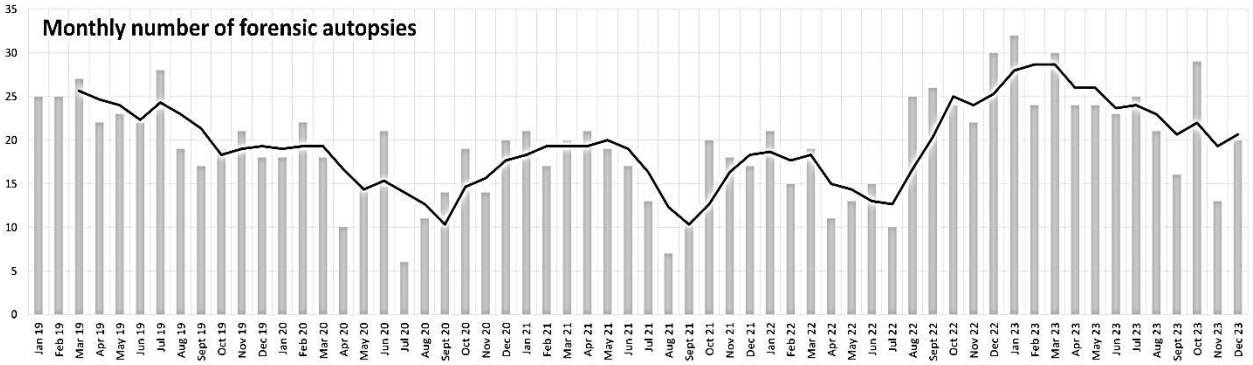

Fig. 1: Monthly number of autopsies commissioned to be performed at the Department of Forensic Medicine of the Medical University of Lodz in the period 2019-2023.

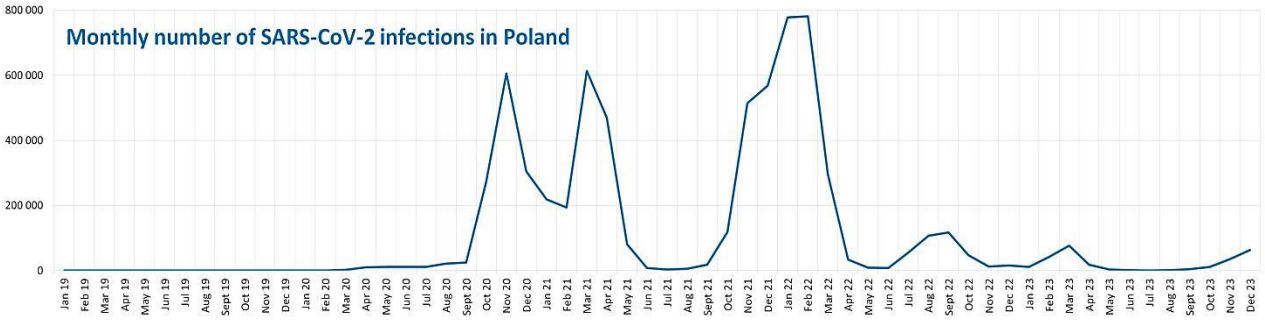

Fig. 2: Monthly number of SARS-CoV-2 infections in Poland in the period 2019-2023.

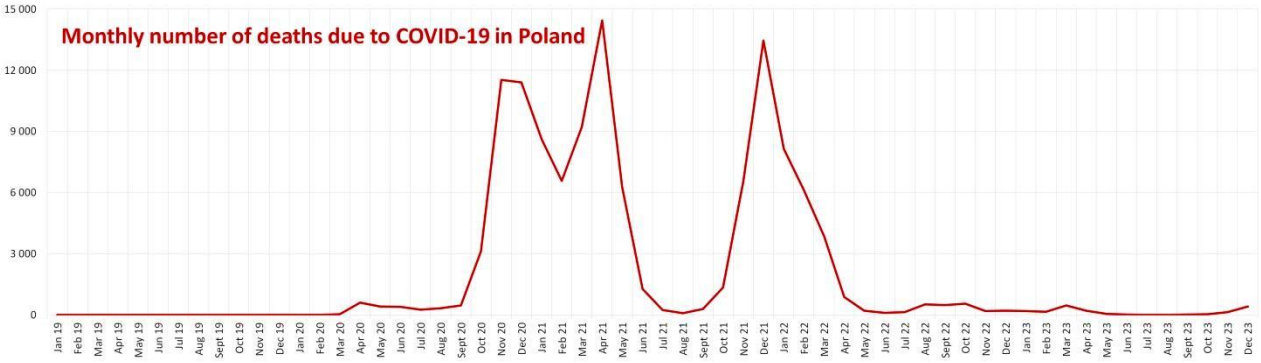

Fig. 3: Monthly number of deaths due to COVID-19 in Poland in the period 2019-2023.

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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.

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Tables and figures should be referred to in the order of appearance in the text in Arabic numerals within parentheses, e.g. (Fig. 1). Tables should have brief titles. Figures should be used only when data cannot be expressed clearly in any other form. Photographs should have a figure number and caption and be attached as jpg files or incorporated into the MS Word document.

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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

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