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Temporal Patterns of Trauma Mortality and Causes of Death in a Level 1 Trauma Center: Implications for Improved Trauma Care

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Learning Point of the Article:

Timely interventions and continuous improvements in trauma care systems are crucial to reducing trauma-related mortality, particularly from brain injuries and preventable immediate deaths.

Abstract

Introduction: Trauma mortality patterns have evolved over time, with distinct phases of immediate, early, and late deaths. Advances in trauma care and changing injury dynamics have contributed to shifts in this pattern. Understanding the causes and timing of trauma deaths is pivotal for enhancing trauma care systems.

Materials and Methods: We conducted a retrospective analysis of trauma deaths in 2020–2022 at a level 1 trauma center. Trauma death data were collected from case records, wound certificates, and death certificates. The time of death from trauma was calculated and deaths were categorized into immediate, early (within 24 h), and late (after 24 h) groups. Statistical analyses, including Chi-square tests, were performed to assess associations.

Results: Of the 186 trauma deaths studied, 86.6% were males, and the mean age was 40 ± 16.91 years. Immediate deaths were predominantly due to brain injury (BI) (54.8%), thoracic injury (17.9%), and spinal cord injury (16.7%). Early deaths were mainly attributed to BI (35.1%) and poly-trauma (35.1%). Late deaths (after 24 h) were primarily a result of multiple organ failure (44.4%) and sepsis (24.4%). The analysis showed a significant association between the cause of death and time from trauma to death ($P < 0.001$).

Conclusion: BI emerged as the leading cause of trauma-related deaths, with a progressive decline pattern observed in a well-established trauma care center. Immediate deaths can potentially be reduced through trauma prevention strategies, particularly in the context of high-speed vehicles and machinery. These findings underscore the importance of timely interventions, effective critical care, and continuous improvements in trauma care systems.

Keywords: Trauma mortality, immediate death, early death, late death, cause of death, trauma care, progressive decline, brain injury, polytrauma, multiple organ failure.

Introduction

Trauma-related mortality follows a distinctive trimodal distribution, as elucidated in the seminal work of Trunkey in 1983 [1]. This pattern encompasses three distinct peaks known as immediate, early, and late deaths, each delineating a critical phase in the trajectory of trauma outcomes. Immediate deaths manifest within minutes, arising from injuries deemed non-survivable. Early deaths transpire within hours, driven by the severity of inflicted harm. Late deaths unfold over days or weeks, often succumbing to sepsis (SS) or multiorgan failure. The reduction of immediate deaths hinges on effective trauma prevention strategies, whereas early deaths necessitate enhanced

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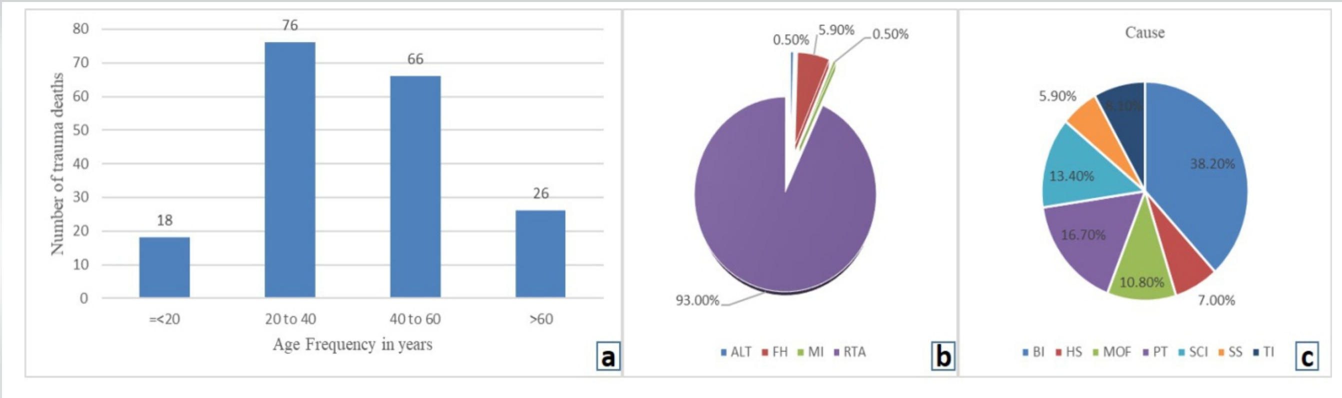

Figure 1: (a) Death distribution in different age groups. (b) Mechanism of trauma. (c) Causes of death due to trauma. ALT: Assault, FH: Fall from height, MI: Machine injury, RTA: Road traffic accident.

access to trauma care. Late deaths can be averted through refinements in critical care and resuscitation approaches.

The contemporary landscape of trauma has undergone profound transformations, propelled by high-speed vehicles, heavy machinery, and advanced weaponry on a global scale. Correspondingly, the evolution of trauma care systems has mirrored these shifts. The advent of focused abdominal sonography in trauma has expedited the identification of internal injuries, wherweas computerized tomography (CT) scans, with or without contrast, have revolutionized the management of injuries affecting the head, chest, abdomen, pelvis, limbs, and vasculature. The integration of advanced trauma life support, early debridement, broad-spectrum antibiotics, damage control surgeries (damage control orthopedics [DCO]), early total care (ETC), and trauma-intensive care protocols has redefined the landscape of trauma-related fatalities.

Consequently, studies spanning from 1983 to 2022 reveal a diverse spectrum of trauma mortality patterns, ranging from trimodal distributions to unimodal and progressive decline trends, as elucidated in Table 1. The dynamics of trauma-related deaths are intrinsically interwoven with the velocity of injury, the quality of pre-hospital care, transportation infrastructure, and the efficacy of hospital-based trauma care systems. Notably, these factors exhibit considerable regional disparities, contingent upon the developmental status of individual countries. Many extant studies have been conducted outside India, where unique factors such as distinct road transport systems, vehicular safety measures, worksite regulations, and trauma care frameworks contribute to a distinct milieu [1-13].

Although a seminal Indian study conducted by Sahdev et al. over a quarter-century ago unveiled a quadruple-peak trauma death pattern, incorporating a delayed death peak within the first 2 days [14], the overarching global burden of trauma deaths remains staggering. Approximately five million lives are claimed by trauma annually across the world, with India accounting for one million of these fatalities. In addition, a staggering 20 million trauma patients are admitted to hospitals in India each year, as reported by the National Health Portal of India [15]. In light of this profound impact, a comprehensive analysis of India's trauma mortality pattern assumes paramount significance, poised to unveil contemporary distributions and underlying causes of trauma-related fatalities. Such insights hold the key to advancing and optimizing the nation's trauma

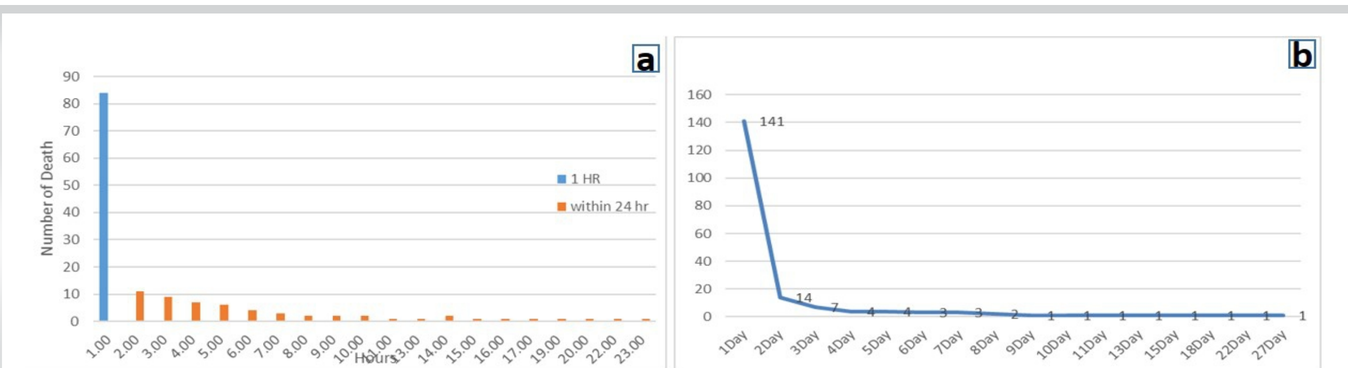

Figure 2: (a) Distribution of time death within 24 h of trauma. (b) Distribution of death after trauma.

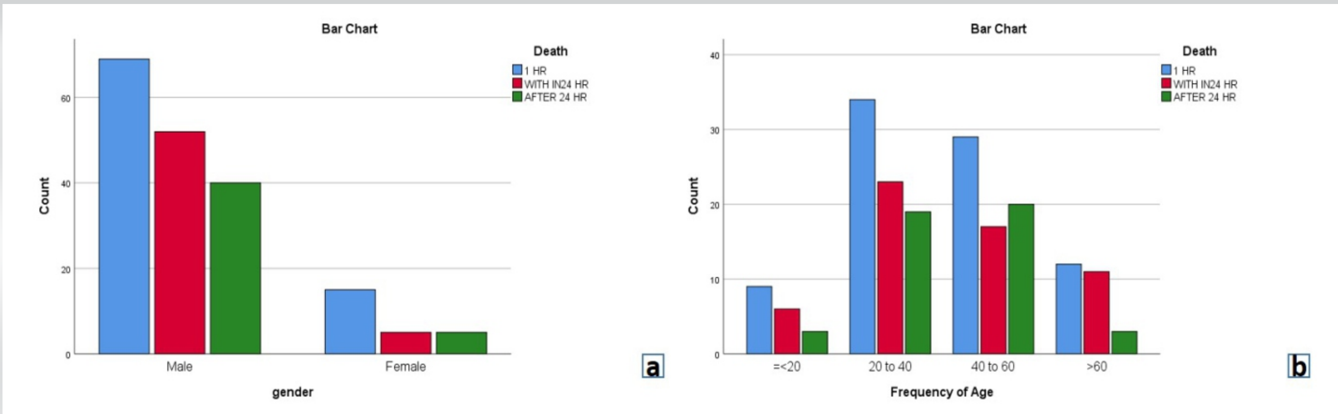

Figure 3: (a) Distribution of death in both genders. (b) Distribution of death in different age groups.

care systems, aligning with a global endeavor to mitigate the harrowing toll of traumatic injuries.

Materials and Methods

Ethical approval

Before commencing the study, ethical clearance was obtained from both the Scientific Review Committee and the Institutional Review Board, ensuring adherence to ethical guidelines and safeguarding the rights of participants.

Study design and data collection

A retrospective analysis spanning 2 years (2020–2022) was conducted at a prominent Level 1 trauma center. The study encompassed a comprehensive review of trauma-related deaths. The primary source of information was the institution's death register. Trauma-related deaths that resulted from drowning, hanging, strangulation, and burns were meticulously excluded from the study.

Subsequently, a meticulous collection of pertinent details was undertaken. These encompassed critical parameters such as age, gender, trauma type, mechanism, time of trauma, cause of death, and time of death. The data were meticulously sourced from a variety of medical records, including case records, wound certificates, and death certificates, all housed within the medical records library.

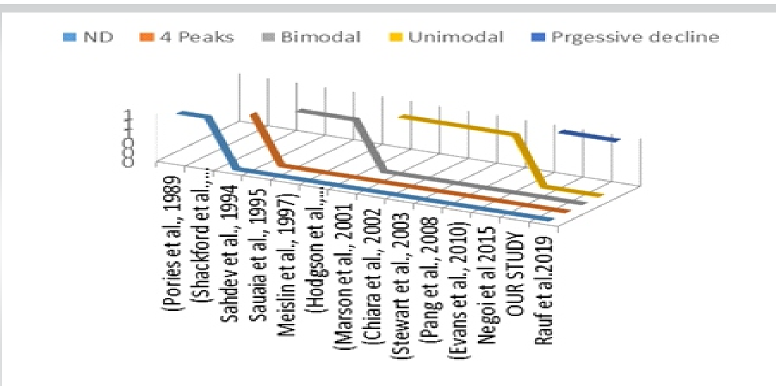

Figure 4: Tendency of death distribution from 1989 to 2019.

Classification of trauma deaths

Drawing inspiration from the classification proposed by Trunkey [1], trauma-related deaths were stratified into three distinct groups, each characterized by unique temporal parameters:

1. Immediate deaths: This group encapsulated fatalities occurring within a remarkably brief timeframe (≤60 min or 1 h) from the moment of trauma

2. Early deaths: Encompassing fatalities that transpired within the initial 24 h subsequent to the traumatic incident, this group excluded cases falling under the immediate death classification

3. Late deaths: This category comprised all remaining trauma-related fatalities occurring beyond the initial 24-h window.

Statistical analysis

The collected data were meticulously documented into Microsoft Excel. To unveil insights and patterns, the International Business Machines Statistical Package for the Social Sciences, Version 26.0, was harnessed for statistical analysis.

Descriptive statistics were employed to present categorical variables through frequencies (expressed as a percentage) and continuous variables as means. Visualization aids such as bar graphs, line graphs, and pie charts were judiciously employed to communicate the study's findings effectively.

The pivotal relationship between the interval from trauma to death and the underlying cause of death was

Cause of death	Time from trauma to death			Total		
	≤1 η	Within 1–24 h	After 24 h		?²	P-value
BI						
Count	46	20	5	71	159.68	0
%	54.8	35.1	11.1	38.2		
HS						
Count	5	8	0	13		
%	6	14	0	7		
MOF						
Count	0	0	20	20		
%	0	0	44.4	10.8		
PT						
Count	4	20	7	31		
%	4.8	35.1	15.6	16.7		
SCI						
Count	14	9	2	25		
%	16.7	15.8	4.4	13.4		
SS						
Count	0	0	11	11		
%	0	0	24.4	5.9		
TI						
Count	15	0	0	15		
%	17.9	0	0	8.1		
Total						
Count	84	57	45	186		
%	100	100	100	100		

BI: Brain injury, HS: Hemorrhagic shock, MOF: Multiple organ failure, ND: No data, PT: Poly -trauma, SCI: Spinal cord injury, SS: Sepsis, TI: Thoracic injury

Table 1: Comparison of our study with other published studies.

subjected to rigorous examination through the application of the Chi-square test. Significance was determined by a P-value threshold of <0.001, signifying a rigorous criterion for establishing meaningful associations within the data.

This comprehensive methodology ensured a rigorous and systematic exploration of trauma-related deaths within the defined timeframe and context, enabling us to unravel critical insights that contribute to the advancement of trauma care strategies.

Results

Demographic characteristics

A comprehensive analysis of 186 trauma-related deaths revealed a predominance of males, with 161 (86.6%) male victims and 25 (14.4%) female victims. The mean age of the deceased individuals was calculated to be 40 ± 16.91 years, reflecting the diverse age range within the study cohort.

Comparison with published studies

Our study was juxtaposed against existing published studies in the field, enabling a comprehensive understanding of the dynamics of trauma-related fatalities. Noteworthy comparisons were drawn, encompassing parameters such as patient numbers, inclusion and exclusion criteria, gender distribution, age profiles, and patterns of mortality. These insights offer valuable context for interpreting our findings.

Pattern of mortality and causes of death

Examination of the pattern of mortality revealed intriguing trends. The prevailing causes of trauma-related deaths were brain injury (BI), hemorrhagic shock, poly-trauma (PT), spinal cord injury (SCI), SS, thoracic injury (TI), and multiple organ failure (MOF). Our study identified a progressive decline in the frequency of trauma-related fatalities from 1989 to 2022, a significant finding shedding light on the evolution of trauma care strategies over time.

Temporal dynamics of trauma deaths

The temporal distribution of trauma-related fatalities unveiled distinctive patterns. Within the initial hour of trauma, a significant proportion (45.2%) of deaths occurred, predominantly attributed to BI (54.8%), TI (17.9%), and SCI (16.7%). Deaths within the first 24 h exhibited a notable

References	Patient no.	Inclusion criteria	Exclusion criteria	Inclusion of Preclinical death	Mean age in years	Gender (% of males)	Blunt trauma (%)	Causes of death	Pattern of mortality
Pories et al., 1989 [2]	54	All trauma victims	ND	No	Median 28	74	84	BI, HS; Other	ND
Shackford et al., 1989 [3]	104	All major trauma victims	ND	No	Mean 34.5	ND	57.7	BI; HS; TI	ND
Sahdev et al., 1994 [14]	177	All road traffic fatalities	ND	Yes	Mean 35	88	100	BI, HS; BI+HS	4 PEAKS
Sauaia et al., 1995 [4]	289	All trauma deaths	ND	Yes	Mean 36.8	79	48	BI; HS; MOF	BIMODAL
Meislin et al., 1997 [5]	710	All trauma deaths (<18 month after trauma)	Drowning, poisoning, burns, overdose	Yes	Mean 42.9–49.3	79.6–67.9	34-71	BI; HS; Other	BIMODAL
Hodgson et al., 2000 [6]	108	All blunt trauma deaths	ND	No	Median 39	72	100	BI; SS; HS	BIMODAL
Marson et al., 2001 [7]	115	Motor vehicle crash deaths	ND	Yes	Mean 33.9–35.3	81.3–82.8	100	BI; HS; BI+HS	UNIMODAL
Chiara et al., 2002 [8]	255	All trauma deaths	Drowning, Poisoning, overdose, hanging	Yes	Mean 44–55	73	78.1	BI+HS; HS; BI	UNIMODAL
Stewart et al., 2003 [9]	753	All trauma deaths	ND	No	Mean 42.5	ND	71	BI; HS; BI+HS	UNIMODAL
Pang et al., 2008 [10]	186	All trauma deaths	Non-residents	Yes	Mean 36.5	74	53.2	BI; HS; BI+HS	UNIMODAL
Evans et al., 2010 [11]	175	All trauma deaths	Poisoning, Drowning, Hanging, Electrocution, strangling	Yes	Mean 55	55	76	BI; HS; BI+HS	UNIMODAL
Negoi et al. 2015 [12]	47	All trauma death	Pre-hospital and post - discharge deaths	No	37.2	83	ND	MOF, BI, HS	Progressive decline
Rauf et al. 2019 [13]	1486	All trauma deaths	Pre-hospital and post - discharge trauma deaths	No	Mean 59.5	67	95	BI, MOF, SEPSIS, HS, TI, PT	Progressive decline
Our study	186	All trauma deaths	Drowning, Hanging, Strangulation, Burns, Electrocution	Yes	Mean 40	86.6	87	BI, HS, PT, TI, SS, MOF, SCI	Progressive decline

BI: Brain injury, HS: Hemorrhagic shock, MOF: Multiple organ failure, ND: No data, PT: Polytrauma, SCI: Spinal cord injury, SS: Sepsis, TI: Thoracic injury

Table 2: Distribution of time from trauma to death by cause of death (n=186).

reliance on BI (35.1%) and PT (35.1%). Subsequent to this period, the occurrences of death were predominantly linked to MOF (44.4%) and Septicaemia (24.4%), reflecting the complex interplay of factors impacting mortality rates.

Association between cause and time of death

A rigorous statistical analysis revealed a profound association between the cause and time of death in trauma-related fatalities ($P < 0.001$). The compelling observation emerged that a substantial majority of BI -related deaths occurred within the initial hour after trauma, underlining the criticality of rapid intervention.

Temporal trends and gender disparities

Temporal trends were meticulously scrutinized, indicating a dynamic evolution in the distribution of trauma-related fatalities from 1989 to 2022. Moreover, the distribution of deaths across genders was presented, further enhancing the granularity of insights into the study population.

Distribution across age groups

The distribution of trauma-related deaths within distinct age cohorts was examined, furnishing a comprehensive understanding of the age-based nuances inherent in such fatalities.

Discussion

The meticulous analysis of mortality patterns in trauma offers profound insights into the evolution and improvement of trauma care practices. Understanding the current distribution of trauma-related deaths is paramount for informing future advancements in the field. By juxtaposing our findings with a comprehensive comparison of mortality patterns from 1989 to 2022 (Table 1), we gain a comprehensive understanding of the trajectory of trauma care.

Demographics and age profile

Our study highlighted a significant prevalence of trauma-related deaths among individuals aged 20–60 years, mirroring the working-age population (Fig. 1a). Corresponding studies (Table 1) showcased similar trends, emphasizing the impact of trauma on the productive sector of society. The preponderance of male victims, consistent with prior research, suggests the involvement of males in high-velocity traumatic incidents, possibly linked to occupations such as vehicle driving, heavy machinery operation, and construction work.

Penetrating versus blunt trauma

A pivotal classification in trauma categorizes injuries as penetrating or blunt. Blunt trauma, commonly arising from road traffic accidents (RTAs) and falls from height, dominated the trauma-related fatalities in our study, paralleling the observations in other studies (Table 1). This underscores the significance of preventive measures targeting these common mechanisms of injury.

Leading causes of trauma

In India, RTAs, falls, and assaults are prevalent causes of trauma [16]. Our study aligns with this trend, with RTAs emerging as the leading cause of trauma-related fatalities (Fig. 1b). Notably, the World Health Organization's data emphasizes the global impact of RTAs, particularly among young adults aged 5–29 years [17]. The multifactorial nature of RTAs, including speeding, inadequate safety measures, and impaired driving, underscores the imperative for comprehensive road safety initiatives.

BI: A dominant cause of mortality

The prominence of BI (38.20%) as the leading cause of trauma-related deaths in our study (Fig. 1c) mirrors global statistics. This observation resonates with reports from the Centres for Disease Control and Prevention attributing approximately 30% of injury deaths in the United States to BI [18]. The complex interplay of primary and secondary insults underscores the challenges in managing such injuries, necessitating expedited interventions to mitigate secondary harm.

Temporal dynamics of trauma deaths

The temporal distribution of trauma-related deaths exposes critical insights into the time-sensitive nature of interventions. Immediate deaths within the 1st h of trauma predominantly stemmed from BI, TI, and SCI (Table 2). Rapid and precise interventions are crucial in managing these conditions, given the often irreversible nature of primary insults.

Challenges in trauma care

Early deaths within 24 h were primarily attributed to BI and PT (Table 2). Trauma-induced coagulopathy and the need for skillful surgeries underscore the intricacies of managing such cases. Complex PT scenarios necessitate a multidisciplinary approach, emphasizing blood transfusions, ETC, or DCO, based on the patients' physiological status [19-25].

Late deaths: A focus on MOF and SS

Late deaths after 24 h were predominantly linked to MOF and SS (Table 2). The interplay of primary and secondary insults, systemic inflammatory response syndrome, and compensatory anti-inflammatory response syndrome underpin the trajectory toward organ failure and infection [26]. Altered phagocytic activity and pathogen-related factors contribute to infections in PT patients [27].

Temporal trends and gender disparities

Our study further dissected temporal trends, with both genders and distinct age groups exhibiting a progressively declining pattern (Fig. 2a and b, Fig. 3a and b). This trend underscores the impact of well-developed trauma care facilities, enabling timely interventions and comprehensive care, ultimately enhancing patient survival.

Trajectory of trauma care

The evolving trajectory of trauma care, transitioning from trimodal to bimodal, unimodal, and progressively declining patterns (Fig. 4, Table 1), reflects advancements in trauma care practices [28]. While immediate deaths remain a challenge, preventive measures and innovative interventions, such as early contrast-enhanced CT scans and bleeding control strategies, hold promise in reducing fatalities within the critical 1st h.

Future directions

Future research endeavors should consider extending the study to include post-discharge fatalities, and intervention-based studies targeting the critical 1st h are warranted. Furthermore, promoting safety measures, such as the evidence-based World Health Organization's Save LIVES road safety technical package, can potentially curb the energy of trauma incidents and reduce their impact.

Conclusion

In conclusion, the comprehensive analysis of mortality patterns in trauma underscores the transformative journey of trauma care. By identifying temporal dynamics, prominent causes, and demographic nuances, this study paves the way for targeted interventions, policy improvements, and enhanced survival rates among trauma patients.

Clinical Message

The findings from this study highlight the critical need for a multidisciplinary approach in trauma care, emphasizing that mortality is often due to non-orthopedic causes such as brain injuries, thoracic trauma, and systemic complications such as SS and MOF. Orthopedic surgeons play a vital role within this framework by stabilizing fractures and contributing to damage control strategies, but survival outcomes rely heavily on timely interventions in other critical areas. Preventive measures, early diagnosis, and comprehensive critical care are essential to reducing trauma-related deaths and improving overall patient outcomes.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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