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Research Article

Comparison of Clinical and Radiological Diagnosis with Autopsy Findings in Fatal Traffic Accident Cases

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This study investigated the alignment between clinical and radiological assessments and autopsy findings in fatal road traffic accidents (RTAs), focusing on the identification of missed injuries and diagnostic discrepancies. Conducted at a tertiary care centre in India, this study examined 146 cases of RTA fatalities over a two-year period. Clinicoradiological diagnoses were compared with autopsy findings across various injury types, including head, thoracic, abdominal, and limb injuries. Autopsy findings revealed a higher incidence of certain injuries, such as cervical spine injuries, cerebral contusions, and small haemorrhages, which were often missed during the initial clinical and radiological evaluations. Injury agreement was statistically evaluated using kappa statistics, revealing a moderate to slight correlation in most cases, with specific areas of notable discordance. In 21.9% of the cases, the cause of death determined clinically differed from autopsy findings, underscoring the critical role of autopsy in refining trauma assessment protocols and improving diagnostic accuracy. These findings highlight the value of autopsy feedback for emergency trauma care and suggest a need for advanced diagnostic techniques to reduce missed injuries in polytrauma cases.

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Introduction

The incidence of traffic accidents is increasing, as are the associated mortality and morbidity rates. According to the 2023 World Health Organization (WHO) data, road traffic accidents (RTA) result in the loss of approximately 1.19 million lives annually, and 20 to 50 million individuals sustain non-fatal injuries, with a significant proportion experiencing permanent disabilities[1][2]. Over 90% of road traffic fatalities occur in low- and middle-income countries, despite these nations possessing only 60% of the world's vehicles. Consequently, the majority of countries incur a cost of approximately 3 to 5% of their Gross Domestic Product (GDP)[1].

Road traffic accidents frequently involve multiple injuries that affect various body systems. These injuries can lead to significant disabilities and pose life-threatening risks. Globally, motor vehicle accidents are the primary cause of polytraumas[1]. Furthermore, instances have occurred where homicides were disguised as traffic accidents by intentionally running vehicles over the bodies of individuals who had already been killed.

For emergency physicians, the initial evaluation of a patient with critical injuries from multiple traumas poses a significant challenge, as every moment can be crucial in determining whether the individual survives or not. The time-sensitive nature of this assessment can have a profound impact on the patient's fate[3]. A common issue at emergency room is missing detection of critical internal trauma, e.g. concealed haemorrhages in the cranial and abdominal cavities. Universally recognized guidelines, as outlined in the Advanced Trauma Life Support Protocol (ATLS), are applied to all trauma case. This protocol establishes strict priorities for the initial care of trauma patients. The process begins with a primary assessment to quickly identify and manage life-threatening conditions followed by a comprehensive secondary evaluation to minimize the risk of overlooking any injuries[4]. Unfortunately, it is noticed that, despite the implementation of ATLS guidelines and various diagnostic methods for assessing trauma patients, some injuries often goes unnoticed by the treating physicians[5]. Patients with severe injuries from traffic accidents, particularly those with head trauma, a Glasgow Coma Scale (GCS) score of eight or below, and a higher Injury Severity Score (ISS) are at increased risk of missed injuries[6]. Missed and delayed diagnoses of injuries result in heightened mortality and morbidity, encompassing extended hospital stays, psychological issues, and higher healthcare expenses[5].

Previous studies have investigated the magnitude of missed injuries in trauma management, particularly in patients with polytrauma. Teixeira et al. observed that despite the adoption of standardized methods such as the ATLS, approximately 12% of trauma patients suffer from missed injuries, many of which pose a significant threat to life[7]. Pfeifer et al. also observed that the most frequently missed injuries occur in the limbs, spine, and chest, with patients with fractures, particularly in the long bones and pelvis, being most susceptible. Diagnostic delays may lead to consequences including infections and extended rehabilitation[6]. Huber-Wagner et al. emphasized the effectiveness of whole-body CT scans in enhancing detection and decreasing missed injuries by approximately 30% relative to traditional imaging, especially in vital regions such as the head, chest, and abdomen[8].

Commonly missed injuries include musculoskeletal and orthopaedic injuries, particularly fractures. Studies indicate that the most common body regions for missed injuries are the head, neck, chest, and extremities[9]. To fully understand the patient's real circumstances, it is crucial to analyze injuries that were missed initially. The autopsy is a critical instrument in the identification of undiagnosed lesions, which are present in 10% to 47% of hospital fatalities in trauma victims[10][11]. Previous studies have predominantly focused on assessing clinico-radiological findings together with autopsy findings. However, studies that thoroughly analyze all anatomical regions of the body are rare. This study aims to identify injuries overlooked during clinical and radiological assessments by comparing them with findings from direct autopsy observations.

The rationale of this study lies in its approach, i.e. examination of individual organ systems and anatomical regions, and evaluation of clinician and radiologist assessments separately.

The novelty of this methodology resides in its divergence from similar other studies which have examined the combined clinico-radiological diagnoses. In contrast, this study systematically evaluated the radiological and clinical findings independently and juxtaposed them with the autopsy findings.

Materials and Methods

Study Design and Participants

This study, conducted over a two-year period (July 2020 to June 2022), aims to evaluate the agreement between clinical and autopsy diagnoses regarding the cause of death in fatal road traffic accident (RTA) cases, as well as to identify injuries/findings overlooked in clinical-radiological diagnoses.

The sample size was calculated to be 146 using formula 4pq/d2, based on a previous study with the expected proportion of missed injuries as 10%, with 5% absolute precision power 80%, alpha error 5%, and 95% confidence interval. The inclusion criteria encompass patients with a history of RTA admitted to the Department of Emergency Medicine at Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER), a national institute in South India. The autopsy findings were recorded in all such RTA cases resulting in death after hospitalization. The team responsible for collecting clinical-radiological findings were different from the team conducting autopsy examinations. This was done to rule out the potential selection biases. A standard autopsy protocol is followed in the institute where the study was done. The study excluded individuals who were declared dead on arrival, as well as those with insufficient or missing data.

Study procedure

Fatal traffic accident cases were identified, and their clinical and radiological findings were collected by the team from the Department of Emergency Medicine and Traumatology. Another team from the Department of Forensic Medicine and Toxicology collected the autopsy findings. This ensured blinding of the post-mortem examiners about the clinical and radiological findings and vice versa.

The data was collected from those cases which satisfied the inclusion criteria. A structured proforma was employed to record various parameters from the clinical and autopsy reports through a smartphone application Epicollect 5 (v.5, 2019). The independent variables include the demographic details of cases (age, sex, primary treatment, brought by, referred from, history of alcohol consumption, co-morbid conditions, and mode of injury). The outcome variables include clinical findings (vitals, records of clinical evidence of injuries), radiological findings (CT, MRI, X-ray, USG findings), and autopsy findings (from the autopsy report).

The antemortem clinical and radiological findings were categorized as Group A, and autopsy findings were classified as Group B. Both the groups were compared to see the agreement between clinico-radiological findings with autopsy findings, also compared the clinical cause of death with the cause of death revealed at postmortem examination. The term missed injuries are defined as injuries that were not identified during the initial stages of patient management, including the primary and secondary surveys and radiological interventions, and remain undetected throughout the patient's hospital stay until their death.

All autopsies followed the standard autopsy protocol laid down by the concerned department, i.e. whole-body examination for external findings and complete dissection of all body cavities including head, neck and vertebral column. Extremities and back were examined for any kind of deformity or for bony crepitus. If indicated, dissection was performed to rule out any underlying pathology. Face and joint dissections were made only indicated as per the history/external findings. Bimastoid incisions were considered for maintaining cosmesis of head and face. As protocol anterior approach used for most of the spinal dissections unless indicated for posterior spinal dissection.

Statistical analysis

Categorical variables, such as the type of RTA, age distribution, and comorbidities, were described using frequency and percentage. Continuous variables, like age and the number of injuries, were summarized using the mean and standard deviation or the median and interquartile range, depending on the distribution of the variables. Sensitivity, specificity, and detection rates of antemortem features were calculated using postmortem findings as the gold standard. Inter-rater kappa agreement was used to assess the agreement between antemortem and postmortem findings. A kappa correlation value between 0 and 0.20 indicates a poor correlation, while a range of 0.21 to 0.39 reflects a minimal correlation. Weak correlations fall between 0.40 and 0.59, showing a slight relationship. Moderate correlations range from 0.60 to 0.79, representing a more apparent connection between variables. Strong correlations, indicated by values between 0.80 and 0.90, show a significant relationship, while values above 0.90 suggest an almost perfect correlation[12]. Data entry was performed using Microsoft Excel. The final analysis was conducted using the Statistical Package for Social Sciences (SPSS), version 24.0 (IBM Corp., Chicago, USA). All statistical tests were two-tailed, and a p-value of <0.05 was considered statistically significant.

Consent and Ethical Considerations

The study was conducted after receiving approval from the *Institute Ethics and Research Monitoring Committee* (Ref no. JIP/IEC/2019/429). Informed written consent was obtained from the concerned cases or from the legal authorized relatives (in unconscious cases) as the guidelines laid by the Indian Council of Medical Research (ICMR). This study confirmed the research ethics norms of the Helsinki Declaration for Human Studies.

Results

The patient characteristics are given in Table 1. The mean age of the study participants was 44.8 ± 17.3 (mean ± SD). Among 146 patients, the predominant age group was 18 to 30 years (21.2%), followed by 41 to 50 years (20.5%), 31 to 40 years (18.5%), 51 to 60 years (19.7%), over 60 years (16.4%), and below 18 years (3.4%). Of these patients, 117 (80.1%) were male and 29 (19.9%) were female. The study indicates that the predominant group of RTA patients comprised two-wheeler riders (55.5%), followed by pedestrians (24%), collectively accounting for three-fourths of the total patients. The remaining one-fourth consisted of individuals involved with heavy motor vehicles such as trucks, buses, and lorries (6.2%), pillion riders were 4.8%, 4.8% were occupants of light motor vehicles such as cars, vans, and auto-rickshaws, 6 (4.1%) were cyclists, and one was undetermined. It was seen that 81% of these patients received primary treatment, out of which 104 were treated in a government hospital, 14 were treated in a private hospital, and the rest of the patients were directly brought to our center. A history of alcohol consumption was found in 23.3% of cases.

	Frequency (%)
Total patients	N=146
Age	44.8 +17.35 (Mean + SD)
< 18 years	5
18 – 30	31
31-40	27
41-50	30
51-60	29
> 60	24
Gender	
Male	117 (80.1%)
Female	29 (19.9%)
Type of traffic accident	
Two-wheeler rider	81 (55.5%)
Two-wheeler pillion rider	07 (4.8%)
HMV	09 (6.2%)
LMV	07 (4.8%)
Bicycle	06 (4.1%)
Pedestrian	35 (24%)
Primary treatment prior to ED Admission	
Received	118 (80.8%)
Not received	28 (19.2%)
Associated Comorbidities	
Hypertension	10 (6.8%)
Diabetes Mellitus	08 (5.5%)
Both Diabetes Mellitus and Hypertension	06 (4.1%)
Alcohol/substance consumption prior to the traffic accident	
No	104 (71.2%)
Yes	34 (23.3%)

Table 1. Demographics and patient characteristics

SD – Standard Deviation
HMV – Heavy Motor Vehicle
LMV – Light Motor Vehicle
ED – Emergency Department

Distribution and agreement of external injuries detected by clinicians and autopsy (Summarised in Table 2)

This study evaluated external injuries in 146 cases, comparing detection rates between clinicians and postmortem surgeons. Significant disparities were observed between the two groups across various injury types. Head injuries were more frequently detected by autopsy surgeons, identifying 134 cases (91.8%) compared to 104 cases (71.2%) reported by clinicians. Subcategories in the head showed that autopsy revealed a higher incidence of abrasions (117 cases, 80.1% vs. 72 cases, 49.3%), contusions (19 cases, 13% vs. 6 cases, 4.1%), and lacerations (80 cases, 54% vs. 57 cases, 39%). Clinicians completely missed neck injuries, which were detected by autopsy in 24.7% of cases. Facial injuries were detected more frequently by clinicians, with 59 cases (40.4%) compared to 36 cases (24.7%) observed during autopsy. Of these, concordance occurred in 22 cases, with discordance in 51. The kappa agreement was 0.22, and the p-value was 0.004. Clinicians identified 31 cases (21.2%) of eye injuries, while autopsy detected 23 cases (15.8%). Concordance was found in 12 cases, with a discordance in 30 cases. The kappa agreement was 0.32, and the p-value was 0.001. Similarly, clinicians reported 21 cases (14.4%) of dental injuries compared to 10 cases (6.8%) identified by autopsy. Concordance occurred in 4 cases, with discordance in 23 cases. The kappa agreement was 0.18, with a p-value of 0.017.

Chest injuries were recorded in only 6 cases (4.1%) by clinicians, whereas autopsy revealed 24 cases (16.4%). Concordance occurred in 3 cases, with discordance in 24 cases. The kappa agreement was 0.14, and the p-value was 0.024. Clinicians detected 64 cases (43.8%) of limb injuries compared to 125 cases (85.6%) in autopsy. Concordance was observed in 61 cases, with a discordance in 67 cases. The kappa agreement was 0.15, and the p-value was 0.003. Pelvic injuries were identified in 1 case (0.7%) by clinicians, while autopsy found 5 cases (3.4%). Concordance occurred in one case, with discordance in 4 cases. The kappa agreement was 0.32, with a p-value of 0.001. The genital injuries were missed entirely by clinicians but observed in three cases (2.1%) during autopsy.

Type of injuries	Detected by clinicians	Detected by autopsy	Concordant		Discordant	Cohen's kappa	P value
			No	Yes			
Facial injury	59	36	72	22	51	0.22	0.004
Eye injury	31	23	104	12	30	0.32	0.001
Nose	17	7	122	0	24	-0.07	0.325
Ear	32	10	108	4	34	0.09	0.152
Dental	21	10	119	4	23	0.18	0.017
Head injury	104	134	4	96	46	0.02	0.715
Abrasion	72	117	17	60	69	0.06	0.34
Contusion	6	19	122	1	23	0.02	0.786
Laceration	57	80	49	40	57	0.23	0.003
Neck	0	36	0	0	0	0	0
Chest	6	24	119	3	24	0.14	0.024
Abdomen	6	29	114	3	29	0.11	0.059
Limb	64	125	18	61	67	0.15	0.003
Pelvic	1	5	141	1	4	0.32	0.001
Genital	0	3	143	0	3	0	0

Table 2. Level of agreement observed for external injuries between the clinical records and the autopsy records of the deceased persons (n=146)

Distribution and agreement of injuries detected clinico-radiologically and by autopsy

The comparison between clinico-radiological findings and autopsy results in this study highlights critical differences in injury detection, with agreement measured using Cohen's kappa statistic. The frequency, concordance, discordance, kappa values, and p-values are presented in Tables 3A, 3B, and 3C.

Facial injuries were detected with almost equal frequency in both clinico-radiological assessments (103 cases) and autopsies (105 cases). There was a concordance in 86 cases, while 36 cases were discordant, showing a fair agreement (Cohen's kappa = 0.39, p-value = 0.001). However, for facial bone fractures, autopsy identified significantly more cases (55) compared to clinico-radiological findings (35). Concordance was observed in only 20 cases (13.6%), with discordance in 50 cases (34.2%), and the kappa agreement was slight (p-value = 0.006). Skull vault fractures were more frequently detected during autopsy (81 cases) than clinico-radiologically (69 cases). Only 46 cases showed concordance, with 58 discordant cases indicating a slight agreement (Cohen's kappa = 0.21, p-value = 0.01). In terms of intracranial bleeds, both methods showed a similar frequency, with autopsy detecting 139 cases and clinico-radiological evaluation identifying 136. Concordance was high, with 131 cases (90%), while 13 cases (9%) showed discordance, reflecting a sensitivity of 94.2% for clinico-radiological detection. The kappa agreement was slight, with a p-value of 0.02. The autopsy revealed that extradural haemorrhages were found in 63 cases (43.2%), subdural hemorrhages in 80 cases (54.8%), and subarachnoid haemorrhages in 83 cases (56.8%). In comparison, clinico-radiological findings identified 41 cases of extradural hemorrhage (28.1%), 58 cases of subdural hemorrhage (39.7%), and 39 cases of subarachnoid hemorrhage (26.7%). Concordance was found in 35 cases (23.9%) for extradural hemorrhage (Cohen's kappa = 0.5, p-value = 0.01, 53 cases (21.9)% for subdural

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hemorrhage (Cohen's kappa = 0.57, p-value = 0.01), and 34 cases (23.3%) for subarachnoid hemorrhages (Cohen's kappa = 0.30, p-value = 0.01). The discordance rates were 23.3%, 21.9%, and 36.9%, respectively. Midline shift was more frequently identified in clinico-radiological investigations, with 41 cases (28.1%) compared to only 8 (5.5%) detected in autopsy. Concordance was found in 6 cases and discordance in 37 cases (25.3%), with slight agreement (Cohen's kappa, p-value = 0.002). For cerebral contusions, autopsy identified more cases (78, 53.4%) than clinico-radiological methods (63, 43.2%). Concordance was seen in 40 cases (27.4%), while discordance was observed in 61 cases (41.8%). The kappa agreement was 0.17, with a p-value of 0.035.

Injuries to the cervical spine were also more frequently detected during autopsy. Autopsy identified 16 cervical spine injuries (11 %) compared to 5 in clinico-radiological findings (3.4%). Thoracic injuries were observed in 39 cases (26.7%) during autopsy, while only 33 cases (22.6%) were detected clinico-radiologically. Sternum injuries were identified in 2 cases during autopsy (1.4%) and 1 case clinico-radiologically (0.7%). Rib fractures were seen in 33 cases (22.6%) during the autopsy, compared to 23 cases (15.8%) in clinico-radiological evaluations. These injuries showed fair to moderate agreement, with a p-value of 0.001.

Pleural injuries were noted in equal frequency in both autopsy and clinico-radiological assessments (21 cases, 14.4%). However, concordance was observed in 13 cases (8.9%), with discordance in 16 cases (10.9%). The agreement was moderate, with a p-value of 0.001. For injuries to vital organs, autopsy revealed pericardial injuries in 1 case, cardiac muscle injuries in 5 cases, abdominal wall injuries in 12 cases, liver injuries in 8 cases, spleen injuries in 4 cases, and kidney injuries in 1 case. Clinico-radiological assessments detected pericardial injuries in 3 cases, cardiac muscle injuries in 1 case, abdominal wall injuries in 9 cases, liver injuries in 6 cases, spleen injuries in 4 cases, and kidney injuries in 2 cases. These findings showed moderate to substantial agreement, with a p-value of 0.001.

Genital injuries and pelvic fractures were detected at nearly equal frequencies in both autopsy and clinico-radiological findings. However, concordance was observed in only 2 cases (1.4%) for genital injuries and 3 cases (2.1%) for pelvic fractures. In both injury types, autopsy identified the majority of cases, showing moderate and substantial agreement with kappa values and a p-value of 0.001.

Type of injuries	Clinical and radiological records findings	Autopsy record findings	Concordant		Discordant	Cohen's kappa	P value	Specificity	Sensitivity
			No	Yes					
Facial injury	103	105	24	86	36	0.39	0.001	58.5	81.9
Facial bone	35	55	76	20	50	0.21	0.006	83.5	36.4
Skull vault	69	81	42	46	58	0.21	0.01	64.6	56.8
Skull base	18	58	79	9	58	0.06	0.341	89.8	15.5
Intraparenchymal haemorrhage	136	139	2	131	13	0.19	0.02	28.6	94.2
Subdural haemorrhage	58	80	61	53	32	0.57	0.001	92.4	66.3
Extradural haemorrhage	41	63	77	35	34	0.50	0.001	92.8	55.6
Subarachnoid haemorrhage	39	83	58	34	54	0.30	0.001	92.1	41.0
Intraventricular haemorrhage	8	26	115	3	28	0.10	0.134	95.8	11.5
Brain stem haemorrhage	14	51	86	5	55	0.004	0.948	90.5	9.8
Midline shift	41	8	103	6	37	0.16	0.002	74.6	75
Cerebral contusion	63	78	45	40	61	0.17	0.035	66.2	51.3
Cerebral oedema	33	54	74	15	57	0.08	0.252	80.4	27.8
Diffuse Axonal Injury	18	00	128	0	18	0	0	87.7	12.3
Trachea	00	02	144	0	2	0	0.001	99.2	26.7
Cervical spine	05	16	130	4	12	0.36	0.001	94.4	69.2

Table 3A. Level of agreement for head and neck injuries observed by the clinical, radiological, and autopsy records

Type of injuries	Clinical and radiological record findings	Autopsy record findings	Concordant		Discordant	Cohen's kappa	P value	Specificity	Sensitivity
			No	Yes					
Thorax	33	39	101	27	18	0.66	0.001	100	50
Sternum	01	02	144	1	1	0.66	0.001	94.7	51.5
Ribs	23	33	107	17	22	0.51	0.001	93.6	61.9
Plural injury	21	21	117	13	16	0.55	0.067	98.5	10
Lungs	03	10	134	1	11	0.12	0.001	99.2	26.7
Pericardial effusion	03	01	143	1	2	0.49	0.001	98.6	100
Cardiac	01	05	141	1	4	0.32	0.001	100	20
Aortic	00	01	145	0	1	0	0	NA	NA
Abdominal	09	12	132	7	9	0.64	0.001	98.5	58.3
Abdominal bleed	08	12	134	8	4	0.78	0.001	100	66.7
Diaphragm	00	02	144	0	2	0	0	NA	NA
Liver	06	08	137	5	4	0.7	0.001	99.3	62.5
Spleen	04	04	141	3	2	0.74	0.001	99.3	75.0
Kidney	02	01	144	1	1	0.66	0.001	99.3	100
Intestine	00	03	143	0	3	0	0	NA	NA
Pancreas	00	02	144	0	2	0	0	NA	NA
Genital injury	5	04	139	2	5	0.42	0.001	98.6	40
Pelvis fracture	04	04	141	3	2	0.74	0.001	99.3	75
Bladder	00	00	146	0	0	0	0	NA	NA
Urethral injury	01	00	145	0	1	0	0	NA	NA

Table 3B. Level of agreement for injuries on the chest, abdomen, and pelvis as observed by the clinical, radiological, and autopsy records

NA – Not Applicable

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Type of injuries	Clinical and radiological record findings	Autopsy record findings	Concordant		Discordant	Cohen's kappa	P value	Specificity	Sensitivity
			No	Yes					
Spine	01	01	144	0	2	-0.007	0.934	99.3	00
Limb injury	31	19	114	18	14	0.66	0.001	89.8	94.7
UL crush injury	00	01	145	0	1	0	0	NA	NA
UL fracture	16	11	129	10	5	0.71	0.001	95.6	90.9
UL joint	01	00	145	0	1	0	0	NA	NA
UL nerve injury	00	00	146	0	0	0	0	NA	NA
UL vessel injury	00	01	145	0	1	0	0	NA	NA
LL crush	01	01	145	1	0	1	0.001	100	100
LL fracture	17	12	129	12	5	0.80	0.001	96.3	100
LL joint	00	01	145	0	1	0	0	NA	NA
LL nerve injury	00	00	146	0	0	0	0	NA	NA
LL vessel	00	00	146	0	0	0	0	NA	NA

Table 3C. Level of agreement for injuries on the spine and limbs as observed by the clinical, radiological, and autopsy records

UL – Upper Limb
LL – Lower Limb
NA – Not applicable

Cause of Death Comparison

In this study, we compared the antemortem cause of death with the postmortem findings. The clinical cause of death was obtained from the patient's clinical records, while the autopsy cause of death was determined from the authorized autopsy report provided by the forensic expert. Each case was reviewed in consultation with forensic specialists and emergency department (ED) consultants to assess the concordance between the antemortem and postmortem diagnoses. The study found discrepancies in 21.9% of cases (32 cases). In 6 cases (4.1%), there was a significant difference between the two diagnoses, while in 26 cases (17.8%), only partial or minor discrepancies were noted. In the remaining 114 cases (78%), the antemortem and postmortem causes of death were consistent.

Discussion

Trauma is the leading cause of death worldwide, accounting for approximately 5.8 million fatalities annually. Among trauma cases, polytrauma is particularly prominent, with the highest mortality rate. It is frequently the consequence of traffic accidents, accidental injuries, or natural disasters that result in damage to various organs and systems of the human body[13]. ATLS, encompassing primary and secondary surveys, a focused assessment with sonography for trauma (FAST) examination, and the judicious application of MDCT, are employed for evaluating patients in trauma scenarios[14]. Despite the enhanced quality of emergency department evaluations for trauma patients and the improved precision of

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radiological methods, the incidence of possibly missed injuries is still a concern[15]. Autopsy remains the gold standard for determining the cause of death and provides valuable insights into missed injuries, offering critical feedback to clinicians to enhance trauma management quality[16]. Existing studies comparing missed injuries in antemortem assessments tend to focus on specific body regions or rely solely on clinical or radiological investigations, comparing these with postmortem findings. However, there is a lack of research combining clinical and radiological data from all body regions and comparing it comprehensively with autopsy findings. Our study focused on comparing the clinical and radiological findings together with the autopsy findings in terms of identifying the injuries and determining the cause of death.

In our study, which spanned two years, 146 trauma cases were evaluated. Road traffic mortality was predominantly observed in males (80.1%) compared to females (19.9%), a trend attributed to higher vehicle usage among men in India, resulting in a death rate 6.2 times greater than that of females[17]. Nearly two-thirds of those affected were between 18 and 30 years old, with the 21–30 age group representing the majority, consistent with previous studies[18][19][20]. Among road traffic accident fatalities, two-wheeler riders comprised the largest category, followed by pedestrians, with cyclists being the least affected, mirroring trends reported in the WHO Global Report on Road Traffic Accidents, 2023[21]. Among the cases, an alcohol intake history was identified in 23.3% of patients. No other substance abuse was recognized among the patients because substance abuse is less prevalent in our region.

We have evaluated the level of agreement observed for external injuries between the clinical and the autopsy findings of the deceased persons. During the initial examination, the clinicians were able to identify more injuries over the face, eye, ear, nose, and tooth compared to the autopsy surgeon. This is attributed to the fact that, during the second survey in the ATLS protocol, clinicians will conduct a systematic examination to identify injuries, starting with the head and neck. The necessary instruments used at this stage are tongue depressors, a Snellen chart, a nasal speculum, a light source, an otoscope, and an ophthalmoscope[17]. This approach allowed for a more detailed evaluation of injuries in areas like the nostrils, eyes, and ears, which are not routinely examined during autopsy and may explain the higher detection rate by clinicians. Additionally, survival time plays a significant role, as more minor injuries often heal before the autopsy is performed. In contrast, autopsy surgeons detect more head injuries than clinicians, particularly blunt force injuries such as abrasions, contusions, and lacerations. This discrepancy may arise because clinicians often need help interpreting and classifying injuries with the same precision as forensic experts[18]. Similarly, the external injuries over the chest, abdomen, and extremities were detected more during postmortem examination compared to the clinical examination.

We assessed the detection rate when combining both clinical and radiological tools in identifying injuries and compared it with the gold standard, i.e., autopsy. Autopsy surgeons identified and classified a higher number of brain hemorrhages, including extradural, subdural, subarachnoid, intraventricular, and brain stem hemorrhages, compared to clinico-radiological examinations with moderate to fair agreement between autopsy and clinico-radiological findings. Notably, there was a significant discordance for subarachnoid hemorrhage, where clinico-radiological methods missed a considerable number of cases. The findings are consistent with the study conducted by Alexis et al., where he also found a disparity in identifying intracranial hemorrhages, in particular subarachnoid hemorrhage (SAH)[19].

This may be due to the initial CT scan performed upon admission frequently missing specific developing lesions, especially subarachnoid hemorrhages, necessitating periodic CT assessments for precise identification[20]. Additionally, when using conventional CT, the high concentrations of contrast, if present, can compromise image quality and hinder precise evaluation; also, it can miss minimal blood volumes that occupy widths smaller than a slice due to volume averaging[21]. In comparing detection rates for cerebral contusion and cerebral edema, autopsy findings showed poor agreement with antemortem diagnostics, with concordant results in only 40 cases for contusion and 15 for edema. For diffuse axonal injury (DAI), autopsies failed to identify DAI in any of the 18 cases detected antemortem, indicating significant limitations in postmortem identification. This discrepancy is likely due to DAI being a histopathological diagnosis; brain specimens are not routinely subjected to histopathological evaluation in traumatic brain injury unless exceptional circumstances necessitate it.

In our study, fractures in the base of the skull, cranial vault, and facial bones were observed more frequently during postmortem examination compared to antemortem findings. The agreement between postmortem and antemortem findings was low, as indicated by poor kappa statistics. The base of skull fractures was missed more than other fractures. These findings were consistent with previous studies[19][22]. This can be attributed to the fact that a significant number of conclusions in head injury cases may go undetected if CT scans are reviewed solely in the axial plane, especially skull fractures that align parallel to the acquisition plane, which can be entirely missed in axial imaging[22]. More importantly, the clinico-radiological examination could identify cervical spine injury only in 5 cases, while autopsy revealed it in 16 cases. Alexis et al. also observed the same findings in their study, where out of ten cervical spine injuries, only three could be detected clinico-radiologically[19]. The incidence of missed cervical spine injuries is reported to range between 4% and 30%. The primary cause of these missed injuries is often an insufficient radiographic examination, and the commonly missed injury patterns include odontoid fractures, teardrop fractures, facet fractures, and hangman's fractures[23]. Injuries to the trachea were detected in two patients during postmortem examination, which was a wholly missed clinical examination.

The current study observed that injuries to the thorax, sternum, and ribs appeared in nearly equal proportions in both clinico-radiological assessments and autopsy examinations. However, autopsies detected a slightly higher number of injuries, with moderate agreement between the two methods, as reflected by the kappa value. Previous studies also showed that rib fractures can be missed during the initial evaluation using a plain chest radiography or CT scan[24][25]. The reason could be that the fractures in the ribs can be easily detected when the fractured ends are displaced. However, subtle and un-displaced rib fractures are commonly missed on plain radiography despite clinical symptoms[26]. Concerning the injuries to the lung and pleura, pleural injuries were identified in equal proportion in both categories, however, there was a discordance seen in 16 cases. Lung injuries were detected significantly higher during autopsy, where clinico-radiological evaluation failed to identify these in 7 out of 10 cases. More significantly, the clinical assessment missed four out of five cardiac injuries. These findings were in alignment with the previous study[19].

Of the 146 patients, the liver was the most commonly injured organ in the abdomen, accounting for 9 cases, followed by the spleen, pancreas, and kidney. The results suggest that there is a significant degree of concordance between clinical/radiological and autopsy records for abdominal bleeding, liver, spleen, and kidney injuries. The kappa values fall within the range of 0.66-0.78, which suggests a moderate diagnostic agreement, particularly for kidney (100% sensitivity) and spleen injuries (75% sensitivity). Abdominal hemorrhage exhibited the highest specificity (100%), indicating no false positives. Liver and spleen injuries also showed high specificity (99.3%), albeit with a lower sensitivity. However, the diagnostic reliability of diaphragm and pancreatic injuries in clinical contexts was inadequate, emphasizing the necessity of enhanced diagnostic tools to ensure precise detection. Of five cases with pelvic fractures, clinical/radiological examination, and autopsy identified fractures in four cases, with concordance observed in three cases. Similar findings were observed for pelvic fractures by Poulsen and Simonsen in their study, where no disparity was found in the identification of pelvic fractures between CT and conventional autopsy in an equal cohort of 20 patients[27]. However, another study by Höch et al. indicated that autopsy was more effective in identifying sacroiliac joint and iliac bone injuries, while CT scans were superior in detecting fractures in the sacrum and pubic rami, which are frequently difficult to assess in autopsies due to their anatomical positioning[28].

Regarding limb injuries, the results indicate a moderate agreement between clinical/radiological and autopsy records, with a kappa value of 0.66. The diagnosis of these cases was highly accurate, as evidenced by the sensitivity of 94.7% and specificity of 89.8% in the detection of limb injuries. The clinico-radiological evaluation detected more limb fractures than the autopsy, with the autopsy missing five fractures in both the upper and lower limbs. Despite this, there was still significant concordance between clinical/radiological findings and autopsy results. Upper limb fractures showed strong agreement, with a kappa of 0.71, sensitivity of 90.9%, and specificity of 95.6%, while lower limb fractures demonstrated even higher concordance, with a kappa of 0.80, sensitivity of 100%, and specificity of 96.3%. The higher number of fractures observed clinico-radiologically is due to the fact that during postmortem examination, a hairline or un-displaced fracture can be easily missed due to the subtle nature of these fractures, which may not be readily identifiable without comprehensive imaging[29].

In this study, discrepancies between antemortem and postmortem causes of death have been examined. Of 146 cases, major discrepancies that had a direct impact on therapeutic management were observed in 6 cases

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(4.1%), and minor discrepancies without such impact were seen in 26 cases (17.8%). In the remaining 114 cases (78%), the antemortem and postmortem causes of death were matching. Similar findings were observed in a study conducted by Tejerina et al. in which of 834 patients, 63 (7.5%) had major discrepancies, and 95 (11.4%) had minor discrepancies[30]. In another study done by Talita Zerbini et al. from Brazil, of 465 cases, the disparity between the clinical and autopsy diagnosis cause of death was seen in 28%, including the major minor discrepancies[31]. In another study from Berlin, Germany, 1112 autopsies were analyzed for the discrepancy in the cause of death, resulting in an overall 26.1% discrepancy[32]. These findings suggest that despite advancements in medical technology and diligent practices, diagnostic errors can still occur, and autopsies remain an essential tool for identifying missed or incorrect diagnoses since a high percentage of clinical diagnoses are wrong or incomplete[11][33].

Conclusion

This study underscores the critical role of autopsies in trauma cases, emphasizing their importance in the identification of missed injuries and discrepancies in clinical and radiological diagnoses. In complex injuries such as brain hemorrhages, base of skull fractures, and cervical spine injuries, the findings disclose substantial discordance despite advancements in diagnostic imaging and emergency assessment protocols. Autopsies have the potential to significantly impact the quality of trauma management by providing critical insights into subtle or initially missed injuries, such as unrecognized fractures and small hemorrhages. The necessity for improved diagnostic techniques and ongoing quality development in trauma care is made evident by the significant discrepancy rates between antemortem and postmortem findings. The integration of newly advanced imaging techniques with regular reassessment, particularly in severe trauma cases, has the potential to reduce diagnostic gaps. This study emphasizes the importance of autopsy feedback in refining trauma assessment protocols, which ultimately enhances patient outcomes by resolving the constraints of clinical and radiological evaluations. However, future studies are recommended using multicenter, longitudinal and AI based techniques. A higher sample size identifying preventable causes of death and correlating clinical and autopsy findings to improve trauma management protocols should be prioritized.

Limitations of this study

- *Sample Size and Single-Center Design:* The study was conducted at a single tertiary care center with a limited sample size (146 RTAs cases), which may limit the generalizability of the findings to other settings or regions.

- *Reliance on Manual Matching:* The comparison of antemortem and postmortem causes of death was done manually, which may potentialy introduce observer bias despite efforts to standardize the process.

Future Recommendations

- *Multicentre Studies:* Conducting similar studies across multiple centers with larger sample sizes would improve the generalizability and robustness of findings.
- *Inclusion of All Fatalities:* Future studies should consider all types of fatalities occurring beyond traffic accident deaths.
- *Automated Analysis Systems:* Utilizing automated or AI-based systems for matching antemortem and postmortem findings to reduce observer bias and improve reproducibility.
- *Longitudinal Studies*: Studies with a longitudinal design to assess the clinical course and treatment outcomes in relation to autopsy findings can provide deeper insights into trauma care efficacy.
- *Standardization of Data Collection Tools*: Developing standardized forms and digital tools for real-time data collection, such as a universal autopsy checklist, can improve data quality and comparability across studies.

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