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Ten year analysis of missed injuries at a major trauma centre in South Africa

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ABSTRACT

Introduction: This analysis retrospectively reviews a tertiary trauma service's experience with missed injuries over a decade.
Methods: The Pietermaritzburg Metropolitan Trauma Service (PMTS) has accumulated electronic data on all admissions since 2012. This data informs the monthly morbidity and mortality conference, where adverse events are discussed. Records of all missed injuries were reviewed.
Results: During the study period there were 17 254 individual patient admissions and 4 624 surgical procedures. A total of 159 missed injuries were identified. Ninety-six were injuries missed on investigation; 60 were missed on CT, 27 missed on x-ray, 1 on blood test, and 8 occurred during an unknown investigation. Thirty-nine injuries were missed during surgery; including thirteen colonic, five small bowel, five gastric, four duodenal, three vascular and three diaphragmatic injuries. Twenty-four injuries were missed on initial assessment, the majority of which were soft tissue injuries. Intraoperative missed injuries resulted in the greatest morbidity.
Conclusion: Missed injuries remain a problem in modern trauma care. Injuries missed during initial clinical assessment and on imaging must be excluded by detailed secondary surveys and in depth review of all imaging. Injuries missed at operation carry greater morbidity than those missed outside the operating room. Ongoing vigilance is necessary to reduce the incidence of these injuries.

Introduction

The timely identification, recognition and treatment of all traumatic injuries is most likely to result in optimal outcomes. Delayed identification of injuries translates into delayed therapy, and this invariably leads to less-than-optimal outcomes. The delayed recognition of a traumatic injury is colloquially referred to as a "missed injury". A missed injury almost always indicates that error has occurred. The study of human error in fields outside of health care has demonstrated that mistakes are not random events, but rather tend to follow patterns. Identification of these patterns allows for the development of strategies designed to reduce the incidence and impact of these errors. This has been shown most notably by the aeronautical industry, which has achieved an enviable safety record over the last five decades. This was achieved by a process of rigorous data collection on all errors, including errors resulting in a safety incident, referred to as a "hit" as well as those which did not result in an overt safety incident, referred to as a "near miss". This data was analyzed and modelled to create a thorough scientific understanding of error in the aeronautical industry. These analyses were successfully translated into strategies and protocols designed to reduce the incidence of error and to mitigate the impact of error when it does occur. Despite a realization that this process and approach is necessary in health care, modern hospitals remain highly error prone environments [1–6]. The patient safety movement has raised awareness about the impact of error on outcomes in health care, and there have been several strategies which have been implemented in an effort to reduce the incidence and impact of human error in modern health care. These include checklists and care bundles. Ongoing collection of data on error and adverse events may allow for the development of further error reduction strategies. This study reviews missed injuries in trauma patients over a decade at our institution. Concepts, taxonomies and strategies developed by industrial psychologists and students of human

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error in fields outside of health care will be used to enhance our understanding of these missed injuries. It is hoped that this review will provide evidence to support ongoing error reduction strategies.

Materials and methods

Clinical setting

The Pietermaritzburg Metropolitan Trauma Service (PMTS) is based in the city of Pietermaritzburg, KwaZulu Natal. It provides definitive trauma care for a population of approximately 4.5 million in the Western third of the province.

Electronic trauma registry data

The Pietermaritzburg Metropolitan Trauma Service (PMTS) developed and instituted the Hybrid Electronic Medical Registry (HEMR) in 2012. This has allowed the collection of ten years of data on all surgical admissions. HEMR has a dedicated module to capture data on adverse events, which is used to generate a monthly morbidity and mortality conference. At this conference all adverse events are collated and discussed, with note taken of all missed injuries. Following ethical approval from the Biomedical Ethics Research Committee of the University of Kwa Zulu Natal (UKZN), all events pertaining to missed injuries were drawn retrospectively for analysis. All trauma admissions captured on HEMR were included, with the only exclusion criterion being removal of duplicate data. The study period was from 1 December 2012 to 31 December 2022.

Taxonomy

All missed injuries were categorized according to type or domain. These domains include injury missed on clinical assessment, injury missed due to misinterpretation of an investigation, or injury missed intra-operatively. An attempt was made to grade the impact of each missed injury using the Clavien-Dindo taxonomy [7].

Results

During the study period there were 17 254 individual patient admissions amounting to 66 298 inpatient days, and 4 624 surgical procedures. Among the 17 254 admitted patients a total of 159 missed injuries were identified, affecting 128 patients. Of the 128 patients, 110 were male, and 18 were female. Fig. 1 shows the demographics of this cohort. In this study 24 missed injuries occurred during clinical assessment, 39 during an operation, and 96 due to errors in investigation interpretation. Fig. 2 shows this distribution.

Missed on initial assessment

Twenty four injuries were missed on initial assessment. Of those 17 were soft tissue injuries, and 3 non-viability of an injured limb. There were one each of malpositioned endotracheal tube, tension pneumothorax, and neurological deficit. In one patient pregnancy was missed, and whilst not an injury, may significantly impact future care and should therefore not be missed.

Missed on investigation

Of the 159 missed injuries, 96 occurred secondary to misinterpretation of an investigation. These included 60 injuries missed or not recognized on CT scan, 27 missed or not recognized on plain X ray, and a single blood test which was misinterpreted. The type of investigation was not clear in 8 instances. Half of the injuries missed on CT scan were bony fractures (47%), of which the majority were spinal fractures. Other injuries missed on CT scan included 9 vascular injuries, 6 abdominal solid organ injuries, and 6 fluid collections. Of the 27 injuries missed on X ray, 15 were haemo/pneumo-thoraces, and 7 long bone fractures. Further information is detailed in Figs. 3 and 4.

Missed at operation

A total of 39 injuries were missed intra-operatively. Of those the majority were enteric (27 injuries; 69%), comprising thirteen missed colonic injuries, and five each in the stomach and small bowel. Four duodenal injuries were missed. Fig. 5 provides further detail.

Impact of the missed injury

Morbidity was stratified against domain using the Clavien-Dindo classification taxonomy. Intra-operative missed injuries were associated with more significant complications than the other two domains. Intra-operative missed injuries accounted for 60% of Grade III-B injuries, 58% of Grade IV-A injuries and 100% of Grade IV-B injuries. Of the injuries missed on investigation, the majority (76%) were associated with much lower degrees of morbidity (Grades I, II, III-A). Details are provided in table 1.

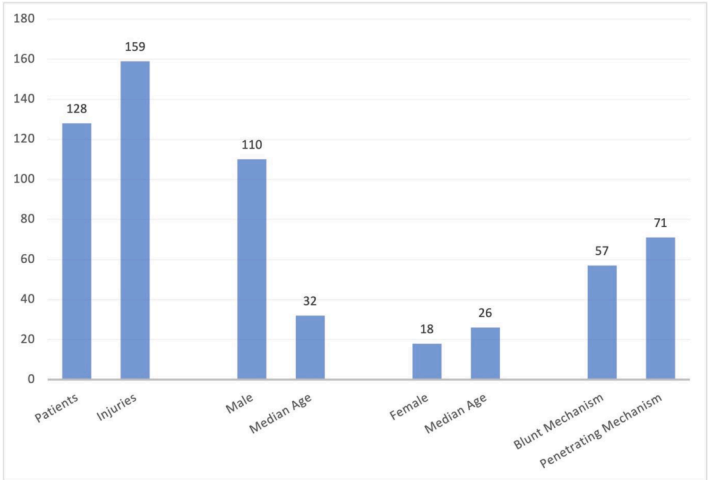

Fig. 1. Basic demographics of the study cohort.

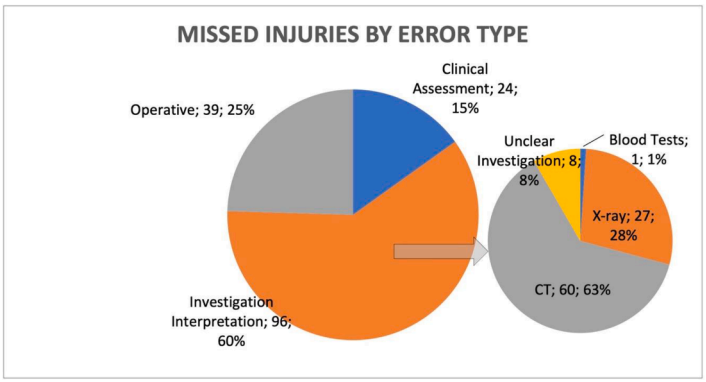

Fig. 2. Missed Injuries by error type.

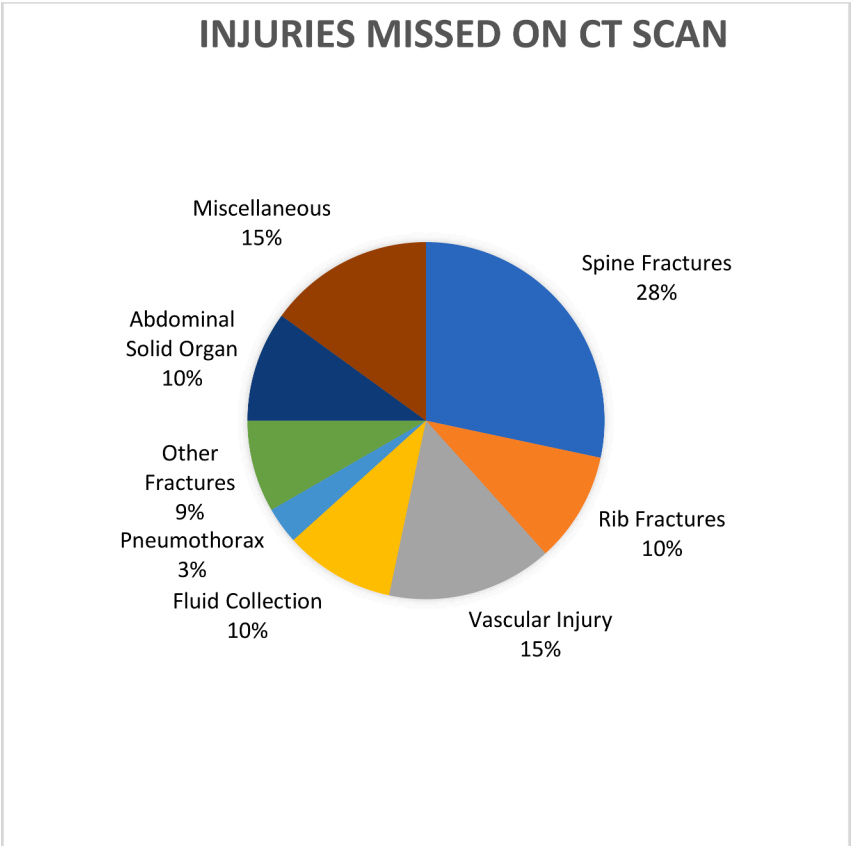

Fig. 3. Injuries Missed on CT Scan ($n = 60$).

Risk factors for missed injuries

Several factors were assessed for their contributions toward missed injuries. Day of admission (weekday vs weekend), time of admission (office hours vs after hours), mechanism of injury, and patient gender did not contribute significantly toward an injury being missed in this study. The presence of shock on admission, higher Injury Severity Score (ISS), and pregnancy were all statistically significant in their association with missed injuries. Table 2 shows this.

Discussion

Although missed injuries in trauma are relatively rare, they incur significant morbidity. They are also most likely to occur in patients with the least physical reserve. The three factors which are statistically associated with missed injuries, include shock on admission, higher Injury Severity Score (ISS), and pregnancy. This means that efforts must be made to eliminate or reduce the incidence of missed injuries. Strategies to reduce error will vary according to the domain in which the error occurs.

Injuries missed on clinical assessment occur less frequently than in other domains [5,8–10]. The structured approach to initial assessment advocated by the Advanced Trauma Life Support (ATLS) course is the best way to reduce errors in this domain. ATLS emphasizes a primary survey to identify and treat immediate life-threatening conditions, followed by a more detailed systematic secondary survey. The addition of a tertiary survey, whilst not formally part of the ATLS teachings at this stage, have been adopted in several trauma units with promising results. A structured and protocolized tertiary survey has been demonstrated to aid in the detection of previously unappreciated injuries [8,11].

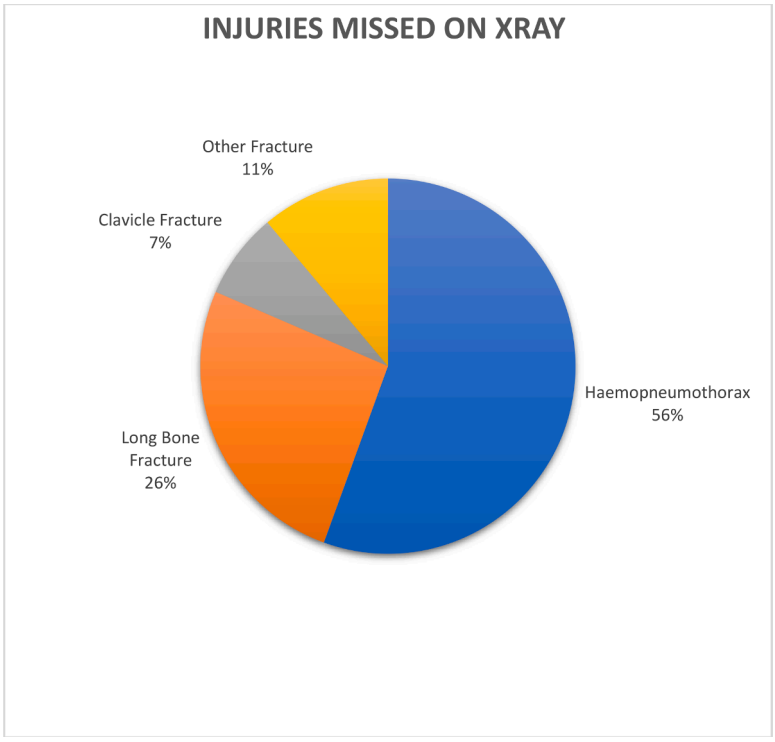

Fig. 4. Injuries missed on Xray ($n = 27$).

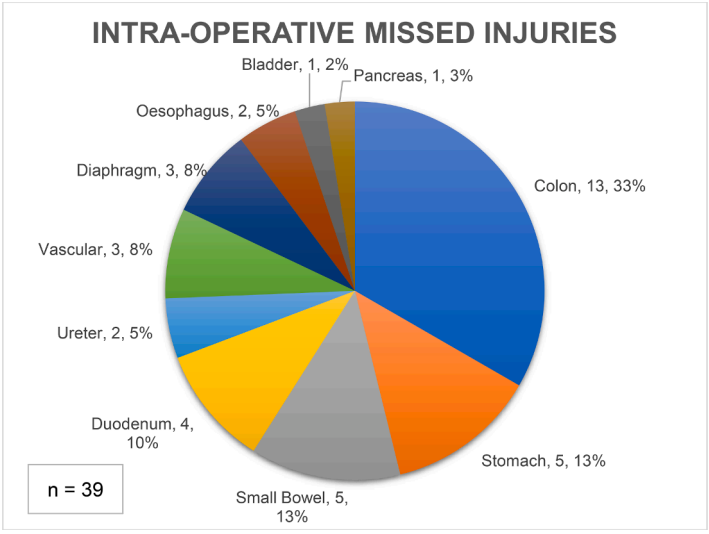

Fig. 5. Injuries missed during an operation. ($n = 35$).

Table 1
Impact of missed injuries graded according to the Clavien-Dindo Classification (7).

Injury Grade	Clinical	Investigation	Operative	Total
Grade I	3	6	0	9
Grade II	6	40	0	46
Grade IIIa	4	32	0	36
Grade IIIb	8	15	31	51
Grade IVa	3	3	7	12
Grade IVb	0	0	1	1
Grade V	0	0	0	0

The majority of missed injuries are secondary to misinterpretation of imaging. The most common missed injuries on plain film were a haemothorax and/or a pneumothorax, followed by long bone fractures. The interpretation of CT scan imaging is highly error prone, in our study accounting for 63% of investigation-related errors. A number of factors are associated with the misinterpretation of CT imaging. These include advancing age of the patient, injuries in three or more distinct body regions, higher injury severity, as well as after-hours reporting and staff seniority [12–14]. The first three factors are patient factors and the last two systems factors. A so called 'defense-in-depth' strategy may help. All imaging needs to be reviewed at multiple points. This includes review by senior radiology and review of all imaging by the managing clinician [15,16]. Surgical trainees need to be taught the principles of CT interpretation.

Table 2
Depicts factors studied that potentially contributed to an injury being missed.

Day Admission (08h00 to 23h59)	$p = 0.5477$
Night Admission (00h00 to 07h59)	$p = 0.5612$
Weekday (Monday 08h00 to Friday 16h00)	$p = 0.3693$
Weekend (Friday 16h00 to Monday 08h00)	$p = 0.4043$
Mechanism of Injury	$p = 0.2279$
Gender	$p = 0.2029$
Shock Present on Admission *	$p = 0.04248$
Pregnant	$p = 0.004998$
ISS score **	$p<0.001$

$p < 0.05$ considered significant.
* assessed by admitting team.
** assessed as continuous variable, i.e. the higher the ISS, the greater the chance of missing an injury
ISS = Injury Severity Score.

Injuries missed at operation although uncommon are associated with significant morbidity. Patient factors such as obesity, previous surgery, concomitant non-trauma related pathology, multiple injuries, significant hemorrhage as well as the need for abbreviated surgery, exacerbate the risk of missed injury. Injuries to the mesenteric border of both the colon and small bowel may be overlooked. The duodenum needs to be adequately mobilized. When assessing enteric injuries, the surgeon must presume the presence of a second injury. Blunt injuries and blast injuries, as well as gunshot wounds tend to result in destructive enteric injuries, which may be more obvious than a small puncture with limited contamination resulting from a stab wound. Although surgeon related factors almost certainly impact on the rate of missed injury at operation, this correlation is more difficult to prove. Our data did not demonstrate a correlation between missed injury and time of assessment. Despite significant literature investigating systems factors such as shift duration, clinician tiredness, as well as the so-called "weekend effect" there is little consensus as to these systems factors impact on clinical performance [17–21].

Conclusion

Although missed injuries are relatively rare they are associated with significant morbidity. Injuries missed during initial clinical assessment and on imaging must be excluded by detailed secondary surveys and review of all imaging. Injuries missed at operation infer greater morbidity than those missed outside of the operating room.

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Author contribution

Howard Wain: Concept, data analysis, manuscript. **Damian L Clarke:** Project Supervisor, concept, manuscript. **Shelley Wall:** Project co-supervisor, concept, statistics, manuscript. **Wanda Bekker:** Concept, manuscript. **Victor Kong:** Concept, manuscript. **John L Bruce:** Concept, manuscript. **Howard Wain:** Concept, data analysis, manuscript. **Damian L Clarke:** Project Supervisor, concept, manuscript. **Shelley Wall:** Project co-supervisor, concept, statistics, manuscript. **Wanda Bekker:** Concept, manuscript. **Victor Kong:** Concept, manuscript. **John L Bruce:** Concept, manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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