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GENERAL SURGERY

Defining the contribution of human error to adverse events in a surgical service

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Background: This study aimed to assess the contribution of human error to adverse events over 10 years in a single surgical department in South Africa.
Methods: A retrospective database analysis was undertaken to identify all adverse events, which were further assessed to identify which were error-associated.
Results: A total of 14 237 adverse events occurred between December 2012 and January 2023, of which 7 504 (52.7%) were judged to be error-associated. An error rate of 14% per admission, or 2% per inpatient day was shown. *Errors during delivery of care* accounted for 76% of all errors and 40% of all adverse events. Of those, medication errors contributed 29%, those due to indwelling devices contributed 28%, and iatrogenic injuries 18%. *Errors in assessment* accounted for 14% of the total errors and 7% of all adverse events, with clinical assessment failure contributing 55.8% and missed injuries 19%. *Mixed type errors* contributed 10% of the total. Assessment by year demonstrated an upward trend from 2013 to 2016, followed by a downward trend from 2016 to 2022. Error-associated adverse events increased length of stay and mortality significantly.
Conclusion: Error contributes to more than half of adverse events and increased length of stay and mortality and is potentially avoidable. Errors may occur at any stage during an admission and highlights the need for multilevel interventions. The decrease in error noted is due to the cumulative effect of multiple endeavours, and not a single intervention.
Keywords: adverse events, error, human error, surgery, trauma surgery, patient safety

Introduction

The realisation that human error is pervasive in complex systems such as the healthcare industry has generated a great deal of interest over the last two decades. Research has highlighted the fact that medical error is more common than previously recognised. *To err is human*, published in 2000, is the foundational text in the field of error in healthcare.[1] It described a significant number of deaths secondary to error in American hospitals, and garnered much attention.[2] *To err is human* built on earlier work by Leape and colleagues in the 1990s.[3-6] In light of this there is a significant interest in strategies to reduce error and enhance safety. The industrial psychologist Reason's work on human error provides insight on the genesis of human error, and he describes error as being either skills based, a slip or lapse, rule-based mistakes, or knowledge-based mistakes.[7] Reason's writings focus on the individual's contribution to an error, which has been adapted more recently into a human performance deficiency identification tool.[8] Whilst an individual certainly plays a role in error genesis, other authors advocate for a wider "systems approach", for example the System Engineering Initiative for Patient Safety (SEIPS).[9] Chang developed a taxonomy of patient safety events, which describes five nodes by which each error event should be considered, namely impact, type, domain, cause, and prevention or mitigation.[10] Chang's approach covers both individual factors and system factors, and asks users to assess how each contributed to a particular adverse event. Other industries have used error theory to drive highly effective safety strategies. The most well-known example of this is the aviation industry, which has an enviable safety record dating back over four decades. In attempting to emulate the successes of aviation, healthcare has adopted similar strategies to improve safety. These include ongoing workplace-based education, simulation-based training, checklists, procedural standardisation, and reporting of all adverse events. Despite this, healthcare has lagged behind aviation in optimising safety. Supporting all these safety efforts is the need to collect data on error. To that end, our department has developed and maintained an electronic medical record for over a decade, which specifically allows for recording of adverse events. We set out with the primary objective of quantifying the contribution of human error to these adverse events. Our secondary objective was to appraise the trend of such error over time, with the view to understanding where the gaps lie.

Clinical setting

The department of surgery at Greys Hospital in Pietermaritzburg, South Africa, is a tertiary surgical service, and is affiliated with the Nelson R Mandela School of Clinical Medicine of the University of KwaZulu-Natal. The department provides undergraduate, post-graduate, and sub-specialist training.

Methods

The department of surgery has maintained an electronic medical record since December 2012, named the Hybrid Electronic Medical Registry (HEMR). The HEMR is a relational database that captures data on admissions, operative procedures, endoscopic procedures, adverse events, and discharges. Data is entered by medical staff, in real time, such that the electronic record may be printed and become incorporated into the patients' hospital (paper-based) file. The adverse events module (termed "Morbidities" on HEMR) allows for the electronic capturing of all adverse events. These events may be recognised by multiple methods, including on daily clinical ward rounds, during operative or endoscopic procedures, during handover meetings, on consultant ward rounds, during departmental mortality conferences, or hospital-level patient enquiries. Adverse events are captured anonymously.

Ethical approval was obtained from the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu-Natal prior to the study commencing. All adverse events between December 2012 and January 2023 were retrieved. Each event was organised against various categories, and an assessment made regarding the contribution of error. Once identified, errors were categorised into three domains: assessment-related, clinical care related, and a mixed group. All captured events were included in the study. Duplicate entries, and incomplete entries were excluded.

Each captured adverse event recorded on HEMR consists of a description, captured as free text. The decision regarding the occurrence of an error was made by the authors. In each case the description was read, and an assessment as to the contribution of human error was determined. Where it was not possible to determine if error occurred with certainty, the event was classified as not being related to an error, to avoid over-reporting.

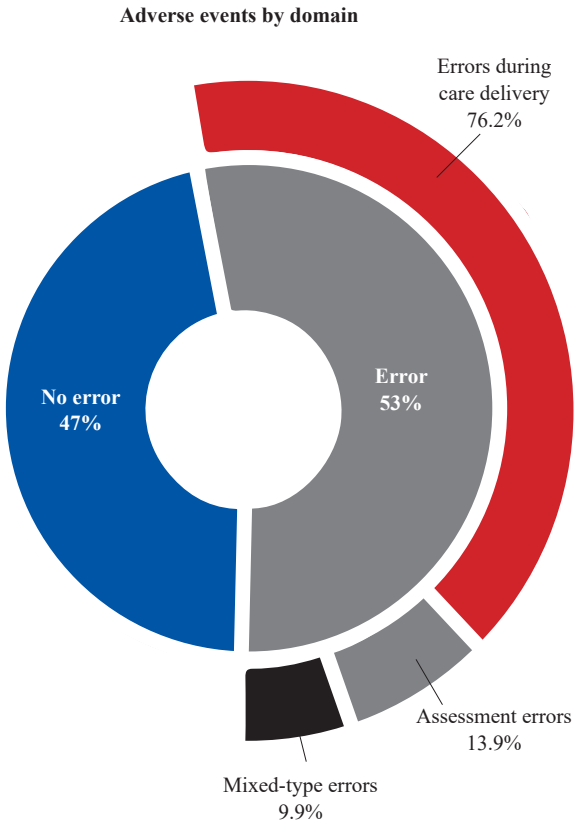

Figure 1: Adverse events categorised by domain

Results

A total of 14 237 adverse events were recorded of which 7 504 (52.7%) were error-associated. The error-related adverse events occurred in 6 608 patients of which 63% (4187/6608) were male, and 37% (2421/6608) female. The errors occurred during 52 835 distinct admissions, totalling 321 385 inpatient days. This translates to an error rate of 14% per admission, or 2% per inpatient day. The error-associated adverse events were further categorised by domain: errors during delivery of care, errors in assessment, and mixed-type errors (Figure 1).

Errors during delivery of care represent the largest domain in which error occurred, accounting for 76% of all errors (5717/7504), and 40% (5717/14237) of all adverse events. Of those, medication errors contributed 29% (1665/5717), comprising 1 000 errors related to medication administration and 665 prescribing errors. Errors resulting from the use of indwelling devices (central and peripheral venous catheters, intercostal chest drains, surgical drains, urinary catheters) contributed 28% (1591/5717), and iatrogenic injuries 18% (1004/5717) (Table I).

Errors in assessment accounted for 14% of the total errors (1044/7504) and 7% (1044/14237) of all adverse events. Further division revealed clinical assessment failure in 55.8% (583/1044), failure to assess patients daily in 22%

Table I: Errors during care delivery

Error during care delivery	5 717	100.0%
Medication related	1 665	29.1%
Adjunct related	1 591	27.8%
Iatrogenic injury	1 004	17.6%
Stoma related	358	6.3%
Pressure sore	167	2.9%
Incorrect or inadequate surgery	160	2.8%
Wound sepsis	101	1.8%
Logistics error	99	1.7%
Wound not dressed	88	1.5%
Anastomotic leak	82	1.4%
Investigation not followed up	64	1.1%
Incorrect patient	59	1.0%
Fall	42	0.7%
Fistula	40	0.7%
Operation cancelled or delayed	39	0.7%
Organ space collection	32	0.6%
Pneumonia	24	0.4%
Drug stock	18	0.3%
Absconded	18	0.3%
Anaesthesia related	13	0.2%
Burn or fire	13	0.2%
Acute kidney injury	11	0.2%
Retained foreign body	10	0.2%
Post procedural bleed	9	0.2%
Incorrect side	6	0.1%
Electrolyte abnormality	4	0.1%

Table II: Errors in assessment

Error in assessment	1 044	100%
Clinical assessment failure	583	55.8%
Not seen daily by surgery	224	21.5%
Missed injury	193	18.5%
Radiology reporting error	24	2.3%
Incorrect investigation	20	1.9%

Table III: Mixed error

Mixed error total	743	100%
Documentation	331	44.5%
Protocol violation	232	31.2%
Not seen by allied disciplines	82	11.0%
Equipment	47	6.3%
Transport delay	40	5.4%
Miscellaneous	11	1.5%

(224/1044) and missed injuries in 19% (193/1044) (Table II).

Mixed-type errors contributed the least of all errors (10%; 743/7504). Documentation errors and protocol violation contributed 45% and 31% respectively (Table III).

Figure 2 shows the breakdown of errors by year, and demonstrates an upward trend from 2013 to 2016, followed by a generalised downward trend from 2016 to 2022.

Over the study period, the median length of stay (LOS) was three days (3±15.6 days). This was significantly increased in patients who sustained at least one adverse event or sustained at least one error-related adverse event. There was a significantly increased chance of death in patients sustaining at least one adverse event, or at least one error-related adverse event (Table IV).

Table IV: Assessment of statistical correlation between patients who experienced an adverse event or error-related adverse event versus those who did not, in terms of length of stay (LOS) in days and death

Correlation between: (Kruskal-Wallis Tests)	*p*-value
Adverse events and LOS	$p < 0.001$
Adverse events and death	$p < 0.001$
Medical error and LOS	$p < 0.001$
Medical error and death	$p = 0.003$

$p < 0.05$ considered significant

Discussion

Potentially avoidable human error in healthcare contributes significantly to adverse events, and our data shows that just over half of all adverse events in our institution are error -related. Chang's Taxonomy is a useful system to appraise adverse events.[11] The HEMR captures the first four nodes namely: impact, type, domain, and cause. The departmental Morbidity and Mortality (M&M) conferences address prevention, which is the fifth node. This approach enhances awareness of error and promotes a culture of patient safety.

Error occurs at all stages of patient interaction, from the initial assessment throughout hospital admission, and during procedures. Error may occur during planning or logistical tasks. The majority of errors (76%) occurred during the delivery of therapy. Whilst most error occurred during delivery of surgical therapy, almost one quarter of errors occurred during patient assessment or were mixed type errors related to logistics and documentation. Errors can occur at any stage during admission, so error reduction strategies must target all domains.

The introduction of HEMR allowed for systematic collection of data on error and adverse events. Several interventions have been implemented to enhance patient safety. The improved M&M conferences from 2013 raised awareness and improved data collection. Handbooks detailing departmental protocols for general surgery and trauma surgery were published in 2013 and 2019, respectively. In 2015, the introduction of weekend handover forms, formalised handovers to the on-call team and highlighted patients at risk for decompensation. The use of the World Health Organization Surgical Safety Checklist provided an additional layer of safety in the operating room. The Advanced Trauma Life Support (ATLS) programme was introduced in KwaZulu-Natal in 1992. The addition of ATLS courses within the Pietermaritzburg region in 2009 has increased access to this international course and increased the local pool of course instructors. The ATLS course standardises the initial assessment of an injured patient, although it is commonly applied to non-trauma surgical patients as well. It teaches a safe method for various interventions during the initial resuscitation period (for example, surgical airway, tube thoracostomy, central

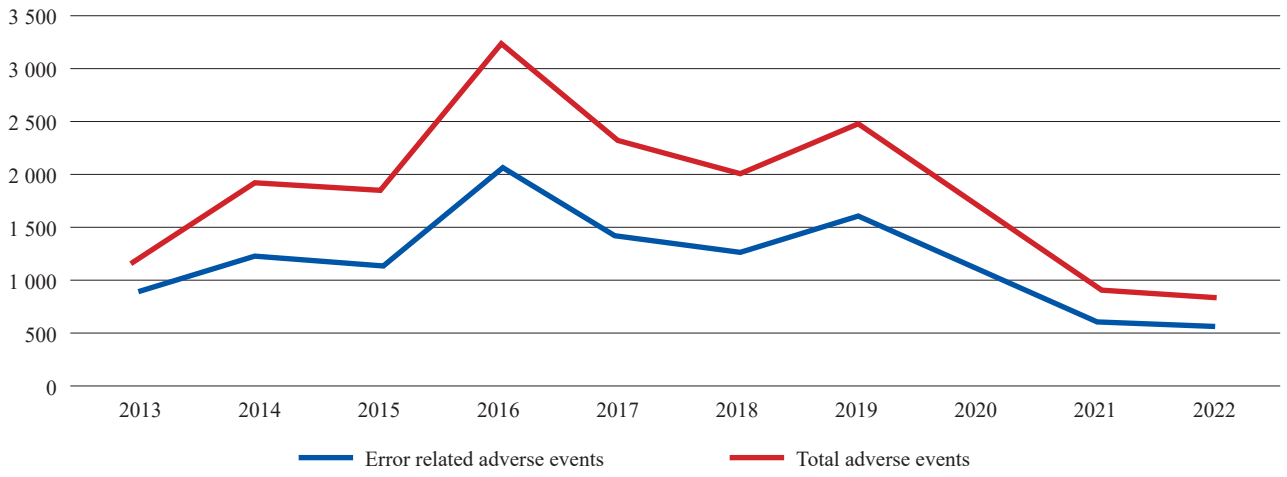

Figure 2: Categorisation by year

venous catheter insertion and fracture immobilisation). Standardisation of these key procedures enhances safety and reduces error. Several publications from our department have highlighted a focus on adverse events and quality improvement.[12-21]

The absolute number of adverse events has changed over time. From 2013 to 2016 there was a general increase. This is almost certainly due to improved awareness and reporting. The decreasing trend from 2016 onwards suggests that the multiple interventions have had a positive effect.

Local publications demonstrate that awareness of adverse events and error predates the introduction of HEMR.[22,23] However, since the introduction of HEMR, the availability of accurate data has facilitated a significant expansion in this interest, and indeed research output.[12-21,24-27] This study allows us to assess temporal trends and suggests that these multiple strategies have had a cumulative beneficial impact. Multiple sustained interventions, have a positive impact. These multifaceted cumulative interventions effect a *culture change* which centralises patient safety.

This study has limitations inherent in the methodology of a retrospective review of an electronic database. These include incomplete and missing data sets. Adverse event recognition relies heavily on self-reporting, which introduces potential inaccuracy. Detail as to the impact of each error associated adverse event is often lacking. Although the HEMR has a dedicated facility to capture the impact of an adverse event according to the Clavien-Dindo grading system, the assessment is often incorrect. Sixty-five per cent of captured error related adverse events did not have a Clavien-Dindo grading, and the descriptions are often not granular enough for accurate retrospective assessment. The impact of a particular event may not be apparent at time of capture onto HEMR. This is a weakness in the system. In addition, the true impact of an error, such as a missed antibiotic dose, may be difficult to quantify.

In light of this, ongoing efforts are directed at enhancing the granularity of captured data, and assessing the accuracy of the impact the adverse event has on the individual patient outcome. Collecting accurate and complete data is essential. We were able to demonstrate a statistically significant correlation between increased length of stay and increased risk of death in patients who experienced an adverse event compared to those who did not. This is in keeping with other studies.[28-32] Establishing causality is challenging and although prolonged hospital stay is associated with increased risk of experiencing an adverse event, this may reflect increased severity of disease.

Conclusion

Error contributes significantly to adverse events in modern surgical care. Strategies to reduce the rate of human error in the system must be implemented. These strategies need to be multifaceted and sustained with the objective of promoting a culture of patient safety. Long-term data suggests that this does have a cumulative positive effect and reduces both the incidence and consequence of human error in healthcare.

Conflict of interest

The authors declare no conflict of interest.

Funding source

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Ethical approval

Ethical approval was obtained from the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu-Natal prior to the study commencing. Ethical approval number BREC/00004792/2022.

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