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Analysis of Surgical Mortalities Using the Fishbone Model for Quality Improvement in Surgical Disciplines

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Abstract

Background The healthcare industry is complex and prone to the occurrence of preventable patient safety incidents. Most serious patient safety events in surgery are preventable.

Aim This study was conducted to determine the rate of occurrence of preventable mortalities and to use the fishbone model to establish the main contributing factors.

Methods We reviewed the records of patients who died following admission to the surgical wards. Data regarding their demography, diagnosis, acuity, comorbidities, categorization of death and contributing factors were extracted from the Research Electronic Data Capture (REDCap) database. Factors which contributed to preventable and potentially preventable mortalities were collated. The fishbone model was used for root cause analysis. The study received prior ethical clearance (M190122).

Results Records of 859 mortalities were found, of which 65.7% (564/859) were males. The median age of the patients who died was 49 years (IQR: 33–64 years). The median length of hospital stay before death was three days (IQR: 1–11 days). Twenty-four percent (24.1%) of the deaths were from gastrointestinal (GIT) emergencies, 18.4% followed head injury and 17.0% from GIT cancers. Overall, 5.4% of the mortalities were preventable, and 41.1% were considered potentially preventable. The error of judgment and training issues accounted for 46% of mortalities.

Conclusion Most surgical mortalities involve males, and around 46% are either potentially preventable or preventable. The majority of the mortality were associated with GIT emergencies, head injury and advanced malignancies of the GIT. The leading contributing factors to preventable and potentially preventable mortalities were the error of judgment, inadequate training and shortage of resources.

Introduction

The complexity of the healthcare industry predisposes it to the occurrence of patient safety incidents (PSI) [1]. Structural or process failures at multiple levels are involved in almost all serious patients' safety incidents [2–5]. More than a third of serious patients' safety incidents in surgery are either preventable or potentially preventable [6, 7]. The occurrence of preventable PSI reflects a poorly functioning healthcare system [6, 8]. Some organizations use the rate of occurrence of preventable mortalities for benchmarking and ranking of hospitals [9].

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Although the recent advances in healthcare in high-income countries (HICs) have led to improved surgical outcomes, the same cannot be said for healthcare facilities in low- and middle-income countries (LMICs) [10]. Among the some of the barriers to improvement in surgical care is inability to collect valuable data, lack of standardization of care and/or care pathways, poor leadership and a prevailing culture of blame [1, 11–14]. Preferably, data collection, evaluation and thorough root cause analysis (RCA) should be done regularly to identify gaps to enable targeted intervention [15, 16].

Among the commonly used RCA strategies is the brainstorming method, the lean method, the use Shewhart control charts or Pareto charts, process mapping, interrelationship diagrams [17], the five whys method, the current reality tree method, fault tree analysis [18], human factors classification framework [19] and the Ishikawa cause and effect diagram (fishbone model) [15, 17, 20]. The fishbone model is preferred because it is simple to learn and facilitates identification and grouping of factors that contributed to unsatisfactory performance [15, 16, 21]. This study was conducted to determine the rate of occurrence of preventable and potentially preventable mortalities in surgical patients. Furthermore, the fishbone model was used to establish the main contributing factors.

Methods

Records of consecutive surgical patients who were 18 years and older who died during admission to the surgical wards in the period starting from January 1, 2017, to December 31, 2018, were studied. Patients who died after they were sent out to other departments and those whose records were incomplete were excluded. Permission to conduct the study was received from the Research Review Board of Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and Human Research Ethics Committee (Medical) of the University of the Witwatersrand (M190122).

The Department of Surgery at CMJAH started running its morbidity and mortality meetings (M&M) on the REDCap platform in 2016. Patients' demographics, admission diagnosis, comorbidities, surgical procedures, intra-operative adverse events, the grade of postoperative complications according to the Clavien–Dindo classification and overall outcome are captured during collection of data for M&M by individual divisions and units of the department. Preventability of the serious adverse events and their contributing factors are also recorded. The units marked the factors which they considered to have contributed to each preventable or potentially preventable mortality from a drop-down list. The list of contributing factors include training, supervision, lack of resources, equipment issues, infrastructure problems and communication failure. There was also an option to add any other factor which was thought to have contributed to a mortality. The decisions that were made at unit-based M&M meetings are ratified at the meeting of the entire department. An additional verification was done by a surgeon with more than 20 years' experience. The senior surgeon was blinded to the allocated category of deaths and their contributing factors that were assigned during the weekly departmental morbidity and mortality meeting.

A mortality was considered preventable if it was not expected to have occurred in any setting regardless the available resources, including the level of expertise. The potentially preventable mortalities meant the deaths that could not have occurred if the setting was ideal, and all the resources were available. The mortalities which were considered not have been preventable including deaths due to advanced cancer, severe traumatic brain injury, arrival in the extremes due to established sepsis, severe burn injury, advanced HIV disease or irreversible organ dysfunction.

Categorical data were reported in numbers and percentages. Mean with standard deviation was used for continuous data where it was appropriate. A Chi-square test was used to find the association between gender, pathology and how preventable mortality was. For the relationship between continuous variables, the nonparametric Kruskal–Wallis test was used, as the data were not normally distributed. A p-value below 0.05 was regarded as being statistically significant. Finally, the factors which contributed to preventable and potentially preventable mortalities were identified and collated, and a fishbone diagram. We used the themes which are used in our M&M for grouping of the factors instead of the usual man, machine, materials, method, measurement and mother nature (Environment).

Results

A total of 862 mortalities were captured, which is 8.2% of the 10,529 patients who were admitted to the surgical wards during the study period (Table 1).

Eight hundred and fifty-nine records were suitable for further analysis. Around 66.0% (564/859) of patients who died were males. The median age of male patients who died was 44.9 years (IQR: 33–64 years). The median length of stay of patients who died was three days (IQR: 1–11 days). Most mortalities involved patients who had GIT emergencies at 24.1% (207/859), head injury 18.4% (158/859) and GIT malignancies 17.0% (146/859). Overall, 5.4% of the mortalities were categorized during weekly M&M as preventable (Table 2).

Table 1 Breakdown of number of admissions, operations, morbidity and mortalities per specialty

Parameter	General surgery	Trauma	Vascular	Transplant	Total
Admissions	6124 (58.16%)	2733 (25.96%)	1111 (10.56%)	561 (5.32%)	10,529 (100%)
Elective operations	1632 (57.5%)	248 (8.7%)	713 (25.1%)	244 (8.6%)	2837 (100%)
Emergency operations	1402 (42.8%)	1155 (35.3%)	450 (13.7%)	267 (8.2%)	3274 (100%)
Morbidities	467 (51.1%)	257 (28.1%)	34 (3.7%)	156 (17.1%)	914 (100%)
Mortalities	404 (46.9%)	352 (40.8%)	88 (10.2%)	18 (2.1%)	862 (100%)

Table 2 Demography, diagnoses and classification of mortalities in patients who died (N = 859)

Variable	Class	Number (%)
Sex	Male	564 (66.0%)
	Female	290 (34.0%)
Age	Median (IQR)	49 (33–64) years
Length of stay before death	Median (IQR)	3 (1–11) days
Pathology classification	Blunt trauma	74 (8.6%)
	Penetrating trauma	100 (11.7%)
	Head injury	158 (18.4%)
	Vascular elective	15 (1.8%)
	Vascular emergency	81 (9.4%)
	GIT malignancy	146 (17.0%)
	GIT non-malignancy	207 (24.1%)
	Endocrine/Breast malignancy	15 (1.8%)
	Endocrine/breast non-malignancy	4 (0.5%)
	Soft tissue malignancy	6 (0.7%)
	Soft tissue non-malignancy	21 (2.5%)
	Burns	20 (2.3%)
	Transplant	11 (1.3%)
Mortality	Not preventable	459 (53.5%)
	Potentially preventable	353 (41.1%)
	Preventable	46 (5.4%)

Forty-six mortalities (5.4%: 46/859) were categorized as preventable during the weekly morbidity and mortality meetings, of which 65.2% (30/46) were males. The median age of patients whose deaths were considered not preventable was 46 years, for potentially preventable mortalities 51 years, and 45 years for preventable mortalities. The difference in the median ages of patients who had the three categories of mortalities was statistically significant (p-value = 0.0028). Similarly, the difference in median length of stay before death of patients in the three groups was also found to be statistically significant (p-value <0.0001).

Most of the mortalities which were considered not preventable were from severe head injury or advanced GIT malignancies (Fig. 1). In 5.9% (20/337) of the decision of the record regarding preventability of the mortality was not made during the M&M meeting. The senior surgeon classified 75.6% (595/787) of the mortalities as not preventable (Table 3).

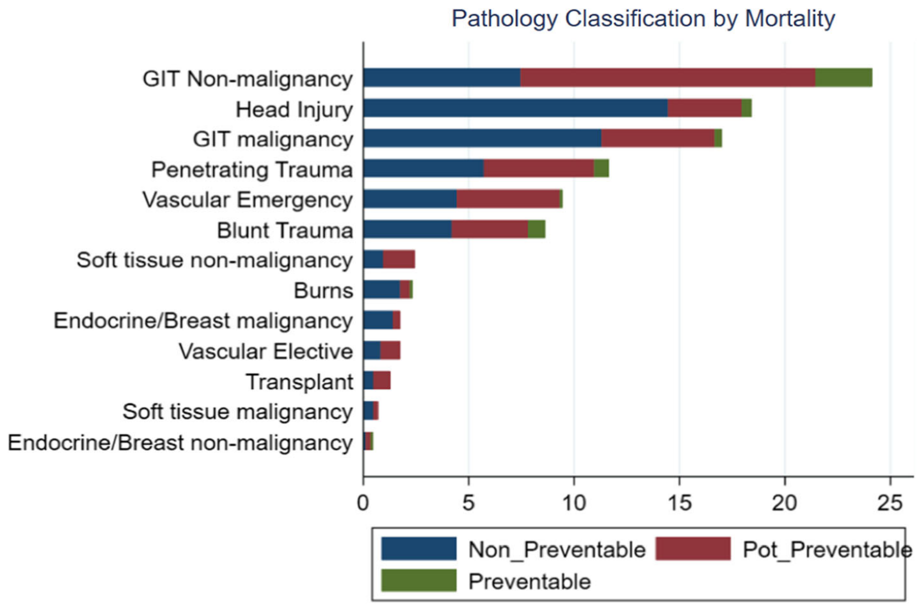

Fig. 1 Pathology classification of mortality

Table 3 Comparison of categorization of mortalities by M&M and a senior surgeon

Classification of mortalities	Departmental morbidity and mortality meeting (N = 859)	Senior general surgeon (n = 787)
Preventable	46 (5.1%)	28 (3.6%)
Potentially preventable	352 (41.0%)	158 (20.1%)
Not preventable	456 (53.1%)	595 (75.6%)
Not known	5 (0.6%)	6 (0.8%)

The factors which contributed to most preventable and potentially preventable mortalities included issues related to the error of judgment (25.8%: 65/252), inadequate training (20.2%: 51/252) and shortage of resources (15.5%: 39/252) (Table 4).

Examples of what were classified under the error of judgment include sending unstable patients for radiological

Table 4 Categorization and weighting of factors which contributed to preventable and potentially preventable mortalities

Category	Number	Actual percentage (%)	Cumulative percentage (%)
Error of judgment	65	25.8	25.8
Training	51	20.2	46.0
Resources	39	15.5	61.5
Systems failure	35	13.9	75.4
Diagnostic dilemma	25	9.9	85.3
Patient factors	16	6.3	91.6
Communication gap	8	3.2	94.8
Lack of supervision	6	2.4	97.20
Nosocomial infection	6	2.4	99.6
Industrial action	1	0.4	100
Total	252	100	100

investigations, not performing abbreviated surgery, underestimating the significance of intra-operative bleeding, doing a primary anastomosis instead of bringing out a stoma, not calling for help, delay in performing a relook, admitting a patient to a low-level care area, not tracing the results of ordered investigations and premature discharge from ICU or the hospital. Additionally, the error of judgment also included underestimation the severity of a disease or a postoperative complication leading to delayed intervention and overestimation of the capability of junior staff members. Included among the issues related to problems of training were diagnostic difficulties, delayed referral, delayed intervention and poor surgical techniques. On the other hand, the shortage of resources included ICU beds, timeous availability of operating theater and unavailability of appropriately qualified staff (Fig. 2).

Discussion

Patient safety incidents including SAEs are intimately linked to the delivery of healthcare services. It is not possible to eliminate all SAEs in the healthcare industry, irrespective of the income status of a community. The healthcare industry's complexity makes it vulnerable to the occurrence of SAEs at multiple points [19]. Some of the PSIs end as just near misses, while others lead to a significant prolongation of the length of hospital stay, disability, or death.

Overview of mortality

This study has shown that more than 45% of surgical mortalities are either potentially preventable or preventable; this is close to the 48.3% which was reported by Chen et al. in 2017 [7]. Following their analysis in the Victorian Audit of Surgical Mortality, different evaluators

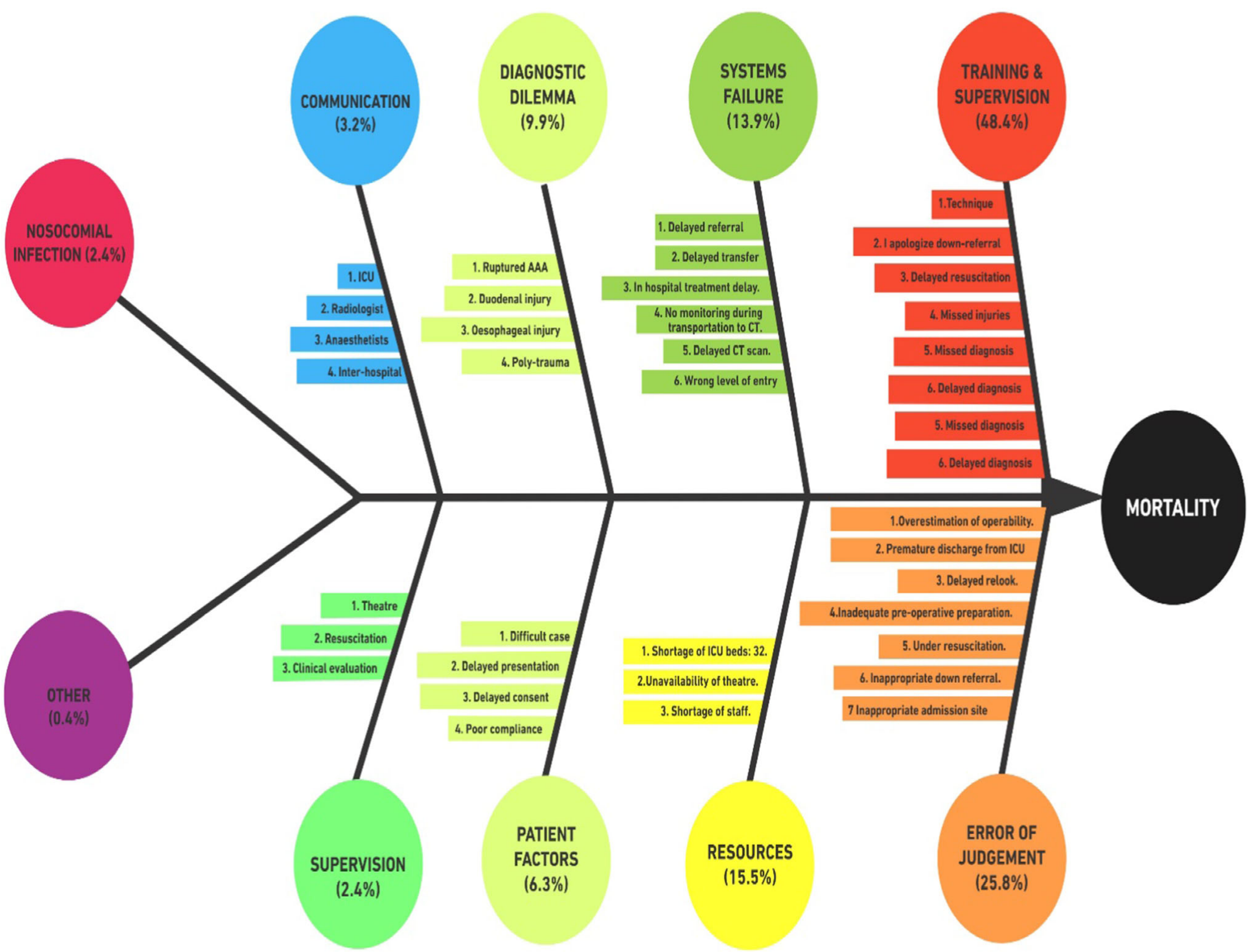

Fig. 2 Fishbone diagram depicted factors which contributed to preventable mortalities in 2018 (n = 141)

in the same study reported a preventable mortality rate of 14.6% [7]. However, Moon et al. in 2015 reported a preventable mortality rate of 25.2%, a figure which most likely have included deaths that would have been considered potentially preventable in other settings [21]. On average, 4.3% of mortalities in the current study were preventable, which is close to the 3.4% reported in a publication by Bindroo et al. in 2015 [22].

Conducting this study was an opportunity to evaluate the regular M&M meetings and to identify factors to be targeted for quality improvement. The overall mortality rate of 8.2% in the study period was within the background of management of patients in a LMIC environment [8, 10]. The preventable mortality was low at 5.1% during the departmental deliberations but even lower when independently assessed by a senior surgeon.

Around 65.7% of the patients who died were males and their average age was 44.9 years, compared to 57.5 years for females. The top 3 causes of death were non-malignant conditions of the GIT, head injury and advanced GIT malignancies. The higher mortality in males is not surprising as complicated non-malignant conditions of the GIT such as ruptured appendix [23] and perforated peptic ulcer [24], trauma [4, 21, 25, 26] are seen in males. It emphasizes the reality that some common GIT malignancies are more prevalent in adult males [27, 28].

Factors associated with mortality

The outcome following surgery is influenced by the age of a patient, the severity of the underlying conditions, associated comorbidities, American Society of Anaesthesiologists class and availability of resources [9, 29, 30]. Fifty-four percent of the patients who died in the current study had comorbidities, with hypertension being the most associated illness at 28.4%. Similarly, Lees et al. also found that hypertension was the most common comorbidity in the elderly patients who had poor outcomes following emergency surgery [30]. The association of HIV was recorded as a contributory factor in only 7.8%. This contribution was far below what was expected as the prevalence of HIV in the adult population in South Africa was around 15% [31]. The profile of surgical conditions is influenced by the geographical location and economic status of a community, which would also influence the causes of death. Whereas non-communicable diseases are more prevalent in high-income countries, infectious disease and trauma are the leading causes of death in LMICs [8, 22]. The fact that non-communicable diseases were the leading causes of deaths in the current study may be reflective of a country in economic transition.

Most of the victims of trauma and violence were males, which is also reflected in a high mortality rate in men [4, 21, 25]. It is estimated that globally up to 48.3% of trauma mortalities are either preventable or potentially preventable [32]. The factors which influence the occurrence of mortality in trauma include the mechanism of injury, site of injury, severity of injury, time of injury, time it took to initiation of therapy and the level of care of a receiving healthcare facility [33]. Management of trauma patients requires coordination across the care pathways which has many layers starting with prehospital care, care during transfer to or between hospitals, emergency departments, intra-operative care, and postoperative management [34]. The multiplicity of the layers involved in trauma care makes it to be vulnerable to deviations and at risk of occurrence of serious PSI.

The common non-trauma surgical emergencies are acute appendicitis, complicated peptic ulcer disease, acute pancreatitis, bowel obstruction, skin and soft tissue infection, complicated hernia and diabetic foot sepsis. What is common across the non-trauma surgical emergencies is the higher mortality in males, older adults and delayed presentation [24]. The average age of patients who died from other causes in the current study was at least 12 years older than those following trauma which is in keeping with the demography of the victims of trauma [32].

Cancer was the third most common cause of surgical mortalities in our study, 5.3% of which was potentially preventable. The common malignancies in surgical patients include cancer of the breast, skin, colon, liver, esophagus, stomach, pancreas and soft tissue. The above cancers are more prevalent after the age of 50 years [28] and are considered irresectable when they are either locally advanced or metastatic. However, local complications such as bleeding, perforation and obstruction may necessitate emergency surgery even for tumors which are irresectable. These complications may further accelerate death if these complications are secondary to iatrogenic causes.

Quality control factors associated with outcomes

Dogget argues that there is a cause for each problem [17]. It is, therefore, reasonable to expect that there would be an underlying cause for every preventable or potentially preventable mortality. Among the factors commonly associated with preventable mortalities are medication errors, delay in diagnosis, delay in transfer and violation of management guidelines [35]. The fishbone method is among the tools used for root cause analysis and is preferred because of the combination of its simplicity and that it can facilitate the grouping of causal factors [17]. From our study the error of judgment, training and supervision had more impact on preventable or potentially preventable mortalities than shortage of resources and systems issues. Medication-related errors did not contribute significantly to preventable and potentially preventable mortalities in surgical patients in the current study. Some of the weaknesses of the fishbone method are that it is subjective, leads to fragmentation of contributing factors that may be interrelated and may hide systems issues [15, 17].

The complexity of the healthcare industry is erroneously compared with that of the nuclear, petrochemical, aviation and airline industry, which is unfortunate. The healthcare industry is much more complex and not easy to coordinate as every step during the delivery of healthcare relies on a combination of trust and independence among healthcare workers themselves and their patients. Furthermore, it is unlikely that a mistake made by a lone healthcare worker would cause a preventable PSI [2, 11] as the factors that contribute to poor healthcare outcomes rarely occur in isolation [36]. Things such as timeous availability of resources, appropriate training, professionalism, service delivery processes and systems issues significantly influence surgical outcomes [4]. While the practice in all other industries emphasizes avoidance of risks, the same cannot be said for the healthcare industry. Flights are not allowed to take off even when the risk is minimal, whereas patients are given a chance in the healthcare industry even in situations when the prognosis is guarded [36].

An essential step for quality improvement programs in any industry is knowing the baseline and to continuously collect data. Unfortunately, there are very few studies emanating from the African continent reporting on quality and patients' safety programs [37]. Some of the advanced reasons for limited reports of PSI from Africa include inability to collect useful data, fear of shame or economic implications, and the potential to attract medicolegal litigations [14, 38, 39]. However, the benefits of honest reporting of clinical outcomes far outweigh the risks [11, 35, 40–43].

Limitations

The study was a retrospective review of records, and some records were incomplete, which could have influenced the results. Additionally, medication-related errors were most probably underreported. The reliability of categorization and weighting of factors that contributed to the outcome of interest using the fishbone method is highly dependent on the number of raters and their expertise. Other disadvantages of the fishbone method include its high subjectivity and inability to assist in identifying a specific root cause. The fishbone method is not good for identification of the possible interconnectedness of the causal factors.

Conclusion

The majority of surgical mortalities involve males, and around 46% are either preventable or potentially preventable. The majority of mortalities are related to GIT emergencies, head injury and advanced malignancies of the GIT. The two most common contributing factors to preventable and potentially preventable surgical mortalities are the error of judgment, training and limited availability of resources. Identification of factors which contribute to preventable or potentially preventable mortalities present an opportunity for improvement the quality of surgical care.

Recommendations

A follow-up prospective study involving a larger data set should be conducted to include a detailed analysis of additional factors contributing to preventable and potentially preventable mortalities is necessary.

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Declarations

Conflict of interest The authors have no conflict to disclose.

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