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Medical errors in neurosurgery

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Abstract

Background: Medical errors cause nearly 100,000 deaths per year and cost billions of dollars annually. In order to rationally develop and institute programs to mitigate errors, the relative frequency and costs of different errors must be documented. This analysis will permit the judicious allocation of scarce healthcare resources to address the most costly errors as they are identified.

Methods: Here, we provide a systematic review of the neurosurgical literature describing medical errors at the departmental level. Eligible articles were identified from the PubMed database, and restricted to reports of recognizable errors across neurosurgical practices. We limited this analysis to cross-sectional studies of errors in order to better match systems-level concerns, rather than reviewing the literature for individually selected errors like wrong-sided or wrong-level surgery.

Results: Only a small number of articles met these criteria, highlighting the paucity of data on this topic. From these studies, errors were documented in anywhere from 12% to 88.7% of cases. These errors had many sources, of which only 23.7-27.8% were technical, related to the execution of the surgery itself, highlighting the importance of systems-level approaches to protecting patients and reducing errors.

Conclusions: Overall, the magnitude of medical errors in neurosurgery and the lack of focused research emphasize the need for prospective categorization of morbidity with judicious attribution. Ultimately, we must raise awareness of the impact of medical errors in neurosurgery, reduce the occurrence of medical errors, and mitigate their detrimental effects.

Key Words: Adverse events, medical error, neurological surgery, quality improvement, systems-based practice

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INTRODUCTION

Preventable medical errors lead to the death of up to 98,000 Americans annually and cost the U.S. economy over $17 billion per year.[9,16] The most expensive of these errors are related to surgery, with postoperative infections, device failure, post-laminectomy syndrome, and operative hemorrhage comprising four of the top five causes. These four causes together account for over $6 billion annually, roughly one-third of the total financial burden of medical error.[16] To what degree neurosurgical care contributes to these errors is unknown, as is the resultant mortality, morbidity, and financial impact.

Mapping the neurosurgical landscape of medical errors will allow us to direct our limited resources to the most pressing problems. Focused interventions have the potential to improve patient outcomes and reduce unnecessary healthcare costs, both of which are becoming increasingly important with new legislative initiatives that target cost-effective care.[1,7,8] While many surgical practices have already adopted error-mitigating techniques, like the World Health Organization (WHO) Safe Surgery Checklist,[5,20] we still do not know what neurosurgery-specific errors are most costly (in terms of morbidity, mortality, and financial burden) and which we have the potential to effectively mitigate.

As a first attempt to chart the environment of medical errors in neurosurgery, we conducted a systematic literature review of published data regarding neurosurgical errors. We report these data, analyze the results, and propose additional studies that must be carried out to advance this critical issue in our field. Importantly, we stress that this review covers medical errors, and not complications or adverse events. Although there is disagreement, medical errors are defined as acts of "commission (doing something wrong) or omission (failing to do the right thing), leading to an undesirable outcome or significant potential for such an outcome."[18] Adverse events, in contrast, are defined by actual harm. According to the Institute for Healthcare Improvement, an adverse event is an "[u]nintended physical injury resulting from or contributed to by medical care (including the absence of indicated medical treatment) that requires additional monitoring, treatment, or hospitalization, or that results in death".[18] Far more literature covers adverse events in neurosurgery (e.g.,[6,12,21,22]), possibly because such events are more objectively measurable. Nonetheless, errors are incredibly important, and below we report the research to date on this subject.

METHODS

A PubMed search was performed on the terms "medical error," "surgical error," "patient safety," or "quality improvement" in conjunction with the terms "neurosurgery" or "neurological surgery." Articles were reviewed by the authors and excluded if they limited their discussion to only a single surgical procedure, only a single error, or did not discuss identifiable medical errors. Additionally, articles describing adverse events that we could not identify as preventable or nonpreventable were excluded. The purpose of these limitations was to place focus on the systems level of errors. Only English-language articles describing human patients were included. The references within identified articles were also reviewed for relevant manuscripts. From each identified article, the type and frequency of errors were abstracted.

RESULTS

A total of 127 manuscripts were identified with our search terms [Figure 1]. Of these, only two met our inclusion criteria.[2,15] Several papers were notable for covering adverse events in a thorough manner,[4,6,10,14,23] but did not include enough information to identify errors as separate from nonpreventable adverse events, and were therefore excluded. The two medical error articles meeting our inclusion criteria are discussed in detail below.

Stone *et al*.[15] prospectively recorded errors by a single neurosurgeon as he operated on 1108 consecutive patients between 2000 and 2006 in Toronto, Canada. In this study, errors were defined as "any act of omission or commission resulting in a deviation from a perfect course for the patient".[15] Complications were defined as "as morbidities or mortalities." A total of 76.1% of the studied cases were cranial procedures, 22.7% spinal procedures (with 1.2% classified as "other"), and two-thirds of the cases (67.7%) used general anesthesia.

The authors reported errors in 965 out of 1108 patients (87.1%), with an average of 2.4 ± 1.76 errors per case. Errors were classified as technical (27.8%), contamination (25.3%), equipment failure/missing (18.2%), delay (12.5%), nursing (5.7%), anesthesia (4.4%), judgment (2.8%), and communication (1.9%; Table 2).

Overall, there were more errors in cranial as compared to spinal cases (2.5 ± 1.8 errors per cranial case vs. 2.2 ± 1.7 errors per spinal case; $P < 0.01$, x^2 test). The cranial patients tended to have greater pre-operative morbidity, as reflected in higher American Society of Anesthesiologists (ASA) Physical Status Classification scores (2.6 ± 0.6 for cranial vs. 1.9 ± 0.6 for spinal; $P < 0.001$, analysis of variance test), which could potentially explain part of this difference. This is not to say that the patients' illnesses themselves led to errors, but rather that the sicker patients required more complex, longer procedures, which exposed them to

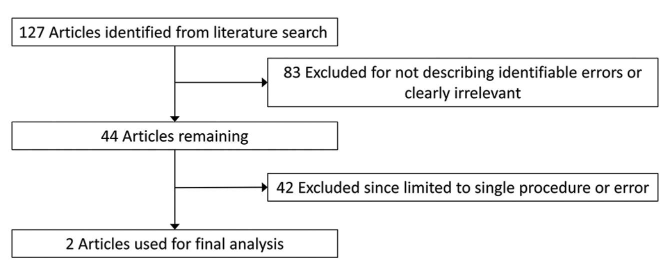

Figure 1: Results of PubMed database search and application of exclusion criteria

greater risk of error (procedure length was not reported in this study). Countering this hypothesis, however, was the finding that there was no statistical difference in patients receiving general versus awake anesthesia, which might also correlate with case difficulty and length.

Stone *et al.*[15] reported on adverse events, along with their primary documentation of errors. A total of 186 adverse events (called "complications" in the paper) were reported, giving an overall rate of 16.8%. However, only 31 adverse events (36%) resulted from errors (making them preventable adverse events), that is, 155 of the reported adverse events were not caused by human error, but rather byproducts of the patient's underlying pathology.

In the second study, Boström *et al.*[2] prospectively studied 756 cases at the University of Bonn Medical Center. Unlike the Stone *et al.* study, Boström *et al.* included emergent and after-hours cases, along with elective cases. Errors in this study were defined as "any act or fact that leads to 'deviation from an optimal course' (DOC) of a procedure," where "optimal course" is further defined as "a course in which nothing goes wrong".[2] Adverse events (complications) were defined, as in Stone *et al.*,[15] as "morbidities or mortalities".[2] Surgeons were given voluntary questionnaires during each surgery in order to document errors, and trained for 3 months on proper documentation procedures. Of the studied cases, 57% were elective, and 43% were emergent. The error rate across procedures was 25% [Table 1]. Elective cases accounted for most of these errors, with an error rate of 30.0%, compared with the unexpectedly low error rate of emergent cases (13.7%). This difference was found to be statistically significant. As in the previous study by Stone *et al.*,[15] the ASA score differed significantly between cases with and without errors (2.4 vs. 2.2).[2] In fact, these ASA scores were identical in both groups to the Stone *et al.* study.[2,15] The authors do not describe all of their recorded errors, but they do note that 37.3% were due to missing equipment or equipment failure, 33.1% were due to errors in medical judgment or management, and 23.7% were technical or procedural errors[2] [Table 2].

While the primary focus of Stone *et al.* was the documentation of medical errors, the group also documented adverse events. Only two adverse events were reported in over 756 patients.[2] One was caused by inserting a subdural screw too deeply and violating brain parenchyma; the other was caused by severing the facial nerve during a schwannoma resection.

DISCUSSION

Across these two studies, medical error rates were highly variable, from 12% to 88.7% of cases. This range is large and our sample size is small, making it difficult to draw definitive conclusions. However, these studies reveal common themes that provide a framework for our discussion and subsequent analysis.

First, in both studies, patient ASA class correlated with a greater numbers of errors. Importantly, however, it should be noted that ASA class is correlated strictly with error in these studies, and not with adverse events. These data suggest that surgeons and supporting personnel are more likely to make errors when taking care of sicker patients. While the cause of this trend is unknown, it is likely that ASA class is correlated to procedure length and complexity. If error rates are constant over case durations (i.e. a fixed rate of errors per minute or errors per hour), then it follows that longer cases generate more errors.

A second common theme in the studies is that technical (procedural) errors account for roughly 25% of committed errors (23.7-27.8%). Management and judgment errors (e.g. not noting a missing laboratory result before the case is scheduled to begin) account for anywhere from 2.8% to 33.1%. The remaining errors are often caused by factors outside the surgeon's direct control—nursing, anesthesia, equipment failures, delays, etc. We believe that this is an extremely important point. Surgeons must recognize their inextricable dependence on support staff, from nursing to X-ray technicians, in ensuring that their patients are treated optimally. If a surgeon perfects his or her operative technique, while neglecting to consider interventions that address the whole team, they should only anticipate a reduction in medical errors for their cases of 25% at best. Effective methods for reducing errors must operate at a systems level.

Limitations

The extreme variability in reported error rates, from 12% to 88.7%, underscores the limitations of interpreting

Table 1: Error rates by procedure type

	Cranial			Spinal			Peripheral			Other			All types combined		
	With error	Total	% error	With error	Total	% error	With error	Total	% error	With error	Total	% error	With error	Total	% error
Boström *et al.*[2]	111	423	26.2	60	241	24.9	17	81	21.0	3	25	12.0	191	770	24.8
Stone *et al.*[15]	748	843	88.7	210	252	83.3	-	-	-	7	13	53.8	965	1108	87.1
Total	859	1266	67.9	270	493	54.8	17	81	21.0	10	38	26.3	1156	1878	61.6

Table 2: Error types, adapted from Stone *et al.*[15] and Boström *et al.*[2]

Error type	Percentage (*et al.*)	
	Stone	Boström
Technical	27.8	23.7
Contamination	25.3	-
Equipment failure or missing equipment	18.2	37.3
Delay	12.5	-
Nursing	5.7	-
Anesthesia (e.g., premature extubation)	4.4	-
Management/judgment (e.g., missed laboratory result)	2.8	33.1
Communication	1.9	-
Other	1.3	-

these studies. These numbers are significantly higher than those investigating errors in healthcare in general. Most similar studies show an error rate between 1% and 8%, specifically, an adverse event rate between 3.7% and 16.6%,[3,13,17] with about one-quarter to one-half judged as preventable adverse events (errors). A large part of the discordance between the error rates in neurosurgery and general healthcare is due to the definition of medical errors. The neurosurgical studies reviewed herein rely on the subjective definition of error as "any act of omission or commission resulting in a deviation from a perfect course for the patient".[15] Many studies within general medicine define errors similarly (e.g. see the definition of error by Wachter in the Introduction).[19] But still others rely on more complicated definitions or methods of capturing errors. For example, the Institute of Healthcare Improvement's Global Trigger Tool relies on first defining and identifying significant adverse events, then examining all identified adverse events for errors.[19] This definition unfortunately limits errors to those that cause injury, ignoring errors of omission or near-miss events. This area, errors of omission, is unfortunately one of the most problematic aspects of identifying errors. This is because failing to deliver care relies on expected norms of care, which are in flux and often contested. For example, the optimal day for initiating venous thromboembolism chemoprophylaxis is unknown. If a patient develops a deep venous thrombosis (DVT) one week postoperatively, this might be considered an error if no DVT prophylaxis was ordered. And it probably would not be considered an error if DVT prophylaxis was started on day 2. But what about day 3, or day 6?.

The psychological literature defines errors in yet a different manner, as circumstances in which planned actions fail to achieve their desired outcome.[11] Errors are further broken down into two primary types. Skill-based errors ("slips") occur when an unintended action is made. For example, a literal slip of a surgical instrument when operating. Rule- and knowledge-based errors ("mistakes") occur when an incorrect action is carried out successfully, either due to the incorrect application of a rule or lack of applicable knowledge. In this case, the technical skills are correct, but the wrong skills were utilized. A particularly egregious example would be a wrong-sided amputation. Even if the operation is carried out perfectly, these technical skills were carried out in a dangerous and ill-considered way. There have been many successful studies utilizing this framework to understand errors across a wide variety of industries. But this large body of knowledge has yet to be applied to neurosurgery. This is clearly a missed opportunity. There is a tremendous opportunity for cross-fertilization between neurosurgery and the psychological study of human error–all that is needed is concerted effort by researchers and organizations to implement some of their practices and research methodologies in the neurosurgical field.

Overall, the most pronounced limitation of this study is the number of papers available for this systematic review. Only two articles met our inclusion criteria, reflecting the overall lack of investigation into medical errors within neurosurgery. Interestingly, though, our search terms identified several papers that sought to describe the frequency and characteristics of adverse events and medical complications, two entities related to medical errors. Unfortunately, the data in these papers were undifferentiated as to whether the adverse events and complications were preventable (due to errors) or simply part of the anticipated consequences of surgical illness. Future studies should strive to better describe the causes of adverse events, so their source within the healthcare system can be adequately addressed.

Recommendations

Given the limitations of medical error research in neurosurgery, we make the following recommendations for improving this field:

- Better distinguish between errors and adverse events: In our systematic review of the literature, we identified multiple articles that studied the incidence of adverse events and complications. Many of these events were in fact due to medical errors, but this was not delineated within these articles. Going forward, we must do a better job of classifying adverse events and complications as preventable and nonpreventable. Only then will we be able to measure and report the true incidence of medical errors in our field. Further, purely documenting and reporting complications while ignoring the root causes of such complications is an inadequate approach to improving patient care

  Many complications are expected and unpreventable. Documenting the incidence of these complications may help us counsel patients, but they will not directly improve patient care. Currently, national databases of complications, like the American College of Surgeons National Surgical Quality Improvement Program (NSQIP), do a superb job of meticulously collecting data on a subset of complications, such as urinary tract infections, pulmonary emboli, perioperative strokes, etc., However, they make no note of whether these were inevitable complications of the patient's disease, or rather stem from errors in medical management. This critical information should be a key element of the ubiquitous morbidity and mortality conferences held in neurosurgery departments across the world. Individual departments and quality champions must take the next step in performing case drilldowns and root cause analyses to effectively distinguish the difference between error and unpreventable complications. Knowing which complications result from medical errors can help formulate the intervention necessary to mitigate these complications

- Objective measures of error: The NSQIP database excels at providing rigorously collected information on the medical complications of surgery. Events like perioperative pneumonia have strict criteria for inclusion as a complication, including bacterial cultures, antigen assays, radiographic findings, and clinical features. The coders of these complications are specially trained and frequently audited. Test cases are provided and their coding accuracy is validated. In the studies included in the above systematic review, medical errors were recorded subjectively, and usually by the operating surgeons themselves. This is a clear conflict of interest, likely subject to high inter-rater variability. Going forward, we should ensure that objective criteria for errors are defined, as they have been for surgical complications
- More research: What is the true incidence of medical errors? What interventions can best ameliorate these errors? Why do higher ASA classes breed more errors? What are the most costly errors, in terms of patient physical and financial health? Answering even a portion of these questions will go a long way in aiding our field. We will be able to focus our efforts at addressing the most important errors, and rationally direct resources at alleviating the most costly errors first. Part of this answer will rely on prospective databases, for example, the new National Neurosurgery Quality and Outcomes Database (N2QOD). Within these new databases, we must ensure that not only adverse events are recorded, but that their preventability is documented (see recommendation 1 above), and also consider adding the ability to document errors that do not result in adverse events, as "near misses" are an important source of valuable information regarding our systems for treating patients.

CONCLUSION

Medical errors lead to nearly 100,000 preventable deaths annually and cost the United States economy over $17 billion per year. Clearly, we must do more to address this issue, particularly in neurosurgery, where little research has so far been conducted. Neurosurgeons need to perform more research in this area, distinguish clearly between medical errors and complications, and form objective criteria for defining medical errors.

An established lexicon for discussing medical error is an essential first step to quantifying and better understanding the errors in our field. And a better understanding of the areas that are most prone to costly errors is critical for allowing us to rationally direct our resources to improve these problematic areas in neurosurgery. As it stands, hospitals and insurers are issuing protocols and requirements for neurosurgical departments that are not based on peer-reviewed analysis of neurosurgical procedures. In order to provide the best care to our patients, neurosurgery as a field must seriously investigate medical error. Only then can we advocate optimal practices based on what is empirically best for our patients, rather than what might be dictated by financially driven third parties.

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