Errors in Neurosurgery

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INTRODUCTION
Despite their training and intentions, health care workers will inevitably make mistakes when caring for patients. Some of these errors can be serious and life threatening, while others are near misses, identified early and fixed before they cause harm. Understanding the frequency and danger posed by medical errors, and offering strategies to prevent them, forms the basis of the modern patient safety movement.

Neurosurgery is far from immune to these errors. The complexity of neurosurgical patients and the interdisciplinary teams required to manage their conditions expose these patients to the same errors found in other medical and surgical specialties, along with errors unique to neurosurgery.

DEFINITION AND CLASSIFICATION OF ERRORS
Medical errors have been defined in various ways, but at their core, they are acts of omission or commission that cause harm or have the potential to cause harm to patients.1,2 This definition was elaborated in the neurosurgical literature by Stone and Bernstein as any act of omission or commission resulting in deviation from a perfect course for the patient. A perfect course was defined as one in which nothing went wrong, from the smallest detail (such as dropping a sponge) to the most obvious example (that is, one that every neurosurgeon would easily recognize, like wrong-sided surgery).3,4

Importantly, patient safety studies differentiate errors from adverse events (Fig. 1), which are inadvertent injuries resulting from medical care, or the failure to deliver medical care.5–7 Errors have the potential to cause harm, while adverse events are harm. In other words, errors can lead to adverse events if they are not caught first (ie, a near miss8), but adverse events can also occur without errors (ie, a nonpreventable adverse event, such as a hemorrhage following a perfectly executed external ventricular drain placement).

KEYWORDS
- Medical error
- Surgical error
- Quality improvement
- Patient safety
- Wrong-sided surgery
- Sentinel event

KEY POINTS
- Medical errors are common and serious, leading to an estimated 440,000 deaths annually in the United States.
- For neurosurgery patients, prospective studies found errors in 25% to 85% of all cases.
- Only 25% of recorded errors are caused by surgical technique; most errors involve the whole health care team, highlighting the importance of systems thinking.
- A wide range of tools has been developed to help reduce the frequency and impact of errors, such as the World Health Organization’s Surgical Safety Checklist, computerized order entry, and surgical navigation systems.

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Errors are further divided into active errors (or sharp-end errors) and latent errors (or blunt-end errors). Active errors are the most recognizable, usually involving a frontline health care worker directly interacting with a patient, such as a surgeon injuring the carotid artery during an aneurysm clipping, or an anesthesiologist connecting the incorrect gas anesthetic, isoflurane in place of oxygen, to an anesthesia machine. Latent errors, on the other hand, refer to errors within the system makeup itself (including bureaucracy, facilities, equipment, or organization) that permit other errors to occur. In the specific case of anesthesia gases noted previously, modern anesthesia machines have specialized connectors (the pin index safety system) that allow only the correct gas cylinder to be hooked up (e.g., only oxygen canisters can link to the oxygen intake), which have almost eliminated this type of error.

Active errors are frequently studied in psychology, and classifications have been proposed to subdivide errors and identify common error-generating mechanisms. Perhaps the best known is James Reason’s classification of active errors into slips and mistakes. Slips occur when planned actions are not executed correctly—as in literally slipping with a scalpel. Mistakes occur when an incorrect action is selected, even if executed perfectly, such as wrong-sided surgery.

An example of a more complex classification of errors is the National Coordinating Council (NCC) for Medication Error Reporting and Prevention, which separates errors into 9 classes (A through I) according to how much harm was caused, where class A is no error and class I is an error potentially contributing to a patient’s death. Notably, the NCC classification divides errors by their effects; Reason’s classification divides errors by their mechanisms.

**EPIDEMIOLOGY OF ERRORS**

The modern patient safety movement arguably began with the publication of the Institute of Medicine’s (IOM’s) *To Err is Human*, in 1999. This study, relying on the Harvard Medical Practice Study, estimated that between 44,000 and 98,000 Americans were killed each year by medical errors. This figure led to the alarming jumbo jet comparison, where the number of deaths caused by medical errors was likened to 1 passenger jet crashing daily. The mortality estimates from the IOM’s report have since been revised still higher, with up to 440,000 deaths caused by medical errors per year. The conservative economic cost of such errors is estimated at $17 billion to $29 billion.

Errors affect all aspects of the medical system, from medication administration to surgical procedures. In the perioperative period, an estimated 3% of patients suffer an adverse event, half of which are preventable. Over 14% of neurosurgical patients, in particular, suffer one or more perioperative complications, many of which are preventable. Wrong-side or wrong-patient procedures occur in roughly 1 case out of every 100,000 operations, and in 2.2 cases of every 10,000 craniotomies. Surveys of neurosurgeons show that 25% of physicians have made an incision on the wrong side of the head, and 35% admitted to wrong-level lumbar surgery in their careers. Unintentionally retained equipment (e.g., instruments and sponges) mar about 1 of every 5500 to 10,000 operations.

Only a few studies have analyzed errors specifically in neurosurgical patients. Stone and Bernstein reported on the prospective collection of error data in neurosurgery patients over a 7-year period from 2000 to 2006 and Oremakinde and Bernstein incorporated data from the prior study, and reported their experience cataloging errors from 2000 to 2013, where all errors were prospectively logged by the senior author for 2082 of his cases. Errors occurred in 85.3% of cases; 24.2% were due to contamination. Twenty-four percent were due to technical errors, and 22.4% equipment failure or missing equipment. The remainder were due to delays, nursing, anesthesia, or other sources; 54.2% of these errors had no or minimal clinical significance.

Bostrom and colleagues also prospectively cataloged errors from neurosurgical procedures
and logged errors in 25% of 756 cases. Their classification showed that 37.3% of errors were caused by missing equipment or equipment failure; 33.1% were caused by errors in medical judgment or management, and 23.7% were technical or procedural errors. In both this study and the study by Oremakinde and Bernstein, American Society of Anesthesiologists (ASA) classification correlated with the presence of errors, and cranial cases had a higher proportion of errors than spinal cases. This increased error rate in cranial cases parallels data looking at raw complications in neurosurgical cases, including nonpreventable adverse events, and showing that cranial cases have higher morbidity.

The economic burden of surgical errors is great. The National Practitioner Data Bank shows $1.3 billion in settlements alone between 1990 and 2010. These data do not include the 90% of patients not receiving payments, but who still filed suit. Wrong-site surgeries have an average payout of $127,159, and retained foreign bodies average $86,247. The number of these events seems to be increasing over time, despite changes in policies and practices, perhaps due to increased worry about inadequate or inaccurate data. That is, they do not specifically state whether the events they report were preventable or caused by human or system error. Furthermore, claims databases rely on data entered by staff not directly affiliated with the health care team (e.g., billing and coding departments), which raises worries about inadequate or inaccurate data. These databases ultimately have high specificity (98.5%) but very low sensitivity (5.8%).

Infections are other harmful complications, and often are caused by errors. According to the Centers for Disease Control and Prevention (CDC), up to 10% of patients will suffer from an iatrogenic infection. Deaths from iatrogenic infections number an estimated 100,000 annually. The costs of iatrogenic infections are around $40 billion. Again, neurosurgery patients suffer from these events as well, with 1.0% suffering a superficial surgical site infection, 1.5% developing postoperative pneumonia, and 2.3% developing a urinary tract infection.

IDENTIFYING ERRORS

Before errors can be tracked, they must first be identified. Many strategies have been developed to accomplish this, with varying degrees of sensitivity and investment. The Global Trigger Tool uses a set of adverse events with a high probability of being associated with errors, like intraoperative deaths and unplanned returns to the operating room. When one of these events occurs (setting off the trigger), the case is flagged and manually analyzed for errors. The ability of the global trigger tool to detect errors is exquisite (94.9% sensitivity and 100% specificity), although the process requires a large investment of time and personnel to carry out, making it often impractical.

Morbidity and mortality conferences are among the most common methods of monitoring errors in the neurosurgical field. The costs are low, and the conferences are typically geared toward education. However, most errors are self-reported by the involved surgeon, and near misses are rarely presented. Physicians also tend to focus on their own performance and that of other individuals, rather than examining the system in which the error occurred.

Incident reports are the typically unstructured event summaries by doctors, nurses, and other health care workers via paper or computerized systems. These reports are not standardized, and different health care workers will have different thresholds for reporting errors. Further, these reports are predominantly driven by nursing and support staff, with unfortunately few physicians participating.

Claims data, like that found in the Nationwide Inpatient Sample (NIS), and prospective registries, like the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP), National Neurosurgery Quality and Outcomes Database (N2QOD), and the International Spine Study Group (ISSG), are frequent sources of data for publications in the neurosurgical literature. They have contributed a great deal of information about complication and adverse event frequencies, but do not track errors specifically. That is, they do not specifically state whether the events they report were preventable or caused by human or system error. Furthermore, claims databases rely on data entered by staff not directly affiliated with the health care team (e.g., billing and coding departments), which raises worries about inadequate or inaccurate data. These databases ultimately have high specificity (98.5%) but very low sensitivity (5.8%).

STRATEGIES TO REDUCE ERRORS

One of the first steps in reducing errors relies on culture. All team members must feel that it is acceptable and desirable to openly discuss and prospectively track errors. This has not been a common practice in neurosurgery, but it is clearly the right thing to do. In fact, the prospective
recording of error may actually be associated with their reduction over time due to a number of factors. There is no financial barrier to changes in culture, and patients have proven to be open to conversations about errors. Yet clearly there may remain hospital and societal barriers to widespread adoption of this approach of openness in discussing individual and institutional errors.

On a more widespread level, a patchwork of error prevention strategies has developed within medicine, and many are now being adopted by neurosurgical services. The use of checklists is one prominent example. The World Health Organization (WHO) created the Surgical Safety Checklist in 2007 to improve team communication and ensure key preoperative steps were conducted. A multisite pilot of the WHO checklist found a 4% reduction in complications and 0.7% reduction in mortality. Subsequently, many neurosurgical programs have adopted similar checklists and time out procedures, and have reported a consequent reduction in wrong-site surgeries and errors in general. These improvements are critical for neurosurgery programs; neurosurgery is the third most likely specialty to perform a wrong-site or wrong-level surgery, after orthopedic and general surgery, and most of these events appear to arise following breakdowns in communication. Embracing checklist procedures appears to address some of these problems, and will almost certainly continue to be an integral part of surgical programs in the future.

Another prominent method for decreasing errors in medicine and surgery has been the engineering of new technologies to eliminate or reduce the chance of errors, like barcode-enabled medication administration, the pin safety system for anesthesia gases, and computerized order entry. An example in neurosurgery is the widely adopted introduction of image-guided surgery, such as frameless stereotactic navigation systems and intra-operative imaging for cranial neurosurgery. Not only does image-guidance make the finding of brain lesions faster and safer, but important normal structures like venous sinuses can be accurately localized prior the creation of craniotomy bone cuts. Moreover, these technologies can help nearly eliminate the chance of wrong-sided surgery.

Other methods to reduce errors include the performance of select procedures in high-volume centers specializing in those procedures. There is an often-noted reduction of morbidity and mortality in centers with higher volumes of procedures compared with lower-volume centers, which is typically attributed to higher quality care and likely a reduced number of errors. Such volume-outcome effects have been documented in aneurysm surgery, carotid endarterectomy, epilepsy surgery, transsphenoidal surgery, endovascular therapy, and spine surgery. Improvement in technical skills is well documented following repetitive performance. Surgeons performing laparoscopic cholecystectomies have a 1.7% chance of causing injuries during their first surgery, reduced to a 0.17% chance on their 50th surgery. This is also seen in transforaminal lumbar interbody fusions, skull base surgeries, and transsphenoidal surgeries. Yet the volume–outcome relationships are also likely due in part to procedure familiarity on behalf of the entire system—nurses, anesthesiologists, sterile processing departments, radiology, and others. All participants in a procedure contribute to patient safety, and all have learning curves.

ETHICAL ISSUES

There are 2 main ethical issues inherent in a discussion of errors: (1) the failure of modern health care—and neurosurgeons in particular—to embrace, discuss, and study errors in an effort to improve patient safety; and (2) the disclosure of errors to patients and their families.

Regarding the study of error, neurosurgeons have dedicated countless hours of work and financial expenditures in clinical and research activity to improve the outcome of every disease they treat. So why have they been so slow to discuss and study an issue that relates to the care of every single patient they treat, irrespective of disease? The main answers to this question are obvious and have been touched on previously. Gladly, this trend is changing, particularly over the last 20 years. It will generally not be considered unethical for a neurosurgeon or team to commit an error, since this is inherent in being human; however, it is unethical to not study and reduce errors and to put systems in place to prevent errors and to prevent committed errors from injuring the patient. The authors respectfully recommend that, at the individual level, every neurosurgeon should participate in some form of prospective error tracking, whether this is through a formalized registry, or simply a personal database kept by the physician. It is not enough to participate in departmental morbidity and mortality conferences. This engagement with tracking follows the tradition of many of the founders of surgery and neurosurgery, such as Codman’s “end results” hospital and Harvey Cushing’s meticulous documentation of errors and adverse events.

Regarding disclosure, it has become clear that from an ethical and legal perspective, immediate
Disclosure of error to a patient and family is imperative. It is clear that any reasonable person would want to know about the occurrence of an error that has injured the patient or has the potential to do so. Not only does this respect the patient’s dignity and autonomy, but from a practical perspective, it is recognized that full and immediate disclosure of errors will likely decrease the chance of medicolegal action, or reduce the size of the financial settlement.\textsuperscript{60} There are guidelines on how, when, and how much to disclose, and most hospitals have risk management teams to help guide clinicians.\textsuperscript{61}

**SUMMARY**

Medical errors are common, dangerous, and an understudied component of neurosurgery. Depending on the report, they occur in anywhere from 25\% to 85\% of all neurosurgical cases. Importantly, only an estimated 25\% of these errors are related to surgical technique. Most errors occur within the context of the complete health care system: nurses, physicians, technicians, administrators, and patients themselves. Fortunately, there is an increasing emphasis on quality improvement and patient safety in medicine that recognizes the importance of the health care team.

To best serve patients, there are several goals that must be accomplished. First, errors must be prospectively tracked, whether at the departmental\textsuperscript{20} or individual level,\textsuperscript{3,4} so that trends, predictors, and the efficacy of interventions can be studied. Second, the culture of neurosurgery needs to accommodate frank and open discussion of errors. Errors are inevitable in human-driven systems. If one can discuss errors openly, one can better seek ways to prevent them in the future.\textsuperscript{9,37} Lastly, innovations must continuously be sought to mitigate and eliminate errors. Advances like stereotactic guidance, computerized order entry, and barcode medication administration are examples of indispensable tools used to engineer the safety of patients.

These goals of tracking, openness, and innovation are intertwined. Innovations to reduce or prevent errors must be tested empirically, which requires prospective analysis of errors. And prospective analysis requires a willingness to admit errors and a tolerance from the community when hearing about errors.

Ultimately, medical errors are a scourge on neurosurgical patients, as important as any particular disease. Just as there are cancer registries and clinical trials for brain tumors, medical error must be treated with the same seriousness. Eliminating errors, like eliminating cancer, often seems an impossible goal. But advances are steadily being made, and to truly care for patients, one cannot ignore these issues.

**REFERENCES**


