A reduction in errors is associated with prospectively recording them

Clinical article

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Object. Error recording and monitoring is an important component of error prevention and quality assurance in the health sector given the huge impact of medical errors on the well-being of patients and the financial loss incurred by health institutions. With this in mind, assessing the effect of reporting errors should be a cause worth pursuing. The object in this study was to examine the null hypothesis that recording and publishing errors do not affect error patterns in a clinical practice.

Methods. Intraoperative errors and their characteristics were prospectively recorded between May 2000 and May 2013 in the neurosurgical practice of the senior author (M.B.). The error pattern observed between May 2000 and August 2006, which has been previously described (Group A), was compared with the error pattern observed between September 2006 and May 2013 (Group B).

Results. A total of 1108 cases in Group A and 974 cases in Group B were surgically treated. A total of 2684 errors were recorded in Group A, while 1892 errors were recorded in Group B. The ratios of cranial to spinal procedures performed in Groups A and B were 3:1 and 10:1, respectively, while the ratios of general to local anesthesia in the two groups were 2:1 and 1.3:1, respectively ($p < 0.0001$ for both). There was a significantly decreased proportion of cases with error (87% to 83%, $p < 0.006$), mean errors per case (2.4 to 1.9, $p < 0.0001$), proportion of error-related complications (16.7% to 5.5%, $p < 0.002$), and clinical impacts of error (2.7% to 1.0%, $p < 0.0001$) in Group B compared with Group A. Errors in Group B tended to be more preventable than those in Group A (85.8% vs 78.5%, $p < 0.0001$). A significant reduction was also noticed with most types of error. A descending trend in the mean errors per case was demonstrated from the years 2001 to 2012; however, an increased severity of errors (22.6% to 29.5%, $p < 0.0001$) was recorded in Group B compared with Group A.

Conclusions. Data in this study showed that the act of recording errors might alter behaviors, resulting in fewer errors. (<http://thejns.org/doi/abs/10.3171/2014.5.JNS132341>)

KEY WORDS • error recording • intraoperative error • neurosurgery • prospective study

AWARENESS of medical errors and patient safety has increased progressively in clinical practice and research over the years. Several studies have shown that medical errors are real and responsible for a large proportion of hospital adverse events.^{2,3,20,23,32} The Harvard Medical Practice Study, a retrospective analysis of 30,121 patient records from 51 hospitals in New York, revealed that medical errors are responsible for 58% of all hospital adverse events.¹² The Institute of Medicine's report showed that medical adverse events were one of the leading causes of death in the United States and were responsible for 44,000–98,000 hospital deaths per year.²⁵ This rate was said to have exceeded the deaths attributable to motor vehicle accidents (43,458), breast cancer (42,297), or AIDS (16,516).

More recent studies have revealed that more than half of hospital adverse events are the result of surgical intervention and that more than half of these are deemed preventable.^{16,21,26,30,31} Many authors have demonstrated

that most errors are the near-miss and/or inconsequential type and that this type of error can lead to serious adverse medical events if not intercepted.¹⁰ It has also been shown that most serious complications are caused by the same errors termed “near misses” in other cases.¹ The near misses were inconsequential in those cases because they were intercepted either by chance or intentionally. This finding shows that preventing most near misses will, in the long run, prevent the occurrence of most serious adverse events.^{10,27,33}

It may be important for surgeons or institutions to record and audit the incidence and nature of errors in their practice. Knowing the nature of errors in a physician's practice or an institution's setting may help to prevent more errors and contribute to quality assurance and functional efficiency.^{13,19} However, few studies have assessed the effect of continuous recording and evaluation of errors on the subsequent pattern of errors in surgical practices. Rebasa et al.²⁸ assessed the influence of the continuous monitoring of adverse events on the quality of care and the incidence of errors in general surgery. They found that the incidence of adverse events remained con-

Abbreviation used in this paper: ASA = American Society of Anesthesiologists.

stant but that the recorded errors decreased from 11.1% to 4.5% ($p = 0.005$) during the study period.

Stone and Bernstein²⁹ prospectively recorded the error pattern occurring in 1108 patients who underwent elective surgery in the senior author's (M.B.) neurosurgical practice between May 2000 and August 2006. They found that 22.6% of all errors were considered major and that 77.4% were minor, with 2.7% of the errors substantially impacting the clinical course of the patient. Of all the errors, 78.5% were deemed preventable. Of the complications, 16.7% were related to errors, and 74.2% of these were declared preventable. Knowing the pattern of errors in this neurosurgeon's practice and the fact that most errors were preventable, we intended to assess whether information from error documentation affects the incidence and nature of errors. Our aim was to compare the pattern of error recorded before the published work of Stone and Bernstein²⁹ with the pattern of errors recorded after their work to determine if recording and publishing errors over time influences the actual incidence and pattern of errors.

Methods

In this comparative observational study, we prospectively recorded the details of error (type, severity, preventability, and ensuing complications), clinical impact of errors, anesthesia details, and surgical parameters of all consecutive elective cases surgically treated by the senior author (M.B.) at the Toronto Western Hospital during the period from September 2006 to May 2013 (Group B). All urgently scheduled and/or after-hours cases were excluded. Recording was done using FileMaker Pro 8 Advance (FileMaker Inc.) as database software, in a manner similar to that used for the data (Group A) in the study by Stone and Bernstein²⁹ in the preceding 6 years (May 2000–August 2006) in the same setting. The definitions and classifications of errors in the present study were equivalent to those applied in that previous report by Stone and Bernstein,²⁹ as developed by the senior author (Table 1). The method of error capturing and recording was similar to the one used in Group A. Following the identification of errors by the se-

TABLE 1: Definitions of error nomenclature*

Word or Phrase	Definition
error	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)†
adverse event/complication	unintended result of medical treatment that results in prolonged hospital stay, morbidity, or mortality; it may also be an injury caused by medical management rather than the underlying condition of the patient‡‡
type of error†	
technical	problems in the use of correctly functioning equipment or the performance of an appropriate procedure (for example, aspirator inadvertently bruised brain)
contamination	e.g., instrument required re-sterilization
equipment failure or missing	e.g., instrument required re-sterilization
delay	e.g., long wait for a spine-localizing radiograph
nursing	e.g., nurse failed to properly set up piece of equipment
anesthesia	e.g., anesthetist prematurely extubated patient requiring urgent re-intubation
management/judgment	e.g., patient arrived in operating room w/ an abnormal blood result missed by the team
communication/information	e.g., no prophylactic antibiotics administered because the anesthetist did not hear the surgeon's request
characteristics of error	
severity of errors†	actual or potential (near miss) nature of error to cause complication
major	caused actual or potential morbidity or mortality
minor	did not cause actual or potential morbidity or mortality
clinical impact of error†	deals w/ actual nature (impact) of errors in a more explicit way; ability of errors to cause potential problems (near-miss errors) not considered
none	self-explanatory
minimal	self-explanatory
transient	self-explanatory
permanent	self-explanatory
death	self-explanatory
preventability of error†	
low (scores of 1–5)	deemed non-preventable
high (scores of 6–10)	deemed preventable

* e.g. = for example.

† Stone and Bernstein, 2007.

‡ Etchells et al., 2003

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nior author and other team members—which included the nurses, residents, and fellows who were present at the time the errors were committed—the errors were both rated according to the error nomenclature in Table 1 and entered into the database by the senior author immediately after every surgery. Delayed errors and/or complications were also identified and recorded in a similar manner as they occurred over time. The preoperative and intraoperative procedures in Group B were essentially the same as those in Group A, except for the introduction of the WHO checklist, which was incorporated during the Group B study period. The pattern of error recorded in Group A was compared with the pattern of error recorded in Group B. The entire period from 2000 to 2013 was also assessed to verify whether there was a continuous change in the error pattern over time. Statistical analysis was done using Microsoft Excel (Microsoft Corp.) and SPSS version 17 (SPSS Inc.), with the level of significance set at a p value < 0.05.

Results

Table 2 demonstrates the demographic characteristics of the study population. Seventeen patients were excluded from analysis because of incorrect and/or incomplete data in the database. A total of 2082 consecutive patients who had undergone elective surgical treatment between May 2000 and May 2013 were included in the present analysis. The number of patients in the two groups was comparable, with Groups A and B representing 53% and 47% of the total population, respectively. There was a significant difference in the frequency of the types of procedures performed and the methods of anesthesia used in the two groups. The ratio of cranial to spine procedures performed in Groups A and B were 3:1 and 10:1, respectively, while the ratio of general anesthesia to local anesthesia (with or without neuroleptics) in the two groups were 2:1 and 1.3:1, respectively (p < 0.0001 for both). A

TABLE 2: Characteristics of study population*

Variable	No. (%)		p Value
	Group A	Group B	
total no. of patients	1108	974	
procedure			
cranial	843 (76.1)	875 (89.8)	<0.0001†
spinal	252 (22.7)	90 (9.2)	
other‡	13 (1.2)	9 (0.9)	
type of anesthesia			
general	750 (67.7)	550 (56.5)	<0.0001†
local w/ or w/o neuroleptic (i.e., awake)	358 (32.3)	414 (42.5)	
missing value‡		10 (1.0)	
mean ASA score§	2.41 ± 0.69	2.82 ± 0.59	<0.0001¶

* i.e. = that is.

† Chi-square test.

‡ "Other" and "missing value" were excluded from analysis.

§ Value expressed as the mean ± standard deviation.

¶ Student's 2-tailed t-test, assuming unequal variances.

comparison of the mean American Society of Anesthesiologists (ASA) scores between the two study groups using independent-samples t-test analysis showed a significant difference in the tendency of patients in Group B to have higher ASA scores than those in Group A (p < 0.0001). However, the tendency of patients with errors to have a higher ASA score than the patients without errors was retained in the two study groups.

The characteristics of recorded errors in the two groups are demonstrated in Tables 3 and 4, while a comparison of the study groups is graphically illustrated in Fig. 1. There was a higher proportion of cases with errors in Group A (87.1%) than in Group B (83.2%; p < 0.006, chi-square). There was a statistically significant reduction in the mean errors per case between the two study groups

TABLE 3: Pattern of errors in the two study groups

Variable	No. (%)		p Value
	Group A	Group B	
total no. of errors	2684	1892	
type of error			
technical	747 (27.8)	352 (18.6)	<0.0001*
contamination	678 (25.3)	431 (22.8)	0.008*
equipment failure or missing	489 (18.2)	538 (28.4)	<0.0001*
delay	336 (12.5)	335 (17.7)	<0.0001*
nursing	152 (5.7)	61 (3.2)	<0.0001*
anesthesia	119 (4.4)	73 (3.9)	0.365*
management/judgment	76 (2.8)	51 (2.7)	0.776*
communication/information	51 (1.9)	17 (0.9)	0.008*
other	36 (1.3)	34 (1.8)	
characteristics of error			
severity			
major	606 (22.6)	558 (29.5)	<0.0001*
minor	2078 (77.4)	1329 (70.2)	
missing values†		5 (0.3)	
clinical impact‡			
none or minimal	1458 (54.3)	1024 (54.1)	<0.0001*
transient	1155 (43.0)	849 (44.9)	
permanent	70 (2.6)	19 (1)	
death	2 (0.1)	0	
preventability			
low (1–5)	578 (21.5)	269 (14.2)	<0.0001*
high (6–10)	2106 (78.5)	1623 (85.8)	
no. of cases w/ error	965 (87.1)	810 (83.2)	<0.0001*
mean errors per case	2.4 ± 1.76	1.9 ± 1.46	<0.0001§

* Chi-square test.

† Missing values were excluded from the analysis.

‡ "None or minimal" and "transient" were re-categorized as "low impact," while "permanent" and "death" were re-categorized as "high impact" before the association was subjected to the chi-square test, which produced the p value quoted.

§ Student's 2-tailed t-test, assuming unequal variances.

TABLE 4: Distribution of patients and errors in each year of the study period

Year	No. of Patients	No. of Patients w/ Errors	No. of Errors	Mean Error
2000	128	94	226.00	1.7656
2001	196	181	627.00	3.1990
2002	163	149	430.00	2.6380
2003	159	139	395.00	2.4843
2004	182	166	433.00	2.3791
2005	171	147	336.00	1.9649
2006	164	142	355.00	2.1646
2007	162	131	318.00	1.9630
2008	151	140	328.00	2.1722
2009	129	115	292.00	2.2636
2010	151	124	299.00	1.9801
2011	144	108	224.00	1.5556
2012	134	106	236.00	1.7612
2013	48	37	78.00	1.6250

($p < 0.0001$, 95% CI 0.618–0.823), as shown in Table 3 and Fig. 2.

When each type of error was compared between the two groups (Table 3 and Fig. 1), a significant reduction

was noticed with technical errors (27.8% to 18.6%, $p < 0.0001$), contamination (25.3% to 22.8%, $p = 0.008$), nursing errors (5.7% to 3.2%, $p < 0.0001$), and communication errors (1.9% to 0.9%, $p = 0.008$). The degree of reduction in anesthesia errors (4.4% to 3.9%, $p = 0.365$) and management/judgment errors (2.8% to 2.7%, $p = 0.776$) was insignificant. However, a significant increase was noticed in the proportion of errors due to equipment failure or missing equipment (18.2% to 28.4%, $p < 0.0001$) and delay (12.5% to 17.7%, $p < 0.0001$).

The characteristics of errors were compared between the two groups as shown in Table 3 and Fig. 2. The clinical impact of errors decreased from 2.6% to 1.0% ($p < 0.0001$). Of the 192 complications that occurred in Group A, 31 were error related; only 8 of the 146 complications that had occurred in Group B were error related. This shows that there was a significant reduction in the proportion of error-related complications from 16.7% in Group A to 5.5% in Group B ($p = 0.002$). There was a greater tendency for errors in Group B to be more preventable than those in Group A ($p < 0.0001$, OR = 1.669, 95% CI 1.424–1.956). However, the errors recorded in Group A appeared to be significantly less severe in nature than those in Group B ($p < 0.0001$, OR = 1.431, 95% CI 1.252–1.636). When the whole study period was assessed in a continuous manner, a descending trend was demonstrated for the mean errors per case from the years 2001 to 2012, as shown in Table 4 and Fig. 3.

Fig. 1. Bar graph showing a comparison of error types between the two study groups.

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Fig. 2. Bar graph showing a comparison of error characteristics between the two study groups.

Discussion

Several studies, including this one and the earlier study by Stone and Bernstein, have reported that the incidence of errors and adverse events are significantly higher in patients who underwent cranial procedures than in those who underwent spine procedures and in patients with a higher ASA score than in those with a lower ASA score.^{11,29} However, the occurrence of errors in Group B in the present study was significantly lower than in Group A, despite the fact that there were more cranial procedures and a higher mean ASA score in Group B than in Group A. This result may mean that the higher error-prone effect of cranial procedures and cases with a high ASA score could not substantially neutralize the apparently high magnitude of error reduction demonstrated in Group B. The significant reduction in many types of error suggested that error reduction was not lopsided. The caliber of error types (technical, contamination, nursing, anesthesia, management/judgment, communication/information) that decreased suggested that most causes of errors are related to human involvement rather than institutional or nonhuman involvement, which in turn suggested that human behavioral and attitudinal changes toward error prevention may be the key factors in the error reduction observed.

This study has also revealed significant improvement in most characteristics of errors. An explanation for this

improvement may be the increased awareness of errors among team members given the continuous conversations about error in this surgeon's practice and operating room. Another explanation is the enculturation of neurosurgery residents, nurses, and anesthesia staff about the commonness and preventability of errors given the outcomes of the intraoperative error monitoring done in this surgeon's practice as well as the increasing publicity about errors in both the medical arena and the lay media. These factors led team members to discuss before all surgical procedures the peculiarities of each procedure, instruments that would be needed, and errors that could be made and thus should be avoided. A third explanation is the WHO checklist, which was introduced and adopted during the Group B period. Despite the fact that other studies have reported a reduction in surgical errors since the introduction of this checklist (<http://maps.cga.harvard.edu:8080/Hospital/>),^{15,22} this instrument alone is unlikely to be responsible for the magnitude of error reduction found, because this error-reducing culture was not the only one assimilated during the Group B period. Moreover, the introduction and adoption of the WHO checklist originated from the same awareness of the commonness and preventability of errors following the appearance of publications on error recording and monitoring. Therefore, the WHO checklist is not a confounder to the Hawthorne effect of error recording on error re-

Fig. 3. Graph showing a descending trend in the mean errors per case over time from the years 2001 to 2012. The record of errors in 2000 and 2013 were not included in this analysis to avoid bias because recording did not involve all of the months in these years, unlike other years. *Black line* depicts the mean error per case, while the *gradient color line* depicts the 2% moving average trend. 2 per.Mov.Avg. = 2% moving average graph, which was introduced to assess the trend of the *black line*.

duction. Rather, its adoption and adherence is the product of the Hawthorne effect of error recording from our and other authors' previous studies. The only characteristic of error that did not decrease, but instead significantly increased, was the severity of error. This finding can be explained by the definition of a major error, which encompassed not only the errors that caused actual mortality or morbidity (errors with high clinical impact) but also errors that had the potential to cause morbidity or mortality (termed "near misses"). For the proportion of high-clinical-impact errors to have significantly decreased, the component of major errors called "near misses" may have been the ones to have significantly increased and not the errors that caused actual morbidity and mortality (clinical impact). Therefore, it can be deduced that it is the impact-causing potential of the near-miss errors that was prevented from manifesting rather than the prevention of these errors. However, studies have shown that errors called near misses are common and that preventing them will, in the long run, reduce the incidence of error-related complications.^{10,27,33}

Our study is one of the few that has assessed the effect of error recording and/or reporting on the pattern of

error in medical practice in general and the first in neurosurgery in particular. Many available error studies have reported only the incidence and pattern of medical errors and adverse events. Rebas et al.,²⁸ who performed a similar study, assessed only the change in the percentage of patients with errors over time, unlike the present study in which we assessed many variables, including the change in the number of errors per patient, proportion of patients with errors, severity of errors, preventability of errors, clinical impact of errors, complications of errors, and types of errors. The significant improvement noted in these error parameters in response to information from error reporting appears to make this study unique and versatile in providing information to health institutions yet to be convinced about the importance of error recording and reporting.

The spectrum of limitations in this study is similar to that already described in a prior report.²⁹ There is likely to be bias given the subjectivity and limited scope of data collection and lack of standardized definitions and classifications of terminologies. The fact that one surgeon has prospectively recorded the errors in every single case can be seen as both a strength and a weakness; it suggests that

there has been consistency in recording, but perhaps the recording criteria of the surgeon can change with time, maturity, and experience. For example, does the fact that there is a higher proportion of serious errors or errors with the potential for serious events in Group B mean that the surgeon developed “recorder fatigue;” that is, he tended to record only more serious errors as time passed. On the other hand, the surgeon’s consistent interest in the area of error for a decade suggests that these data are honest and reliable.^{4–9,14,17,18,24} Arguably, the greatest weakness of this study is that the data were gathered from the practice of one academic neurosurgeon, in one hospital, in a socialized health care system, and thus generalizability may be an issue.

Conclusions

In this study we have shown that information from error recording can cause behavioral and attitudinal changes, which may have led to a significant reduction in the total number of errors, proportion of patients with errors, mean errors per patient, clinical impact of errors, and complications due to errors. There may be a strong cause-effect relationship between error recording and the incidence and severity of errors, and we believe that this finding may hold an important message for clinicians. We humbly suggest that personal error recording should be part of every surgeon’s practice. Not only can it decrease error, but it is also an important personal audit/quality assurance for surgeons.

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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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