Neurosurgery Morbidity and Mortality: A Prospective Surgical and Medical Analysis

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Objective: The analysis of morbidity and mortality is fundamental for improving the quality of patient care. The objective of this study was to evaluate the combined medical and surgical morbidity and mortality of neurosurgical patients.

Methods: We performed a daily prospective compilation of morbidities and mortalities during a consecutive 4-month period in all the patients who were 18 years of age or older and had been admitted to the neurosurgery service at the Puerto Rico Medical Center. For each patient, any surgical or medical complication, adverse event, or death within 30 days was included. The patients' comorbidities were analyzed for their influence on mortality.

Results: Fifty-seven percent of the patients presented at least 1 complication. The most frequent complications were hypertensive episodes, mechanical ventilation for more than 48 hours, sodium disturbances, and bronchopneumonia. Twenty-one patients died, for an overall 30-day mortality of 8.2%. Mechanical ventilation for more than 48 hours, sodium disturbances, bronchopneumonia, unplanned intubation, acute kidney injury, blood transfusion, shock, urinary tract infection, cardiac arrest, arrhythmia, bacteremia, ventriculitis, sepsis, elevated intracranial pressure, vasospasm, stroke, and hydrocephalus were significant factors for mortality. None of the analyzed patients' comorbidities were significant for mortality or longer length of stay. The type of surgical procedure did not influence the length of stay.

Conclusion: The mortality and morbidity analysis provided valuable neurosurgical information that may influence future treatment management and corrective recommendations. Indication and judgment errors were significantly associated with mortality. In our study, the patients' comorbidities were not significant for mortality or increased length of stay. [*P R Health Sci J 2023;42(1):29-34*]

Key words: Adverse event, Complication, Morbidity, Mortality, Neurosurgery

Hospital mortality review committees were created to examine adverse outcomes and improve the standard of care. These hospital committees are thought to be the most immediate precursors to the modern morbidity and mortality conference. Morbidity and mortality conferences are fundamental for improving the quality of patient care and outcomes. These conferences are also utilized as a teaching mechanism for problem-based learning during resident training and education and to generate awareness of and recognize areas of care that need improvement. Ernest Amory Codman, an early-20th-century surgeon, promoted the evaluation of medical practice by introducing the end-result concept to his surgical practice at the Massachusetts General Hospital (1). His concept used a card documenting each patient's symptoms, clinical diagnosis, treatment plan, complications, final diagnosis, and outcome. By 1970, morbidity and mortality conferences became an integral part of resident training programs in the United States. During that time, patient comorbidities began to be analyzed for their association with mortality (2–3).

The first published results of neurosurgical morbidity and mortality are from 2001 (4). However, evidence exists that Harvey Cushing, the father of modern neurological surgery, maintained documentation of his self-reported surgical errors (5). The Patient Safety and Quality Improvement Act of 2005 was passed to provide confidentiality protections to physicians to encourage them to report and discuss medical errors (6). In 2011, the Accreditation Council for Graduate Medical Education included morbidity and mortality conferences as a requirement for all neurosurgical residency programs in the United States. Houkin et al (7) classified the causes of neurosurgical adverse

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events as being related to a patient's disease, a technical issue, a medical problem, an equipment problem, a diagnostic issue, or an unidentified issue. Steiger et al (8) retrospectively analyzed their department's neurosurgical morbidity and mortality in systematic conferences and recognized this kind of a conference as being a well-accepted instrument for quality control and problem-oriented teaching.

For this study, we decided to explore the principal causes of and factors influencing morbidity and mortality in our neurosurgical service. Our study aimed to answer specific questions concerning the causes of morbidity and mortality in our service. What were the principal morbidities in the neurosurgery service? Did morbidity and mortality vary depending on the admission type? What were the significant risk factors associated with morbidity and mortality? Was there a major neurosurgical area most prone to morbidity? What were the specific errors most related to neurosurgical morbidity, and which of them can be avoided to prevent mortality?

Methods

Every day, we performed a prospective compilation of morbidities and mortalities, doing so over a consecutive 4-month period, from January 1st, 2020, through April 30, 2020, in all the patients 18 years of age and older who had been admitted to the neurosurgery service at the University District Hospital of the Puerto Rico Medical Center. The primary outcome was to measure the short-term overall postoperative morbidity, which included all surgical and medical complications within the 30-day postoperative period. The mortality rate for this period was also calculated. The admission type (elective, emergency, transfer), the length of stay (LOS), the diagnosis, age, comorbidities, reoperations, and readmission were analyzed. The entire neurosurgery faculty and residents participated in the care of the patients included in the study. A multidisciplinary care team of specialists, including a neurocritical care intensivist, also helped manage the patients.

The morbidity and mortality for each neurosurgical admission area (tumor, vascular, spine, trauma, peripheral nerve, general) were recorded. The general neurosurgical area included all the admissions unrelated to a traumatic, vascular, or tumoral etiology and was further divided into cranial and spinal cases. Trauma cases included individuals with isolated head or spine trauma; patients with multisystem involvement were admitted to the trauma unit. Chronic and subacute subdural hematomas were not included under the trauma category and were placed under general neurosurgery. The morbidity and mortality attributed to a specific error (indication, procedural, technical, judgment, or critical) were analyzed. Complications were prospectively recorded daily by the resident team and then discussed with the faculty supervisor of the study at the end of each week to assign, if possible, a specific type of error. Indication errors were defined as errors that occurred in the preoperative period and that were secondary to poor surgical decision-making. Procedural errors were defined as errors that occurred because of a failure to adhere to the established perioperative safety procedures and protocols. Technical errors were defined as errors that occurred in the technical aspects of the surgery. Judgment errors were defined as errors secondary to incorrect intraoperative surgical decisions. Critical events represented adverse events that occurred in the perioperative period and that were not classified into any of the previous categories.

Every complication was recorded immediately after it was detected to neutralize any memory bias for this study. Descriptive statistics were used to determine the median, mean, interquartile range (IQR), frequency, and proportion. A chi-square test or Fisher's exact test was used to determine the association between mortality and patient characteristics. The Wilcoxon signed-rank test and the Kruskal–Wallis 1-way analysis of variance were used to measure LOS associations. A P value of less than 0.05 was considered statistically significant. Statistical analysis was performed using R (version 4.0.5). This study aimed to prospectively analyze the morbidity and mortality in an academic neurosurgical service to implement corrective initiatives and measures. The University of Puerto Rico Medical Sciences Campus Institutional Review Board approved this study (protocol B0940119).

Results

The study included 256 adult patients treated by the neurosurgery service during the study period. Sixty-one percent of the patients were male. The age of the patients ranged from 19 to 97 years, with a median of 64 years (IQR = 51–75). The ages of the patients were uniformly distributed in groups from 18 years to 84 years, but with only 7% of the patients in the age group of 85 or above (Table 1). The majority of the admissions (86.7%) were from the emergency room; of the remaining, 11.7% were for elective surgeries and 1.6% were transfers from other hospitals. Cranial nontumoral and cranial nonvascular cases were the most frequent (31.6%), and most of these were burr holes for nontraumatic chronic subdural hematomas or shunts for hydrocephalus. Spine nontumoral cases were the second most frequent (26.2%), and most of them involved cervical/lumbar discectomies with or without instrumentation or cervical/lumbar laminectomies with instrumentation. Other cases included cranial tumors (16.4%), those of a vascular nature (12.9%), those involving trauma (7.8%), spinal tumors (3.9%), and those involving the peripheral nerves (1.2%). The LOSs varied from 1 to 82 days, with a median stay of 7 days (IQR = 3–12.3).

Surgical and medical complications

Fifty-seven percent (n = 146) of the patients presented at least 1 complication. The most frequent complications identified were hypertensive episodes, mechanical ventilation for more than 48 hours, sodium disturbances (hyper or hyponatremia), bronchopneumonia, unplanned intubation, reoperation, hyperglycemia, and acute kidney injury (AKI).

Table 1. Patient characteristics, admission type, and procedure type

Variable	N = 256	%
Sex		
Male	157	61.3
Female	99	38.7
Median age (IQR)	64 (51–75)	-
Age		
18–49	61	23.8
50–64	69	27.0
65–74	57	22.3
75–84	51	19.9
≥ 85	18	7.0
Type of admission		
Elective	30	11.7
Transfer	4	1.6
Emergency	222	86.7
Type of procedure		
General cranial	81	31.6
General spine	67	26.2
Trauma	20	7.8
Vascular	33	12.9
Cranial tumor	42	16.4
Spine tumor	10	3.9
Peripheral nerve	3	1.2
Median LOS (IQR)	7.0 (3.0 – 12.3)	-

Mortality, comorbidities, and length of stay

Twenty-one patients died, for an overall 30-day mortality rate of 8.2%. The patient's gender or the type of surgical procedure that patient underwent did not influence mortality. All the patients who died were emergency room admissions. A long postoperative LOS and advanced age were significant factors for mortality. Seventy-eight percent of the patients had at least 1 comorbidity risk factor. The most common such risk factors, in decreasing frequency, were hypertension, being over 65 years old, obesity, diabetes mellitus, being functionally dependent, smoking, and congestive heart failure (Table 3). None of these comorbidity risk factors were significant for mortality or longer LOSs. Age, gender, and type of surgical procedure were not significant in terms of the LOS; however, the type of admission influenced the LOS. Transfers and emergency admissions were significant factors for a longer LOS. Nine patients were readmitted during the study period, with 1 death occurring among them.

Neurosurgical errors

Sixty-one errors were documented; most of them were technical errors or critical events. In 85.7% of the patients who died, we identified a specific error. After analyzing the type of

No patient showed a deep vein thrombosis by sonographic studies; however, 3 patients (1.2%) had pulmonary embolisms that were discovered with chest computed tomography. Mechanical ventilation for more than 48 hours, sodium disturbances, bronchopneumonia, unplanned intubation, AKI, blood transfusion, shock, urinary tract infection (UTI), cardiac arrest, arrhythmia, bacteremia, ventriculitis, sepsis, elevated intracranial pressure, vasospasm, stroke, and hydrocephalus were significant for mortality (Table 2). All the types of shock that required vasopressor medication were included under the "shock" category. Hypertensive episode, reoperation, hyperglycemia, readmission, hemiparesis, postoperative hematoma, wound infection, and pulmonary embolism were not significant for mortality. The following complications significantly prolonged the LOSs of the patients: hypertensive episodes, mechanical ventilation for more than 48 hours, sodium disturbances, bronchopneumonia, unplanned intubation, hyperglycemia, AKI, blood transfusion, shock, UTI, hemiparesis, postoperative hematoma, and arrhythmia. Reoperation did not prolong the LOSs of any of the patients.

Table 2. Complications and mortality rates

Complication	Frequency n	%	Mortality n	%	*P* value
Hypertensive episode	84	32.8	4	4.9	.195
Mechanical ventilation > 48 hours	36	14.1	16	44.4	<.001
Sodium disturbance	35	13.7	13	37.1	<.001
Bronchopneumonia	33	12.9	11	33.3	<.001
Unplanned intubation	27	10.6	10	37.0	<.001
Reoperation	26	10.2	1	3.8	.393
Hyperglycemia	26	10.2	3	11.5	.513
Acute kidney injury	26	10.2	7	26.9	<.001
Blood transfusion	25	9.8	9	36.0	<.001
Shock	19	7.4	10	52.6	<.001
Readmission	19	7.4	3	15.8	.210
Urinary tract infection	18	7	4	22.2	.025
Cardiac arrest	17	6.6	14	82.3	<.001
Hemiparesis	14	5.5	2	14.3	.321
Postoperative hematoma	13	5.1	1	7.7	.945
Arrhythmia	11	4.3	5	36.4	<.001
Bacteremia	9	3.5	3	33.1	.029
Ventriculitis/meningitis	8	3.1	3	37.5	.021
Sepsis	8	1.1	5	62.5	<.001
Wound infection	8	3.1	1	12.5	.501
Elevated intracranial pressure	7	2.7	3	42.9	<.001
Aphasia	7	2.7	0	-	-
Vasospasm	6	2.4	3	50.0	.008
Seizure	6	2.4	2	33.3	.079
Stroke	6	2.4	3	50.0	.008
Hydrocephalus	6	2.4	3	50.0	.008
Pulmonary embolism	3	1.2	1	33.3	.227
Cerebrospinal fluid leak	2	0.8	0	-	-
Dialysis	2	0.8	2	-	-
Fungemia	1	0.4	1	-	-
Myocardial infarction	1	0.4	1	-	-

Table 3. Comorbidities and associated mortality

Comorbidity	Frequency n	%	Mortality n	%	*P* value
Hypertension	127	49.6	13	10.2	.239
Age over 65 years	126	49.2	13	10.3	.225
Obesity	43	16.8	3	7.0	>.99
Diabetes mellitus	27	10.7	3	11.1	.472
Functionally dependent	26	10.3	4	15.4	.246
Smoker	16	6.2	1	6.3	>.99
Congestive heart failure	12	4.7	2	16.7	.257
Disseminated cancer	6	2.4	1	16.7	.405
Anemia	5	2.0	0	-	-
Low weight	5	2.0	1	20.0	.351
Dialysis	4	1.6	1	25.0	.291

error, we found that indication errors, judgment errors, and critical events were significantly associated with mortality. Indication errors caused mortality in 75% of the patients in which an indication error was identified; judgment errors caused mortality in 66.6% of the patients in which a judgment error was identified; critical events caused mortality in 54.5% of the patients in which a critical event was identified (Table 4). Technical errors were not significantly associated with mortality; however, they were significantly associated with longer LOSs. Indication, procedural, and judgment errors were not associated with longer LOSs.

Table 4. Type of error and associated mortality

Error	Frequency n	%	Mortality n	%	*P* value
Technical	28	10.9	3	10.7	.711
Critical event	22	8.6	12	54.5	<.001
Indication	4	1.6	3	75.0	.002
Procedure	4	1.6	-	-	-
Judgment	3	1.2	2	66.6	.01

Discussion

Morbidity and mortality data collection should be prospective as retrospective collection and analysis can lead to the underreporting of complications and deaths (9). Our data came from an academic center where residents participate in the care of neurosurgical patients under an attending physician's supervision. This type of care can sometimes be more prone to complications; however, in a multivariate analysis, Bydon et al (10) showed that the participation of residents was not an independent risk factor for the postoperative 30-day morbidity or mortality. In their study, there were higher complication and mortality rates in procedures that involved resident care; but those procedures were performed on patients with greater comorbidities. Weaver et al (11) observed no increase in neurosurgery morbidity or mortality that could be linked to the "July phenomenon," which assumes the belief that more complications and deaths occur in July, which is when new residents in the United States begin their training.

In most neurosurgical morbidity and mortality conferences, medical complications are not discussed (12). Medical complications are important for hospital quality metrics and are discussed in quality assurance conferences to evaluate patient care quality and establish subsequent measures to achieve the best possible patient care (9). Quality assurance conferences that evaluate patient care standards must be distinguished from morbidity and mortality conferences, as the latter focus mainly on education. Rotman et al (12) recognized a divergence between the complications discussed in morbidity and mortality conferences and those sustained by the patient population admitted to the neurosurgical service; thus, they recommended that morbidity and mortality conferences include a discussion of medical-based complications. Our study included any type of surgical or medical complication that was experienced during a given patient's hospitalization and observed that 57% of the patients had at least 1 complication, with a mortality rate of 8.2%. Our 30-day morbidity was high; however, we included any medical complications that might adversely affect the patients. Most studies have shown a neurosurgical morbidity of 4 to 17% and mortality of 2 to 4% (4,8,13–17). Those series with a higher morbidity rate usually include all the medical complications in addition to the surgical complications. Rolston et al (16) reviewed the American College of Surgeons National Surgical Quality Improvement Program database and analyzed 38,000 neurosurgical cases, identifying a 14.3% complication rate. In their study, the most frequent complications were transfusions (4.5%) and reoperations (4.3%), followed by the failure to wean from mechanical ventilation, postoperatively (2.5%). They showed that the most significant predictors for complications were stroke, sepsis, blood transfusions, and chronic steroid use. Rotman et al (12) observed that the most frequent complications were reoperation, readmission, seizures, UTI, failure to wean from a ventilator, and unplanned intubation. The inability to wean from mechanical ventilation is a frequent complication that is commonly forgotten in morbidity and mortality conferences. It is also a complication that is rarely discussed preoperatively with the patient. Although rare, occurring in 1 to 2% of patients, cardiac arrest, myocardial infarction, and pulmonary embolism significantly contribute to mortality (13). Pediatric neurosurgery carries higher complication rates, ranging from 15 to 20%, although with similar mortality rates compared to adult neurosurgery (18–21).

In our cohort, all the deaths occurred in cases involving emergency room admissions. Our neurosurgery service is the only referral center for traumatic, complicated, and complex neurosurgical cases. Three deaths occurred during the first

postoperative day; however, they occurred in critically ill patients on whom heroic measures intended to save their lives were performed. Pires Siqueira et al (22) showed that the mortality rate significantly depended on the admission status of each patient, with a 26.7% mortality rate in the non-elective surgery group compared to 5.5% in the elective surgery group. Hammers et al (17) showed that mortality rates were significantly higher for emergency admissions and transfers than for elective admissions. In their series, 42% of the deaths were in cases who had been admitted to the emergency room and 39% were in patients who were transfers.

Ravindra et al (23) classified neuroendovascular complications into 4 subcategories: mechanical complications, technical complications, judgment errors, and critical events. A few years later, they classified all the neurosurgical adverse events into 5 subgroups: indication errors, procedural errors, technical errors, judgment errors, and critical events (14). We analyzed our complications according to these 5 subgroups and identified 59 errors, most of them being technical errors or critical events. Our results were like those of Ravindra's study, in which nearly half of the errors were critical events, and technical errors accounted for one-third of the complications. In our study, errors leading to mortality were identified in 85.7% of the patients who died. In addition, critical events, indication errors, and judgment errors were significantly associated with mortality. Technical errors were not significantly associated with mortality; however, they were significantly associated with longer LOSs.

Gozal et al (14) divided their complications within neurosurgical subspecialties and observed that vascular neurosurgery had the most complications (36.5%), followed by spine and peripheral nerve (21.7%), neuro-oncology (14.8%), cranial trauma (13.9%), general neurosurgery (12.2%), and functional neurosurgery (0.9%). In our patients, the type of neurosurgical subspecialty did not influence mortality. The influence of comorbidities and their association with mortality has been long recognized (2–3). The impact of comorbidities has also been used to evaluate neurosurgical morbidity and mortality (15,24–26). In our study, comorbidities were not significantly associated with mortality.

Our study identified a substantial number of medical complications involving neurosurgical patients. Many medical complications were significant for neurosurgical mortality. Based on the high number of medical complications identified in our study, we recommend that other neurosurgical programs have a neurocritical care physician present during morbidity and mortality conferences to discuss these medical complications and enhance the residents' learning. In our experience, the knowledge that neurointensivists can impart about these complications can influence patient care and improve outcomes. Understanding morbidity- and mortality-associated factors can help the neurosurgeon and resident team counsel the patients and their families, preoperatively.

This study had some limitations as some complications may not have been recognized and so have been omitted for the final analysis, even with the prospective nature of the study. It is possible that some patients experienced complications and/or death after they were discharged from our team's care but within the 30-day postoperative period. These complications and deaths were not accounted for, if the patient was admitted into another hospital without our awareness, or if they occurred at their homes without our knowledge. We also might have failed to record other risk factors that could have contributed to mortality or morbidity. Mortality in some patients may have been affected by the interaction of 2 or more individual factors that we did not analyze. Neither the length nor the complexity of the surgical procedure was measured for this study, either of which might be associated with a greater number of errors in long and/or complex procedures. Lastly, our study depended on the nature of the cases that came in, which was beyond our control and may be dissimilar to those of other health systems and/or geographical areas.

Conclusions

A mortality and morbidity analysis provided valuable neurosurgical information that can influence future treatment management and corrective recommendations. Mechanical ventilation for more than 48 hours, sodium disturbances, bronchopneumonia, unplanned intubation, AKI, blood transfusion, shock, UTI, cardiac arrest, arrhythmia, bacteremia, ventriculitis, sepsis, elevated intracranial pressure, vasospasm, stroke, and hydrocephalus were significant for mortality. Indication and judgment errors were significantly associated with mortality. In our study, patient comorbidities were not significant for mortality; however, they prolonged hospitalization. This study can serve as a guide for the overall morbidity and mortality of neurosurgical patients and can be used to inform and counsel patients and their families, preoperatively.

Resumen

Objetivo: El análisis de morbilidad y mortalidad es fundamental para mejorar la calidad del cuido al paciente. El objetivo de este estudio fue evaluar la morbilidad y mortalidad medicoquirúrgica de pacientes neuroquirúrgicos. Métodos: Realizamos una recopilación prospectiva diaria de morbilidad y mortalidad durante un período de cuatro meses en pacientes de 18 años o más en el servicio de neurocirugía del Centro Médico de Puerto Rico. Se incluyó cualquier complicación quirúrgica o médica, evento adverso o muerte dentro de los primeros 30 días. Se analizaron las comorbilidades del paciente para analizar su influencia en la mortalidad. Resultados: El 57% de los pacientes presentó al menos una complicación. Las complicaciones más frecuentes fueron episodio hipertensivo, ventilación mecánica durante más de 48 horas, alteraciones del sodio y bronconeumonía. Murieron 21 pacientes, para una mortalidad de 8.2% en los primeros 30 días. Ventilación

mecánica durante más de 48 horas, alteraciones del sodio, bronconeumonía, intubación no planificada, lesión renal aguda, transfusión de sangre, shock, infección del tracto urinario, paro cardíaco, arritmia, bacteriemia, ventriculitis, sepsis, presión intracraneal elevada, vasoespasmo, accidente cerebrovascular e hidrocefalia fueron factores significativos para mortalidad. Ninguna de las comorbilidades del paciente fue significativa para mortalidad. Conclusiones: El análisis de mortalidad y morbilidad proporcionó información neuroquirúrgica valiosa que puede influir en el manejo del tratamiento futuro y hacer recomendaciones correctivas. Los errores de indicación y juicio se asociaron significativamente con mortalidad. En nuestro estudio, las comorbilidades del paciente no fueron significativas para mortalidad o aumento en la duración de la hospitalización.

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