The Effect of Surgical Start Time on Complications Associated With Neurological Surgeries

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BACKGROUND: Neurosurgical procedures are necessary at all times of day. Other surgical specialties have examined the effect of surgical start time (SST) on morbidity and mortality; however, a similar study has not been performed for neurosurgical procedures.

OBJECTIVE: To perform a retrospective cohort study describing the association between SST and operative morbidity.

METHODS: We analyzed all patients undergoing neurological surgery between January 1, 2007 and August 1, 2014 at our institution. This study included 15 807 patients. A total of 785 complications were identified through the self-reported morbidity and mortality reports created by faculty and resident neurosurgeons. We used multilevel logistic regression to investigate the association of SST with morbidity.

RESULTS: In multilevel logistic regression, our Baseline model demonstrated that the odds of complication increased by more than 50% for start times between 21:01 and 07:00 (odds ratio [OR] 1.53, 95% confidence interval [CI] 1.03-2.29, $P = .04$). When accounting for the length of the surgery, the odds of a complication were even greater for later time periods 21:01 to 07:00 (OR 2.16, 95% CI 1.44-3.23, $P < .001$). The only statistically significant factor that predicted severity of the complication was if the operation was emergent compared to elective (OR 1.70, 95% CI 1.11-2.60, $P = .02$). An SST between 21:01 and 07:00 substantially contributed when severe complications were isolated (OR 1.61, 95% CI 1.50-2.90, $P = .08$).

CONCLUSION: Patients with SSTs between 21:01 and 07:00 are at an increased risk of developing morbidity compared to patients with an SST earlier in the day.

KEY WORDS: Surgical start time, Operative complications, Neurosurgical complications

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Morbidity caused by complications of surgical treatment of disease is a major health care concern and leads to significant cost.[1-2] The etiologies of surgical complications vary widely from preventable causes of morbidity and mortality (M&M) to complications that are intrinsic to the operation, condition of patient, and the particular disease. It is necessary to identify those types of complications that are amenable to intervention and correction.

Many other occupations and surgical specialties have examined the mediating effect of time of day on performance with a fairly consistent theme that if a task is accomplished outside the "normal" timeframe for completing the task (ie, after-hours or on the weekend) then the outcomes from that task are statistically worse.[3-9] Surgical specialties have noted an increased morbidity associated with surgical start times (SSTs) that are late in the evening.[6-7] For example, Kelz et al[6] performed a retrospective cohort study of 144 740 general and vascular surgery patients from the VA (Veteran's Affairs Hospital). He found that operations with an SST between 16:00 and 18:00 and between 18:00 and 23:00 had an increased risk of morbidity (odds ratio [OR] 1.25, $P \leq .0005$; OR 1.60, $P \leq .0005$, respectively). Previous studies have documented the relationship between surgical and medical management of diseases at night leading to a worse outcome and it has particularly been exemplified in those undergoing: coronary angioplasty, orthopedic surgery, transplant surgery, colorectal surgery, and cardiac arrest patients.[10-16]

ABBREVIATIONS: CI, confidence interval; **M&M,** morbidity and mortality; **OR,** odds ratio; **SST,** surgical start time

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While other surgical specialties have investigated the relationship between SST and associated complications, neurosurgery has yet to examine this potentially clinically significant association. We aimed to analyze all neurosurgical cases that have been performed at our institution from 2007 to 2014 to determine if SST was associated with an increase in morbidity related to neurosurgical cases. We hypothesized that a later SST would be significantly associated with increased odds of morbidity.

METHODS

Study Design

We performed a retrospective cross-sectional study of all patients undergoing neurological surgery at our institution. Our local Institutional Review Board approved this study and it was deemed that patient consent was not necessary, as the data were de-identified.

Patient Selection

All patients undergoing neurological surgery between January 1, 2007 and August 1, 2014 at our institution were included in this study. Interventional radiology and radiosurgical procedures were excluded. This included 15 807 procedures. Patient medical record numbers were collected through Medical Center Information Technology. They selected all operative cases that were scheduled in the operating room as a neurosurgical procedure.

Clinical Data

A total of 785 complications were identified through the self-reported (M&M) reports created by faculty and resident neurosurgeons during this time period. The chief residents in charge of each neurosurgical service fill out a standardized form documenting any complication observed. The cultural norm is to report all adverse events and to err on the side of over-reporting if there is a question of whether any problem represents an adverse event. A complication, in this case, is defined as an unexpected, adverse event that had the potential to negatively influence the postoperative course of the patient. The specific type of complication was obtained and categorized into mild, moderate, and severe subcategories (Table 1). Complication severity categories were determined by unanimous agreement between 3 board certified faculty neurosurgeons. Other data that were obtained for each patient included: age, gender, smoking status, SST, length of surgery (minutes), physician performing procedure, whether the procedure was emergent or elective, the type of procedure performed, and Charlson coded comorbidities.

SST categories were designated as: 07:01 to 09:00, 09:01 to 11:00, 11:01 to 13:00, 13:01 to 15:00, 15:01 to 17:00, 17:01 to 19:00, 19:01 to 21:00, and 21:01 to 07:00. When the SST categories were grouped into 3 groups (7:01-11:00, 11:01-15:00, and 15:01-7:00) for a sensitivity analysis, we found no statistically significant difference in complication rates as a function of the previously described SST groups ($P = .63$). Types of procedure were grouped into 9 larger categories: acoustic surgeries, spinal fusion surgeries, spinal decompression surgeries, cranial decompression surgeries, cerebrovascular surgeries, peripheral nerve surgeries, endonasal surgeries, endoscopic surgeries, and minor surgeries. Procedure type was also agreed upon by 3 practicing board certified neurosurgeons. Finally, in a post hoc analysis, we explored whether there was an interaction between SST and whether a case was elective or emergent based on the theory that emergent cases may be uniquely complication-prone when performed after hours.[17-18] To adequately power this analysis, we used the 3 time periods for SST as previously described.

Statistical Analysis

Demographic data were compared for patients with different SSTs utilizing chi-squared and *t*-tests depending on whether the variable was categorical or continuous. Demographic analysis was completed using the SPSS software (IBM SPSS Statistics for Windows, Version 22.0, Armonk, New York).

The association between start time and whether a patient had any complication was measured using multilevel logistic regression. First, our Baseline model predicted any complication (dependent variable) with independent variables including start time categories, demographics, comorbidities, whether the procedure was emergent/elective, procedure type while including a fixed provider-level intercept. Next, we created a Time Mediation model in which we added length of surgery to our Baseline model to determine whether differences in procedure time may alter the magnitude of estimated after-hour time categories. Our third model was a Conditional Severity model. With this model, we repeated our Baseline model with an Ordinal Logistic model to determine whether, conditional on having a complication, procedure start time could predict the severity of the complication (mild vs moderate vs severe). Our last model, the Severe Complications model, used the entire dataset instead of just those patients with a complication to analyze if any factors were predictive of severe complications. The rationale for this model was to enhance statistical power to identify complication severity by analyzing the entire dataset, as opposed to just those individuals that had a complication, as explored in the Conditional Severity model. All regression models were estimated in Stata 14 (StataCorpLP, 2015, *Stata Statistical Software: Release 14*, College Station, Texas). We considered a 2-sided $P \leq .05$ to be statistically significant.

RESULTS

Data from 15 807 neurosurgical procedures were obtained and analyzed. The average age of the patients was 44.4 (22.4) yr and 48.5% of the patients were females. In total, 14 065 (89.0%) of the 15 807 procedures were performed nonemergently, while the remaining 1742 (11.0%) were emergent. Patient demographics, comorbidities, as well as surgical type are summarized in Table 2.

Demographic comparisons across start-time groups (Table 2) revealed that the average age of the patient population varied across the surgical day with higher ages (mean 45.0 [standard deviation 21.9]) earlier in the day (07:01-09:00), and lower ages later in the day (39.8 [24.2] from 19:01 to 21:00 and 38.1 [25.3] from 21:01 to 07:00, $P < .001$). While other patient factors statistically varied over the course of the day, the magnitude of variation was unlikely to be clinically significant (Table 2). In addition, the type of surgical procedure (elective vs emergent) varied throughout the day (Table 3).

As would be expected, as it got later in the day, the percentage of elective cases decreased while emergent cases predominated. Patients with higher number of comorbidities were more likely to have an SST later in the day. Patients with an SST during the earliest time period (07:01-09:00) had an average of 0.4 (0.8)

TABLE 1. Categories of Complications

Mild complication	Moderate complication	Severe complication
Anemia	Anesthesia related	Cerebral edema
Coagulation disorder	Aspiration	Clip error
Complication from positioning	CSF leak—cranial and spinal	Death
Corneal abrasion	Device infection	Cerebral herniation
Electrolyte abnormality	Deep vein thrombosis	Hydrocephalus
Medication reaction	General infection	Intracerebral abscess
Near miss	Instrument related complication	Intracranial or spinal hemorrhage
Other	New deficit—cranial and peripheral nerve	Intraoperative hemorrhage
Pneumocephalus	Pneumonia	Meningitis/ventriculitis
	Pneumothorax	Myocardial infarction
	Pseudomeningocele	New deficit in brainstem, cortex, or spinal cord
	Recurrent disc	Pulmonary embolism
	Seizure	Respiratory failure
	Shunt malfunction or malpositioning	Shunt infection
	Technical error	Stroke
	Vasospasm	Vascular injury
	Wound dehiscence	
	Wound hemorrhage	
	Wound infection	

comorbidities per patient compared to 0.6 (1.0) comorbidities per patients in the latest time period (21:01-07:00; $P < .001$). Minor surgeries and cranial decompression surgeries represented a larger portion of the performed surgeries later in the night compared to the morning (33.5% vs 10.4% and 42.0% vs 25.6%, respectively; $P < .001$). The average length of surgery also decreased from 305.5 (186.5) min to 203.4 (111.7) min from the earliest to latest time category ($P < .001$). Complication rate increased from 5.3% for cases started between 07:01 and 09:00 to 10.8% for cases starting between 21:01 and 07:00 ($P < .001$). Table 4 describes the specific complications in the patients with an SST between 21:01 and 07:00.

Our Baseline model demonstrated that after adjusting for all patient and procedure characteristics, a number of factors were significantly associated with increased odds for complications. The odds of a complication were increased by more than 50% for start times between 21:01 and 07:00 (OR 1.53, 95% confidence interval [CI] 1.03-2.29, $P = .04$). In addition, complications were more likely if the operation was emergent compared to elective (OR 1.44, 95% CI 1.14-1.82, $P = .002$) and for each medical comorbidity (OR 1.10, 95% CI 1.06-1.14, $P < .001$).

To determine if procedure length may have mediated the after-hours effect when procedure time was added we used the Time Mediation model. This model demonstrated that the odds of a complication were even greater for later time periods 21:01 to 07:00 (OR 2.16, 95% CI 1.44-3.23, $P < .001$).

To assess whether procedure time affected complication severity, we used a Conditional Severity model, which predicted ordinal severity among patients with any complications. No time categories were associated with severity and the only significant factor was whether the procedure was emergent compared to elective (OR 1.70, 95% CI 1.11-2.60, $P = .02$).

Given the necessarily limited statistical power of conditional models, we secondarily explored predictors of the binary outcome, severe complication or not, in the entire population (Severe Complication model). Again, emergent compared to elective cases increased the odds of complications (OR 2.08, 95% CI 1.50-2.90, $P < .001$). Comorbid conditions also increase the odds (OR 1.14, 95% CI 1.08-1.20, $P < .001$). Though it is not statistically significant, the strongest time period-severe complications association was noted for start times between 21:01 and 07:00 (OR 1.61, 95% CI 1.50-2.90, $P = .08$). Finally, we did not find any statistically significant interactions between SST and whether a case was emergent or elective.

DISCUSSION

Reducing preventable surgical morbidity is an important goal as we strive to decrease total healthcare costs and increase the well-being of patients.[1-2] While studies in other surgical specialties have analyzed the association between the SST and operative complications, a similar study has not been completed for neurological surgeries.[6-7] Our analysis demonstrated that a patient's odds of having a surgical complication increased significantly when the SST was between 21:01 and 07:00 even after accounting for whether the case was emergent vs elective or if the patient had comorbid conditions. When accounting for the length of the surgery, the odds of a complication more than doubled in the 21:01 to 07:00 time interval.

Our finding that shorter surgeries are performed at late start times reproduces the work of Kelz et al.[6] The shorter length of

TABLE 2. Demographic Information

	07:01-09:00 n = 6704	09:01-11:00 n = 1554	11:01-13:00 n = 2366	13:01-15:00 n = 2307	15:01-17:00 n = 1505	17:01-19:00 n = 708	19:01-21:00 n = 275	21:01-07:00 n = 388	*P*-value
Age	45.0 (21.9)	43.0 (22.8)	45.9 (21.4)	44.2 (22.4)	44.2 (23.0)	43.7 (23.1)	39.8 (24.2)	38.1 (25.3)	<.001
Gender									.001
Female	3347 (49.9%)	742 (47.7%)	1065 (45.0%)	1157 (50.2%)	733 (48.7%)	326 (46.0%)	127 (46.2%)	174 (44.8%)	
Male	3357 (50.1%)	812 (52.3%)	1301 (55.0%)	1150 (49.8%)	772 (51.3%)	382 (54.0%)	148 (53.8%)	214 (55.2%)	
Smoking	592 (8.8%)	128 (8.2%)	218 (9.2%)	222 (9.6%)	133 (8.8%)	64 (9.0%)	25 (9.1%)	37 (9.5%)	.91
Medical comorbidities									
Chronic obstructive pulmonary disease	320 (4.8%)	61 (3.9%)	103 (4.4%)	105 (4.6%)	74 (4.9%)	18 (2.5%)	9 (3.3%)	24 (6.2%)	.08
Peripheral vascular disease	279 (4.2%)	31 (2.0%)	40 (1.7%)	68 (2.9%)	50 (3.3%)	8 (1.1%)	5 (1.8%)	13 (3.4%)	<.001
Congestive heart failure	59 (0.9%)	17 (1.1%)	23 (1.0%)	24 (1.0%)	19 (1.3%)	3 (0.4%)	5 (1.8%)	10 (2.6%)	.03
Myocardial infarction	79 (1.2%)	21 (1.4%)	31 (1.3%)	27 (1.2%)	14 (0.9%)	5 (0.7%)	2 (0.7%)	2 (0.5%)	.68
Cerebrovascular disease	503 (7.5%)	91 (5.9%)	132 (5.9%)	180 (7.8%)	161 (10.7%)	74 (10.5%)	38 (13.8%)	72 (18.6%)	<.001
Hemiplegia	265 (4.0%)	81 (5.2%)	115 (4.9%)	105 (4.6%)	108 (7.2%)	54 (7.6%)	27 (9.8%)	59 (15.2%)	<.001
Dementia	7 (0.1%)	6 (0.4%)	4 (0.2%)	7 (0.3%)	0 (0.0%)	3 (0.4%)	2 (0.7%)	1 (0.3%)	.02
Peptic ulcer disease	11 (0.2%)	5 (0.3%)	3 (0.1%)	7 (0.3%)	0 (0.0%)	1 (0.1%)	1 (0.4%)	1 (0.3%)	.39
Mild liver disease	24 (0.4%)	10 (0.6%)	14 (0.6%)	13 (0.6%)	5 (0.3%)	4 (0.6%)	2 (0.7%)	6 (1.5%)	.05
Moderate/Severe liver disease	3 (0.0%)	1 (0.1%)	1 (0.0%)	3 (0.1%)	1 (0.1%)	0 (0.0%)	0 (0.0%)	2 (0.5%)	.05
Moderate/Severe renal disease	70 (1.0%)	20 (1.3%)	27 (1.1%)	26 (1.1%)	25 (1.7%)	14 (2.0%)	4 (1.5%)	7 (1.8%)	.25
Uncomplicated diabetes Mellitus	313 (4.7%)	60 (3.9%)	122 (5.2%)	104 (4.5%)	68 (4.5%)	27 (3.8%)	18 (6.5%)	19 (4.9%)	.42
Complicated diabetes mellitus	26 (0.4%)	8 (0.5%)	12 (0.5%)	9 (0.4%)	12 (0.8%)	5 (0.7%)	1 (0.4%)	1 (0.3%)	.52
Cancer without metastases	308 (4.6%)	104 (6.7%)	171 (7.2%)	171 (7.4%)	114 (7.6%)	57 (8.1%)	18 (6.5%)	23 (5.9%)	<.001
Cancer with metastases	134 (2.0%)	43 (2.8%)	74 (3.1%)	65 (2.8%)	48 (3.2%)	26 (3.7%)	5 (1.8%)	8 (2.1%)	.01
AIDS	3 (0.0%)	2 (0.1%)	2 (0.1%)	4 (0.2%)	2 (0.1%)	2 (0.3%)	1 (0.4%)	0 (0.0%)	.32
Average comorbidities per patient	0.4 (0.8)	0.4 (0.8)	0.4 (.08)	0.4 (.08)	0.5 (0.9)	0.4 (0.8)	0.5 (0.9)	0.6 (1.0)	<.001
Surgical category									<.001
Acoustic surgeries	154 (2.3%)	6 (0.4%)	9 (0.4%)	9 (0.4%	3 (0.2%)	1 (0.1%)	1 (0.4%)	0 (0.0%)	
Spinal fusion surgeries	1496 (22.3%)	213 (13.7%)	426 (18.0%)	359 (15.6%)	170 (11.3%)	74 (10.5%)	33 (12.0%)	39 (17.8%)	
Spinal decompression surgeries	974 (14.5%)	187 (12.0%)	364 (15.4%)	348 (15.1%)	193 (12.8%)	101 (14.3%)	33 (12.0%)	39 (10.1%)	
Cranial decompression surgeries	1717 (25.6%)	425 (27.3%)	503 (21.3%)	513 (22.2%)	307 (20.4%)	145 (20.5%)	84 (30.5%)	163 (42.0%)	
Cerebrovascular surgeries	549 (8.2%)	52 (3.3%)	91 (3.8%)	119 (5.2%)	82 (5.4%)	24 (3.4%)	9 (3.3%)	11 (2.8%)	
Peripheral nerve surgeries	693 (10.3%)	293 (18.9%)	305 (12.9%)	319 (13.8%)	175 (11.6%)	68 (9.6%)	15 (5.5%)	4 (1.0%)	
Endonasal surgeries	359 (5.4%)	75 (4.8%)	131 (5.5%)	52 (2.3%)	35 (2.3%)	5 (0.7%)	1 (0.4%)	2 (0.5%)	
Endoscopic surgeries	46 (0.7%)	7 (0.5%)	35 (1.5%)	41 (1.8%)	27 (1.8%)	4 (0.6%)	1 (0.4%)	0 (0.0%)	
Minor surgeries	716 (10.4%)	296 (19.0%)	502 (21.2%)	547 (23.7%)	513 (34.1%)	286 (40.4%)	98 (35.6%)	130 (33.5%)	
Length of surgery (min)	305.5 (186.5)	238.5 (158.1)	225.7 (131.7)	216.8 (120.9)	190.3 (105.9)	186.5 (95.6)	183.2 (84.1)	203.4 (111.7)	<.001
Complications	355 (5.3%)	70 (4.5%)	99 (4.2%)	106 (4.6%)	66 (4.4%)	34 (4.8%)	13 (4.7%)	42 (10.8%)	<.001

TABLE 3. Type of Neurosurgical Case

	07:01-09:00 n = 6704	09:01-11:00 n = 1554	11:01-13:00 n = 2366	13:01-15:00 n = 2307	15:01-17:00 n = 1505	17:01-19:00 n = 708	19:01-21:00 n = 275	21:01-07:00 n = 388	*P*-value
Type of procedure									<.001
Elective	6498 (96.9%)	1421 (91.4%)	2159 (91.3%)	2070 (89.7%)	1246 (82.8%)	486 (68.6%)	129 (46.9%)	56 (14.4%)	
Emergent	206 (3.1%)	133 (8.6%)	207 (8.7%)	237 (10.3%)	259 (17.2%)	222 (31.4%)	146 (53.1%)	332 (85.6%)	

the surgeries could be explained by the fact that the percentage of minor surgeries completed between 21:01 and 07:00 was higher compared to 07:01 to 09:00 (33.5% vs 10.4%, $P < .001$; Table 1). However, since the complication rate was also higher, it is possible that the shorter surgery length could be the result of physician fatigue with subsequently hasty work.[5,9] This is contradictory to previous studies that demonstrated that complication rates increased with longer surgical lengths.[18-19] In addition, those with a later SST and more complications tended to be younger patients, which also contradicts prevailing thought.[20] This is important because it emphasizes that even with both of these protective factors—shorter length of surgery and younger patient population—the complication rate was still significantly increased for patients with an SST between 21:01 and 07:00.

TABLE 4. Type of Complication for SST 21:01 to 07:00

Age	Gender	Procedure type	Complication type	Complication severity
50	Male	CDS	Infection—wound	2
60	Male	CDS	Pulmonary embolism	3
67	Female	CDS	Vascular injury	2
68	Male	CDS	Respiratory failure	3
86	Female	CDS	Hemorrhage—intracranial	3
47	Male	CDS	Hemorrhage—intracranial	3
81	Male	CDS	Pneumothorax	2
61	Male	CDS	Hemorrhage—intracranial	3
55	Male	CDS	Shunt malfunction	2
60	Female	CDS	Cerebral edema	3
64	Male	CDS	Hemorrhage—intracranial	3
73	Female	CDS	Hemorrhage—intracranial	3
9	Male	CDS	Hemorrhage—intracranial	3
57	Female	CDS	CSF leak—cranial	2
64	Male	CDS	Vascular injury	3
43	Female	CDS	New deficit—spinal cord	3
27	Male	CDS	Hemorrhage—intracranial	3
22	Female	CDS	Hemorrhage—intracranial	3
41	Female	CDS	Infection—wound	2
5	Male	CDS	New deficit—cortical/subcortical	3
31	Female	CDS	Other	1
55	Male	CVS	DEATH—NOT moribund on admit	3
14	Male	MS	DEATH—NOT moribund on admit	3
55	Male	MS	Hemorrhage—intracranial	3
64	Male	MS	Shunt malfunction	2
24	Male	MS	Infection—shunt	3
28	Male	MS	Other	1
16	Female	MS	Infection— intracerebral abscess	3
16	Female	MS	Infection—meningitis/ventriculitis	3
17	Male	MS	Infection—shunt	3
33	Male	MS	Infection—shunt	3
1	Male	MS	Infection—shunt	3
45	Male	MS	New deficit—spinal cord	3
20	Male	MS	Other	1
2	Female	MS	Shunt malfunction	2
1	Female	MS	Wound dehiscence	2
14	Female	PNS	Infection—device	2
45	Male	PNS	Other	1
10	Male	SDS	CSF leak—spinal	2
63	Male	SDS	Anesthesia related	2
7	Male	SDS	New deficit—spinal cord	3
16	Male	SFS	Infection—wound	2

CDS, cranial decompression surgery; CVS, cerebrovascular surgery; MS, minor surgery; PNS, peripheral nerve surgery; SDS, spinal decompression surgery; SFS, spinal fusion surgery.

The Conditional Severity model demonstrated that the SST does not significantly predict the severity of the complication. In other words, after-hour complications are not any more or less severe than nonafter-hour complications; however, they are much more common. We also found that complications were more likely if the operation was emergent compared to elective and that complications increased with each medical comorbidity. This trend was particularly notable with severe complications. Emergent cases were more than twice as likely to have a severe complication compared to elective cases and each comorbidity increased the odds for a severe complication (OR 1.14). Though not statistically significant, there was a trend towards more severe complications with SST between 21:01 and 07:00 ($P = .08$). Given that the magnitude of the association is similar to that in the Baseline model, the lack of significance for severe complications may represent inadequate statistical power as a result of an insufficient number of severe complications.

A recent single institution retrospective analysis at a Canadian hospital evaluating 30-d mortality in those undergoing elective and emergent surgical procedures has revealed that those patients operated on at night were 2.17 times more likely to die within the first 30 d of admission than those operated on during day hours. Those undergoing surgical procedures later in the day were 1.43 times more likely to die within 30 d of admission as compared to those undergoing procedures early in the day. These data were presented at the World Congress of Anesthesiologists in Hong Kong and have yet to be published in a peer-reviewed journal (Wang N, Tessler MJ, Charland L, unpublished data, 2016). Nonetheless, these results are in alignment with our findings that nighttime leads to more complications. The above-mentioned study could be biased by the fact that night-time surgeries are usually performed on patients who are in extremis and clinically unstable as compared to elective surgeries, which are mostly performed during day hours. However, our study has not only shown that mortality is higher during night surgery but also that the occurrence of surgical complications increases.

There are studies that have counteracted the notion of nighttime surgery as a risk factor of operative complications and mortality. George et al[21] have reported that 1-yr survival in patients undergoing heart and lung transplant did not vary in relation to when the transplant was performed. While so many surgical procedures have been shown to have worse outcome when performed at night, George et al[21] explains that transplant surgeries may vary secondary to the fact that surgical teams consisting of transplant surgeons, nurses, and perfusionists frequently work together at nighttime in performing these procedures. Thus, the authors raise the possibility that the transplant teams may have overcome the previously identified pitfalls encountered during night-time surgery: surgical fatigue, nondisease specific nursing and anesthesia teams, and reliance on resident staff.[12-14] The transplant model is very different from the neurosurgical model as there is a whole host of neurosurgical procedures performed during late hours. Thus, the ability for an emergent team to become accustomed to 1 particular procedure in the case of a transplant cannot be duplicated in the neurosurgical world where there are numerous procedure types being performed by numerous neurosurgeons who may not have subspecialization in the particular neurosurgical procedure they are managing at night hours. In addition to this unique aspect of neurosurgery, features common to many areas of medicine could potentially account for the increased morbidity associated with patients undergoing neurosurgical procedures at nighttime. Surgeon fatigue is a realistic consideration when elucidating complications and its relation to late SST.[5,9] In addition, residents tend to be more involved in patient care overnight than attending surgeons, although attendings are always present for the actual operation, the preoperative work-up could be delayed or ineffective due to the lack of experience by resident staff. A greater proportion of patients undergoing overnight operations had more comorbidities as compared to patients undergoing surgical procedures during day-time hours, and thus, this could possibly account for an increased complication rate. The above-described factors in combination with the lack of the usual, dedicated surgical team are all potential explanations for an increased complication rate for surgeries with a later SST.

Future studies are needed to quantify the effect of SST on M&M. We plan to make use of the American College of Surgeons National Surgical Quality Improvement Program to increase the sample size and allow for an improved analysis of more granular details. With the basis that SSTs between 21:01 and 07:00 increases the odds of morbidity, it is important to delve deeper and examine the effect of day of the week (weekday vs weekend) as well as separating out M&M data. It would also be interesting to do a similar study by isolating the elective cases and determining the effect of time-of-day or weekday vs weekend effects with strictly elective procedures. Unfortunately, a randomized controlled trial is not especially practical to address this question as majority of surgeons and operating room staff would likely resist having operations randomly assigned to have an SST between 21:01 and 7:00.

Limitations

The retrospective nature of this analysis could have caused us to have an incomplete sample size, as it is possible that surgical cases were inappropriately classified in the operating room and thus would not have appeared in our population. If this did occur, we anticipate that this number would be so small that it would not affect the results. In addition, there is a potential for missed complications due to the self-reported nature of the M&M reports. However, due to our institute's emphasis on reporting even minor complications, we do not believe that a significant number of complications were missed. With our current dataset, we were also unable to tease out specific reasons "elective" procedures were performed overnight and not simply delayed to a future day, though busy operating room schedules and surgeon preference could account for some of this anomaly. In addition, our study is not able to decipher the reasons that led to a much higher incidence of complications associated with procedures performed at night. It is possible that the higher complication rate overnight could be secondary to the fact that there are a higher percentage of cases, either of a specific procedure type or of an emergent nature, overnight that drives the complication rate up. The current study was underpowered to determine a significant interaction between these variables, but this represents a good topic for future investigation. Additionally, there are potential unmeasured confounders, such as severity of a comorbid condition, for which we have not accounted. Future studies will be necessary in defining the causative variables toward the goal of improving clinical outcome in patients undergoing surgery at nighttime.

CONCLUSION

Neurosurgical patients with SSTs between 21:01 and 07:00 are at an increased risk of developing surgery-related complications compared to patients with an SST earlier in the day. Further analysis is necessary to understand such relationship and the possibility of reducing the number of surgeries during the 21:01 to 07:00 time period.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

This important study has demonstrated that surgical start-time between 2100 and 0700 hours are correlated with a higher burden of complications. While the study is admittedly underpowered, it still offers an important warning around an identifiable patient risk factor. Two responses are called for: careful efforts at safety engineering to uncover and address systematic risks that might appear or intensify during this time period, and additional monitoring and analysis to identify subpopulations of patients with specific (and addressable) vulnerabilities to systematic or nonsystematic risks. Efforts of this nature are common in industry – in reducing workplace accidents, for example, and in nuclear power. Such efforts require independence, but never so much so as to disregard and discard the expertise of those involved.

This problem is an excellent example of the power of descriptive and predictive analytics. A problem cannot be addressed properly until it is identified and defined. Just as the automobile insurance industry has invested heavily in research around automotive safety, one would imagine medical liability carriers should find it in their best interests to do the same in this instance.

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