Managing overlapping surgery: an analysis of 1018 neurosurgical and spine cases

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OBJECTIVE Overlapping surgery—the performance of parts of 2 or more surgical procedures at the same time by a single lead surgeon—has recently come under intense scrutiny, although data on the effects of overlapping procedures on patient outcomes are lacking. The authors examined the impact of overlapping surgery on complication rates in neurosurgical patients.

METHODS The authors conducted a retrospective review of consecutive nonemergent neurosurgical procedures performed during the period from May 12, 2014, to May 12, 2015, by any of 5 senior neurosurgeons at a single institution who were authorized to schedule overlapping cases. Overlapping surgery was defined as any case in which 2 patients under the care of a single lead surgeon were under anesthesia at the same time for any duration. Information on patient demographics, premorbid conditions, surgical variables, and postoperative course were collected and analyzed. Primary outcome was the occurrence of any complication from the beginning of surgery to 30 days after discharge. A secondary outcome was the occurrence of a serious complication—defined as a life-threatening or life-ending event—during this same period.

RESULTS One thousand eighteen patients met the inclusion criteria for the study. Of these patients, 475 (46.7%) underwent overlapping surgery. Two hundred seventy-one patients (26.6%) experienced 1 or more complications, with 134 (13.2%) suffering a serious complication. Fourteen patients in the cohort died, a rate of 1.4%. The overall complication rate was not significantly higher for overlapping cases than for nonoverlapping cases (26.3% vs 26.9%, $p = 0.837$), nor was the rate of serious complications (14.7% vs 11.8%, $p = 0.168$). After adjustments for surgery type, surgery duration, body mass index, American Society of Anesthesiologists (ASA) physical classification grade, and intraoperative blood loss, overlapping surgery remained unassociated with overall complications (OR 0.810, 95% CI 0.592–1.109, $p = 0.189$). Similarly, after adjustments for surgery type, surgery duration, body mass index, ASA grade, and neurological comorbidity, there was no association between overlapping surgery and serious complications (OR 0.979, 95% CI 0.661–1.449, $p = 0.915$).

CONCLUSIONS In this cohort, patients undergoing overlapping surgery did not have an increased risk for overall complications or serious complications. Although this finding suggests that overlapping surgery can be performed safely within the appropriate framework, further investigation is needed in other specialties and at other institutions.

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KEY WORDS overlapping surgery; complications; neurosurgery; outcome; surgical technique

THE practice of overlapping surgery—in which a single lead surgeon is responsible for 2 cases at the same time—has been brought under intense scrutiny since it was highlighted in the *Boston Globe* in late 2015.¹ Although it is a long-standing and common occurrence in academic medical centers,³ public perception of overlapping

surgery has led to heated debate over the safety and ethics of the practice.^{11,23} Assessment of overlapping surgery is made more difficult by the lack of data on its impact on complications and outcomes. In this study, we examined our institutional experience with overlapping surgery in the neurosurgical population and its effect on complication rates.

ABBREVIATIONS ASA = American Society of Anesthesiologists; BMI = body mass index.

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Methods

Study Population

With approval from the University of Utah Institutional Review Board, we performed a retrospective chart review of all cases performed between May 12, 2014, and May 12, 2015, by any of 5 neurosurgeons at our institution who were authorized to run overlapping surgeries. Patients younger than 10 years of age were excluded from this study, as were cases performed on weekends since they are essentially never performed in an overlapping fashion. “Emergent” cases were also excluded as these were almost exclusively nonoverlapping and had high rates of adverse events given the patient condition on presentation. In the rare instance in which an emergent case overlapped with an elective or urgent case, the elective or urgent case was also excluded from our analysis.

Data Collection

A comprehensive review of the medical record, including operative reports, inpatient progress notes, discharge summaries, and follow-up clinic notes, was conducted. Patient characteristics such as demographics, comorbidities, operative variables, postoperative course, and complications were recorded for each included case.

Demographic variables consisted of age, sex, race and/or ethnicity, body mass index (BMI), and insurance type (private, Medicaid/self-pay, or Medicare). Assessed comorbidities included the American Society of Anesthesiologists (ASA) physical classification grade; active tobacco, alcohol, or illicit drug use; preoperative corticosteroid use; cardiovascular comorbidities (for example, atrial fibrillation, coronary artery disease); pulmonary comorbidities (for example, obstructive sleep apnea, asthma); hepatobiliary comorbidities (for example, cirrhosis, hepatitis); renal comorbidities (for example, chronic kidney disease); diabetes; and hypertension. Patients were also assessed for neurological comorbidities (for example, stroke, multiple sclerosis), but they were included only if the neurological condition was not the indication for surgical intervention. Finally, patients were assessed for oncological comorbidities (that is, the presence of active cancer or ongoing cancer treatment), but again these were only included if the oncological condition was not the indication for surgical intervention.

Operative variables consisted of surgery type (divided into 1 of 10 subcategories), the attending neurosurgeon (dichotomized based on postresidency practice > or < 20 years), the level of training of the resident or fellow assisting during the operation (dichotomized into “junior” and “senior” assistants, with the latter defined as postgraduate year 7 and above), the start time of the operation (defined based on the start of anesthesia), the duration of surgery (defined based on the start and end time of anesthesia), and intraoperative blood loss. The surgery scheduling category (elective vs urgent) was also recorded. Elective cases at our institution are defined as operations booked more than 24 hours prior to the start of the surgery, whereas urgent cases begin less than 24 hours after being added to the schedule but are not immediately life-threatening in nature. Postoperative course data included length of stay postsurgery and discharge destination.

Each case was dichotomized into overlapping or nonoverlapping, with overlapping defined as any case in which 2 patients under the care of a single lead surgeon were under anesthesia at the same time. For each surgery, the amount of time during which cases overlapped was recorded.

For this study, a complication was defined as any deviation from the expected intraoperative or postoperative course (Table 1).⁵ Complications were divided into intraoperative, postoperative, and those occurring within 30 days of discharge. Complications were graded in severity based on a modified Clavien-Dindo scale⁸ as proposed by Landriel Ibañez et al.¹³ for neurosurgical complications. Briefly, this classification has 4 categories: Grade I, complications that are not life-threatening and do not require invasive treatment; Grade II, events requiring invasive surgical, endoscopic, or endovascular interventions; Grade III, life-threatening events that require intensive care management; and Grade IV, complications resulting in death. For our analysis, Grade 0 signified no identified complications. In patients with multiple complications, the highest-grade complication was recorded.

Outcomes

Our primary outcome was the occurrence of any complication from the time of surgery to 30 days after discharge. Our secondary outcome was the occurrence of “serious complications” (Grade II or higher) during this same period. Particular attention was paid to the association between overlapping surgery and each outcome measure in our analysis.

Statistical Analysis

Continuous variables in all cases were analyzed using the Student t-test, whereas categorical variables were analyzed using chi-square analysis. Univariate analysis was first performed on the overlapping surgery variable to assess the differences between groups. We then performed a univariate analysis to determine what factors were associated with any complications during surgery, postoperatively, or in the first 30 days after discharge. Finally, we performed a univariate analysis to determine what factors were associated with life-threatening (Grade II or higher) complications during this period.

Variables with a $p < 0.2$ on univariate analysis were included in a forward, stepwise, multivariable regression model with an entry cutoff of 0.05 and a removal cutoff of 0.20. A separate model was constructed for both overall complications and serious complications. The overlapping variable was included in both multivariable models regardless of p . In all analyses, $p < 0.05$ was considered statistically significant. All statistical analysis was performed using SPSS version 20.0 (IBM Corp.).

Results

Of 1101 cases performed by the 5 neurosurgeons during the study period, 1018 (92.5%) met the criteria for inclusion. Forty-four cases were excluded because they were classified as emergent, 33 cases because they occurred on a weekend, 3 cases because the patients were younger than 10 years old at the time of surgery, and 3 cases because

TABLE 1. Representative complications and grades

Grade	Intraoperatively	Postoperatively	w/in 30 Days of Discharge
I	Blood loss requiring blood transfusion; dural tear repaired intraoperatively; venous/visceral tear repaired intraoperatively	Anemia requiring blood transfusion; urinary tract infection treated w/ antibiotics; pneumonia treated w/ antibiotics	Nausea/vomiting requiring admission for fluids & antiemetics; urinary tract infection treated w/ antibiotics; hyponatremia/syndrome of inappropriate antidiuretic hormone
II	Vertebral artery injury necessitating angiogram, no treatment; intraop hypotension leading to case abortion & return to OR at later date	Ventricular shunt failure requiring revision in OR; CSF leak requiring CSF diversion; pseudo-meningocele requiring CSF diversion/wound revision	Ventricular shunt failure requiring revision in OR; CSF leak requiring CSF diversion; wound infection requiring washout in OR
III	Carotid artery injury resulting in stroke; vertebral artery injury necessitating angiogram & endovascular treatment; intraventricular hemorrhage	Respiratory failure necessitating reintubation; persistent postop hemiparesis/hemiplegia (>30 days); epidural/subdural/intraparenchymal hemorrhage requiring op evacuation	Respiratory failure necessitating reintubation; delayed hydrocephalus necessitating emergent external ventricular drain placement; meningitis/abscess/subdural empyema
IV	Aneurysm rupture resulting in death	Cerebral edema resulting in death; status epilepticus resulting in death; intraparenchymal hemorrhage resulting in death	Intraparenchymal hemorrhage resulting in death; septic shock resulting in death

OR = operating room.

The 3 most common complications for each grade during each time period are listed. In cases in which fewer than 3 complications within a grade occurred during the time period, all complications are listed.

they were elective or urgent cases that overlapped with an emergent case.

Overlapping Versus Nonoverlapping Surgery Analysis

Demographically, patients undergoing overlapping surgery were similar in age (52.7 ± 17.0 vs 52.8 ± 16.1 years, $p = 0.907$), sex (50.3% vs 54.7% male, $p = 0.163$), rates of private insurance use (50.9% vs 57.6%, $p = 0.068$), and BMI (28.6 ± 7.1 vs 28.5 ± 6.3 kg/m², $p = 0.754$) compared with those having nonoverlapping surgery (Table 2). White patients were more likely to undergo nonoverlapping operations (91.0% vs 86.5%, $p = 0.006$) than non-whites. In terms of comorbidities, patients in the 2 groups were similar except that overlapping surgery patients had a higher ASA grade (52.2% vs 44.9% with an ASA Grade III and 7.6% vs 5.7% with an ASA Grade IV or V, $p = 0.012$), a lower rate of alcohol use (29.7% vs 36.3%, $p = 0.026$), and a higher incidence of neurological comorbidities (18.5% vs 12.5%, $p = 0.008$).

Compared with patients having nonoverlapping surgeries, those undergoing overlapping surgery were significantly less likely to be undergoing spinal surgery (either instrumented or non-instrumented) and were more likely to be undergoing a craniotomy or transnasal approach for tumor resection ($p < 0.001$). Attending physicians with more than 20 years' postresidency experience were more likely to undertake overlapping cases than those with less experience ($p < 0.001$).

The average start time for overlapping cases was 37 minutes later than that for nonoverlapping cases ($p = 0.002$), although neither the duration of surgery nor the estimated blood loss differed significantly between the 2 groups. The average overlap time for overlapping cases was 197.5 ± 113.4 minutes (95% CI 187.34–207.73). Regardless of case overlap, patients spent similar periods in the hospital postoperatively, and the majority of patients in both groups were discharged to home.

There were no significant differences in intraoperative,

postoperative, or 30-day complication rates when comparing the overlapping and nonoverlapping surgery groups. Neither was the severity of complications significantly different between these 2 groups.

All Complications Analysis

Patients experiencing complications at any point during the intraoperative period, postoperative period, or within the first 30 days after discharge tended to be older ($p = 0.016$) and to have a lower BMI ($p = 0.010$) than those who did not have any complications. Moreover, patients with complications also had significantly higher ASA grades ($p < 0.001$) and were more likely to have had a craniotomy or transnasal approach for tumor resection, a bur hole craniotomy, an instrumented spinal procedure, or a craniotomy for a nonvascular or nonneoplastic pathology than a non-instrumented spinal procedure and shunt procedure ($p < 0.001$). Patients experiencing complications tended to have significantly longer operative times ($p < 0.001$) and to lose more blood during the case ($p < 0.001$). They were also more likely to have a prolonged stay postoperatively ($p < 0.001$) and to be discharged to a location other than home ($p < 0.001$). There was no significant difference in the incidence of overlapping surgery between patients with and without complications (46.1% vs 46.8%, $p = 0.837$).

In our multivariable model (Table 3), surgery type remained significantly associated with the overall complication rate ($p = 0.001$), as did a longer operative time (OR 1.003, 95% CI 1.001–1.005, $p = 0.001$), higher intraoperative blood loss (OR 1.001, 95% CI 1.001–1.002, $p < 0.001$), and higher ASA grade ($p < 0.001$). Higher BMI was associated with a lower incidence of overall complications (OR 0.957, 95% CI 0.934–0.981, $p < 0.001$). We were particularly interested in the impact of overlapping surgery. In our multivariate model, overlapping surgery was not associated with the risk of complications (OR 0.810, 95% CI 0.592–1.109, 0.189).

To account for the range of overlap times between over-

TABLE 2. Univariate analyses of overlapping surgery, any complication, and serious complications

Variable	Nonoverlapping Surgery	Overlapping Surgery	p Value	No Complication	Any Complication	p Value	No Serious Complication*	Serious Complication*	p Value
No. of cases	543	475		747	271		884	134	
Mean age in yrs	52.8 ± 16.1	52.7 ± 17.0	0.907	52.0 ± 16.5	54.8 ± 16.4	0.016	52.4 ± 16.5	55.2 ± 16.1	0.066
Male sex (%)	297 (54.7)	239 (50.3)	0.163	384 (51.4)	152 (56.1)	0.186	458 (51.8)	78 (58.2)	0.167
Race/ethnicity (%)									
White	494 (91.0)	411 (86.5)	0.006	671 (89.8)	234 (86.3)	0.163	781 (88.3)	124 (92.5)	0.838
Hispanic/Latino	17 (3.1)	36 (7.6)		38 (5.1)	15 (5.5)		49 (5.5)	4 (3.0)	
African American	4 (0.7)	0 (0)		4 (0.5)	0 (0)		4 (0.4)	0 (0)	
Asian	6 (1.1)	4 (0.8)		7 (0.9)	3 (1.1)		9 (1.0)	1 (0.7)	
American Indian	5 (0.9)	8 (1.7)		8 (1.1)	5 (1.8)		12 (1.4)	1 (0.7)	
Hawaiian/Pacific Islander	2 (0.4)	6 (1.3)		3 (0.4)	5 (1.8)		7 (0.8)	1 (0.7)	
Other/unknown	15 (2.8)	10 (2.1)		16 (2.1)	9 (3.3)		22 (2.5)	3 (2.2)	
Mean BMI in kg/m ²	28.5 ± 6.3	28.6 ± 7.1	0.754	28.9 ± 6.6	27.6 ± 6.7	0.010	28.7 ± 6.6	27.5 ± 7.1	0.060
Insurance type (%)									
Private	313 (57.6)	242 (50.9)	0.068	419 (56.1)	136 (50.2)	0.240	485 (54.9)	70 (52.2)	0.772
Medicaid/self-pay	52 (9.6)	61 (12.8)		81 (10.8)	32 (11.8)		96 (10.8)	17 (12.7)	
Medicare	178 (32.8)	172 (36.2)		247 (33.1)	103 (38.0)		303 (34.3)	47 (35.1)	
ASA grade (%)									
I or II	268 (49.4)	191 (40.2)	0.012	370 (49.5)	89 (32.8)	<0.001	422 (47.7)	37 (27.6)	<0.001
III	244 (44.9)	248 (52.2)		346 (46.3)	146 (53.9)		415 (46.9)	77 (57.5)	
IV or V	31 (5.7)	36 (7.6)		31 (4.1)	36 (13.3)		47 (5.3)	20 (14.9)	
Tobacco use (%)	61 (11.2)	59 (12.4)	0.558	93 (12.4)	27 (10.0)	0.277	108 (12.2)	12 (9.0)	0.275
Alcohol use (%)	197 (36.3)	141 (29.7)	0.026	260 (34.8)	78 (28.8)	0.071	297 (33.6)	41 (30.6)	0.492
Illicit drug use (%)	30 (5.5)	24 (5.1)	0.737	42 (5.6)	12 (4.4)	0.452	50 (5.7)	4 (3.0)	0.199
Preop corticosteroid use (%)	73 (13.4)	71 (14.9)	0.492	104 (13.9)	40 (14.8)	0.735	122 (13.8)	22 (16.4)	0.418
Cardiovascular comorbidity (%)	84 (15.5)	83 (17.5)	0.389	121 (16.2)	46 (17.0)	0.768	148 (16.7)	19 (14.2)	0.455
Pulmonary comorbidity (%)	177 (32.6)	135 (28.4)	0.149	238 (31.9)	74 (27.3)	0.164	277 (31.3)	35 (26.1)	0.222
Hepatobiliary comorbidity (%)	17 (3.1)	17 (3.6)	0.691	20 (2.7)	14 (5.2)	0.051	30 (3.4)	4 (3.0)	0.806
Renal comorbidity (%)	14 (2.6)	7 (1.5)	0.216	13 (1.7)	8 (3.0)	0.229	18 (2.0)	3 (2.2)	0.878
Neurological comorbidity (%)	68 (12.5)	88 (18.5)	0.008	105 (14.1)	51 (18.8)	0.062	123 (13.9)	33 (24.6)	0.001
Oncological comorbidity (%)	69 (12.7)	59 (12.4)	0.891	86 (11.5)	42 (15.5)	0.090	105 (11.9)	23 (17.2)	0.085
Diabetes (%)	63 (11.6)	58 (12.2)	0.765	84 (11.2)	37 (13.7)	0.294	103 (11.7)	18 (13.4)	0.553
Hypertension (%)	209 (38.5)	170 (35.8)	0.374	275 (36.8)	104 (38.4)	0.649	330 (37.3)	49 (36.6)	0.865
Surgery category (%)									
Craniotomy for tumor, simple	72 (13.2)	83 (17.5)	<0.001	104 (13.9)	51 (18.8)	<0.001	125 (14.1)	30 (22.4)	<0.001
Craniotomy for tumor, complex	22 (4.0)	30 (6.3)		27 (3.6)	25 (9.2)		36 (4.1)	16 (11.9)	
Craniotomy for aneurysm/vascular malformation	15 (2.8)	20 (4.2)		24 (3.2)	11 (4.0)		28 (3.2)	7 (5.2)	
Craniotomy for other	15 (2.8)	30 (6.3)		37 (5.0)	8 (3.0)		40 (4.5)	5 (3.7)	
Bur hole craniotomy	16 (2.9)	18 (3.8)		20 (2.7)	14 (5.2)		23 (2.6)	11 (8.2)	
Non-instrumented spine	104 (19.2)	45 (9.5)		135 (18.1)	14 (5.2)		142 (16.1)	7 (5.2)	

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TABLE 2. Univariate analyses of overlapping surgery, any complication, and serious complications

Variable	Nonoverlapping Surgery	Overlapping Surgery	p Value	No Complication	Any Complication	p Value	No Serious Complication*	Serious Complication*	p Value
Surgery category (%) (continued)									
Instrumented spine	159 (29.3)	81 (17.0)	<0.001	169 (22.6)	71 (26.2)	<0.001	220 (24.9)	20 (14.9)	<0.001
Transnasal approach for tumor	22 (4.0)	46 (9.7)		45 (6.0)	23 (8.5)		60 (6.8)	8 (6.0)	
Shunt	52 (9.6)	54 (11.4)		81 (10.8)	25 (9.2)		91 (10.3)	15 (11.2)	
Miscellaneous	66 (12.2)	68 (14.3)		105 (14.0)	29 (10.7)		119 (13.5)	15 (11.2)	
Senior attending (%)†	174 (32.0)	273 (57.5)	<0.001	336 (45.0)	111 (41.0)	0.253	390 (44.1)	57 (42.5)	0.731
Overlapping surgery (%)	0 (0)	475 (100)	—	350 (46.8)	125 (46.1)	0.837	405 (45.8)	70 (52.2)	0.165
Scheduling type (%)									
Elective	475 (87.5)	426 (89.7)	0.271	668 (89.4)	233 (86.0)	0.128	789 (89.2)	112 (83.6)	0.055
Urgent	68 (12.5)	49 (10.3)		79 (10.6)	38 (14.0)		95 (10.7)	22 (16.4)	
Assistant training level (%)‡									
Junior	298 (54.9)	241 (50.7)	0.186	416 (55.7)	123 (45.4)	0.004	475 (53.7)	64 (47.8)	0.197
Senior	245 (45.1)	234 (49.3)		331 (44.3)	148 (54.6)		409 (46.3)	70 (52.2)	
Mean start time	9:52 ± 3:14	10:29 ± 3:14	0.002	10:14 ± 3:16	9:56 ± 3:13	0.194	10:09 ± 3:14	10:10 ± 3:26	0.960
Mean duration of surgery in mins	276.4 ± 138.4	285.4 ± 133.6	0.294	260.9 ± 119.5	334.7 ± 162.4	<0.001	273.0 ± 129.4	330.8 ± 166.3	<0.001
Mean overlap time in mins	0 ± 0	197.5 ± 113.4	—	91.4 ± 123.9	94.4 ± 129.4	0.735	88.9 ± 123.1	113.7 ± 138.1	0.033
Mean estimated blood loss in ml	224.5 ± 434.6	187.9 ± 269.1	0.112	147.2 ± 208.6	373.3 ± 591.3	<0.001	193.1 ± 351.1	301.9 ± 449.3	0.001
Mean length of stay post-surgery in days	4.3 ± 4.3	4.7 ± 4.9	0.166	3.4 ± 3.2	7.4 ± 6.4	<0.001	3.8 ± 3.4	8.9 ± 7.9	<0.001
Discharge destination									
Home	372 (68.5)	321 (67.6)	0.744	584 (78.2)	109 (40.2)	<0.001	650 (73.5)	43 (32.1)	<0.001
Home health	20 (3.7)	28 (5.9)		32 (4.3)	16 (5.9)		38 (4.3)	10 (7.5)	
Acute rehab	84 (15.5)	71 (14.9)		68 (9.1)	87 (32.1)		104 (11.8)	51 (38.1)	
SNF	40 (7.4)	32 (6.7)		42 (5.6)	30 (11.1)		59 (6.7)	13 (9.7)	
LTAC	16 (2.9)	16 (3.4)		16 (2.1)	16 (5.9)		26 (2.9)	6 (4.5)	
Death	7 (1.3)	4 (0.8)		0 (0)	11 (4.0)		0 (0)	11 (8.2)	
Other	4 (0.7)	3 (0.6)		5 (0.7)	2 (0.7)		7 (0.8)	0 (0)	
Intraop complications (%)	36 (6.6)	21 (4.4)	0.126	0 (0)	57 (21.0)	—	38 (4.3)	19 (14.2)	—
Intraop complication grade (%)									
0	507 (93.4)	454 (95.6)	0.099	747 (100)	214 (79.0)	—	846 (95.7)	115 (85.8)	—
I	32 (5.9)	17 (3.6)		0 (0)	49 (18.1)		38 (4.3)	11 (8.2)	
II	2 (0.4)	0 (0)		0 (0)	2 (0.7)		0 (0)	2 (1.5)	
III	1 (0.2)	4 (0.8)		0 (0)	5 (1.8)		0 (0)	5 (3.7)	
IV	1 (0.2)	0 (0)		0 (0)	1 (0.4)		0 (0)	1 (0.7)	
Postop complications (%)	98 (18.0)	84 (17.7)	0.880	0 (0)	182 (67.2)	—	90 (10.2)	92 (68.7)	—
Postop complication grade (%)									
0	445 (82.0)	391 (82.3)	0.091	747 (100)	89 (32.8)	—	794 (89.8)	42 (31.3)	—
I	62 (11.4)	37 (7.8)		0 (0)	99 (36.5)		90 (10.2)	9 (6.7)	
II	8 (1.5)	12 (2.5)		0 (0)	20 (7.4)		0 (0)	20 (14.9)	
III	22 (4.1)	31 (6.5)		0 (0)	53 (19.6)		0 (0)	53 (39.6)	
IV	6 (1.1)	4 (0.8)		0 (0)	10 (3.7)		0 (0)	10 (7.5)	
30-day complications (%)	41 (7.6)	41 (8.6)	0.527	0 (0)	82 (30.3)	—	30 (3.4)	52 (38.8)	—
30-day complication grade (%)									
0	502 (92.4)	434 (91.4)	0.822	747 (100)	189 (69.7)	—	854 (96.6)	82 (61.2)	—

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TABLE 2. Univariate analyses of overlapping surgery, any complication, and serious complications

Variable	Nonoverlapping Surgery	Overlapping Surgery	p Value	No Complication	Any Complication	p Value	No Serious Complication*	Serious Complication*	p Value
30-day complications grade (%) (<i>continued</i>)									
I	15 (2.8)	16 (3.4)	0.822	0 (0)	31 (11.4)	—	30 (3.4)	1 (0.7)	—
II	17 (3.1)	13 (2.7)		0 (0)	30 (11.1)		0 (0)	30 (22.4)	
III	8 (1.5)	10 (2.1)		0 (0)	18 (6.6)		0 (0)	18 (13.4)	
IV	1 (0.2)	2 (0.4)		0 (0)	3 (1.1)		0 (0)	3 (2.2)	
Any complication (%)	146 (26.9)	125 (26.3)	0.837	0 (0)	271 (100)	—	137 (15.5)	134 (100)	—
Serious complication (%)*	64 (11.8)	70 (14.7)	0.168	0 (0)	134 (49.4)	—	0 (0)	134 (100)	—
Worst complication grade (%)									
0	397 (73.1)	350 (73.7)	0.172	747 (100)	0 (0)	—	747 (84.5)	0 (0)	—
I	82 (15.1)	55 (11.6)		0 (0)	137 (50.6)		137 (15.5)	0 (0)	
II	26 (4.8)	22 (4.6)		0 (0)	48 (17.7)		0 (0)	48 (35.8)	
III	30 (5.5)	42 (8.8)		0 (0)	72 (26.6)		0 (0)	72 (53.7)	
IV	8 (1.5)	6 (1.3)		0 (0)	14 (5.2)		0 (0)	14 (10.4)	

Home health = home with home health care; LTAC = long-term acute care facility; rehab = rehabilitation; SNF = skilled nursing facility; — = not applicable.

Mean values expressed with standard deviation. Boldface type indicates statistical significance ($p < 0.05$ is considered statistically significant).

* Serious complications were Grade II or higher.

† Senior attending had 20+ years postresidency experience.

‡ "Junior assistant" indicated that no resident was assisting or that the assistant was postgraduate year 6 or earlier. "Senior assistant" indicated a postgraduate year 7 assistant or a fellow.

lapping surgeries, we ran a supplemental analysis using the overlapping percentage (overlap time divided by total surgery duration) in our multivariable model of overall complications in place of the overlapping surgery variable. This had no influence on the factors significantly associated with the overall complication rate.

Serious Complications Analysis

In our univariate analysis, patients experiencing serious complications had significantly higher ASA grades ($p < 0.001$) than those who did not and were more likely to have preexisting neurological comorbidities ($p = 0.001$; Table 2). Serious complications were more frequently seen after craniotomies and bur hole procedures than after other surgical categories ($p < 0.001$). Patients who had a prolonged operative time ($p < 0.001$) and those with higher intraoperative blood loss ($p = 0.001$) also had a higher rate of serious complications. Although patients with an increased period of overlap with another surgery had a higher incidence of serious complications ($p = 0.033$), this finding may be attributable to the longer overall operative time in these patients. Postoperatively, patients experiencing serious complications tended to have a significantly longer stay ($p < 0.001$) and were significantly less likely to be discharged home ($p < 0.001$). There was no significant difference in the incidence of overlapping surgery between patients with and without serious complications (52.2% vs 45.8%, $p = 0.165$).

In our multivariable model (Table 4), surgery type ($p = 0.004$) remained significantly associated with the likelihood of serious complications. A longer operative period (OR 1.003, 95% CI 1.002–1.005, $p < 0.001$), the presence of a preoperative neurological comorbidity (OR 1.629, 95%

CI 1.009–2.629, $p = 0.046$), and a higher ASA grade ($p < 0.002$) were also risk factors for serious complications. Higher BMI was associated with a lower rate of serious complications (OR 0.969, 95% CI 0.940–0.998, $p = 0.038$). Once again, overlapping surgery was not associated with a higher rate of serious complications (OR 0.979, 95% CI 0.661–1.449, $p = 0.915$).

To account for the range of overlap times between overlapping surgeries, we ran a supplemental analysis using the overlapping percentage (overlap time divided by total surgery duration) in our multivariable model of serious complications in place of the overlapping surgery variable. This had no influence on the factors significantly associated with the serious complication rate.

Finally, we ran a similar analysis of factors associated with mortality (Grade IV complications) in our cohort. The only variables associated with mortality were a higher ASA grade ($p = 0.001$) and the presence of a preoperative oncological comorbidity (OR 12.033, 95% CI 3.007–48.152, $p < 0.001$). Overlapping surgery was not associated with mortality in this analysis (OR 0.427, 95% CI 0.118–1.536, $p = 0.193$).

Discussion

The use of overlapping surgery has recently become a contentious issue and will likely remain so as increased public awareness drives the topic into the realm of legislation.²⁰ The lack of data on the impact of overlapping surgery significantly hinders the ability of patients, physicians, and policy makers to reach informed conclusions. Our study marks the first analysis of the effects of overlapping surgery on complication rates. We found no associa-

TABLE 3. Multivariable regression analysis of any complication

Variable	OR (95% CI)	p Value
Surgery category		0.001
Craniotomy for tumor, simple	1.00 (reference)	—
Craniotomy for tumor, complex	1.170 (0.577–2.373)	0.663
Craniotomy for aneurysm/vascular malformation	0.882 (0.380–2.044)	0.770
Craniotomy for other	0.578 (0.239–1.396)	0.223
Bur hole craniotomy	2.694 (1.164–6.231)	0.021
Non-instrumented spine	0.422 (0.210–0.847)	0.015
Instrumented spine	0.859 (0.527–1.399)	0.541
Transnasal approach for tumor	2.547 (1.302–4.980)	0.006
Shunt	1.547 (0.818–2.927)	0.180
Miscellaneous	1.323 (0.708–2.472)	0.380
Overlapping surgery	0.810 (0.592–1.109)	0.189
Duration of surgery in mins	1.003 (1.001–1.005)	0.001
BMI	0.957 (0.934–0.981)	<0.001
ASA grade		<0.001
I or II	1.00 (reference)	—
III	1.545 (1.100–2.170)	0.012
IV or V	4.449 (2.450–8.079)	<0.001
Estimated blood loss in ml	1.001 (1.001–1.002)	<0.001

Boldface type indicates statistical significance ($p < 0.05$).

tion between overlapping surgery and rates of intraoperative, postoperative, and early postdischarge complications in our cohort. Furthermore, we found no significant association between overlapping surgery and life-threatening complications or mortality. Variables associated with overall complications and life-threatening complications included higher intraoperative blood loss and higher ASA grade, both of which are known independent predictors of adverse events.^{7,16,17,22} Although different surgery types, unsurprisingly, had varying complication rates, our multivariable model suggested that the dangers of these procedures are less likely to be associated with their overlapping with another operation and more likely to be associated with the nature of the surgeries themselves. For example, the increased complications noted for the transnasal approach are influenced by the readmission rate for delayed hyponatremia following pituitary surgery, which occurs in approximately 5% of patients undergoing pituitary tumor resection at our institution. Similarly, patients undergoing bur hole craniotomies frequently did so because they were deemed too unstable to undergo formal craniotomy, as evidenced by the fact that the average ASA grade for bur hole patients was significantly higher than for all other patients (3.14 vs 2.55, $p < 0.001$).

Overlapping surgery has played an important role in academic medicine for decades^{1,3} but only recently has it become a concern for the general public. Overlapping surgery is important in the training of future surgeons. The experience gained from a modicum of operative autonomy during training—autonomy that is earned through 100s of hours of intense interactions and meted out in a carefully graduated fashion—is crucial to producing safe physi-

TABLE 4. Multivariable regression analysis of serious complications

Variable	OR (95% CI)	p Value
Surgery category		0.004
Craniotomy for tumor, simple	1.00 (reference)	—
Craniotomy for tumor, complex	1.191 (0.550–2.581)	0.657
Craniotomy for aneurysm/vascular malformation	0.863 (0.335–2.224)	0.761
Craniotomy for other	0.583 (0.206–1.653)	0.310
Bur hole craniotomy	2.912 (1.175–7.213)	0.021
Non-instrumented spine	0.365 (0.148–0.896)	0.028
Instrumented spine	0.414 (0.219–0.783)	0.007
Transnasal approach for tumor	1.076 (0.445–2.600)	0.871
Shunt	1.155 (0.540–2.469)	0.711
Miscellaneous	0.959 (0.450–2.041)	0.913
Overlapping surgery	0.979 (0.661–1.449)	0.915
Duration of surgery in mins	1.003 (1.002–1.005)	<0.001
BMI	0.969 (0.940–0.998)	0.038
ASA grade		0.008
I or II	1.00 (reference)	—
III	1.520 (0.971–2.380)	0.067
IV or V	2.922 (1.474–5.792)	0.002
Neurological comorbidity	1.629 (1.009–2.629)	0.046

Boldface type indicates statistical significance ($p < 0.05$).

cians. Nearly half of the overlapping cases in our cohort were assisted either by residents in their 7th and final year of postgraduate education or by fellows who had already completed their neurosurgical residency. In contrast, fewer than 15% of overlapping cases in our cohort involved residents with any less than half a decade of postgraduate experience. The controlled operative autonomy that overlapping surgery can help to provide is invaluable to those who must one day become independent surgeons. The need to prepare the next generation of surgeons and the overriding primary directive of the practitioner to ensure that the patient receives optimal care often appear in conflict with one another;⁹ however, with proper discussion, disclosure, and mentorship, resident involvement has been shown to be both safe and acceptable to the public.^{4,6,18}

Fueling the need to train tomorrow's surgeons is the steadily worsening shortage of health care professionals nationwide.^{10,24,25} This shortage may be especially acute in neurosurgery, with the majority of counties in the United States having no neurosurgeons in practice. Access to highly subspecialized care is even more difficult, with only 13.4% of neurosurgeons identifying as neuro-oncology specialists, 5.2% as cerebrovascular specialists, and 0.7% as skull base specialists.¹² These low percentages contribute to protracted wait times for access to care.¹⁹ Of the 5 neurosurgeons in our cohort, all are highly subspecialized and may represent the only source of specialized neurosurgical care for hundreds of miles. Optimizing the use of both surgical expertise and medical facilities is essential to deliver efficient and high-quality care to patients.³ While the 475 overlapping surgeries analyzed in this cohort make

up only 10%–20% of the annual neurosurgical procedures performed at our institution, many of these surgeries are highly specialized in nature. The elimination of overlapping surgery would probably have an outsized impact on patient care, possibly leading to higher costs, increased delays from referral to treatment, and a greater proportion of operations starting after-hours.³

Our study has several limitations. The retrospective nature of our analysis introduces a significant risk of confounding, although we attempted to control for as many variables as possible to ameliorate this risk. Any analysis of the association of complications to one particular variable is obscured by the difficulty in analyzing the root cause of the complication. By casting our net broadly and incorporating intraoperative, postoperative, and early postdischarge complications in our analysis, we may have included a large number of events that were unrelated to the practice of overlapping surgery. It is our hope, however, that by doing so we avoided missing significant adverse events. Although certain events such as wrong-site or wrong-side surgery may be more easily attributable to the distraction that can result from running multiple overlapping cases, the incidence of these complications is fortunately very low. Indeed, within our cohort, no wrong-site or wrong-side surgical errors occurred during the study period. The rarity of these complications makes studying them exceedingly difficult, and a dramatically larger cohort of patients would probably be needed to focus on any individual adverse event.

Perhaps the most significant limitation of our study is the restriction to a single center and a single subspecialty. Although we did not find any association with overlapping surgery and complications, it is impossible to broadly generalize our findings, nor do we advocate a laissez-faire approach to running multiple operating rooms.¹⁵ The American College of Surgeons recently released new guidelines regarding the topic of overlapping surgery.² Its statement distinguishes between “overlapping surgery” and “concurrent surgery.” The latter refers to operations in which “the critical or key components of the procedures for which the primary attending surgeon is responsible are occurring all or in part at the same time.”²² Overlapping surgery refers to a situation in which there is a clear staggering or separation of the critical components of ongoing surgeries. The guidelines highlight the importance of the surgeon’s undivided attention during the critical portion of every procedure, stress the need for discussions with patients regarding the team that will be involved in their care, and emphasize the fact that the “overriding goal is the assurance of patient safety.”

At our institution, regardless of the training level of the assistant, we adhere strictly to the principle that the attending physician of record must be present and actively involved in any critical portion of the case and that he or she frequently remains so throughout the majority of the operation. In addition, specific criteria are in place to determine which attending physicians can perform overlapping surgeries: 1) The lead physician must be an associate professor or above in academic rank; 2) the lead physician must be board certified in neurosurgery; 3) the lead physician must have at least 5 years of experience within the

University of Utah Department of Neurosurgery, regardless of prior practice and/or training; 4) the lead physician must be a subspecialist in the area of the overlapping cases; and 5) qualified assistants of the appropriate training level must be available in both rooms.

In addition to adhering to these restrictions, overlapping surgeries are carefully chosen with attention to multiple factors such as case complexity, schedules, patient characteristics, operating room staffing, and resident or fellow experience. During the study period, while conversations regarding the makeup of the operative team occurred routinely, the topic of overlapping surgery was not a formal part of our consent document. Pursuant to the goals of continuously improving care, we recently added this topic to our surgical consent forms and made discussions of overlapping surgery a standard part of the consent process.

Similar to other institutions, the view at our institution is that overlapping surgery should only be performed with such meticulous attention to detail and with full disclosure and discussion with the patient undergoing the procedure.^{14,21} It is likely that the minimal impact of overlapping surgery on complication rates in our study is attributable to the strict control of the practice within our department. On the other hand, we believe that a ban on overlapping surgery would certainly have a significantly deleterious effect on both resident education and the ability of surgeons to deliver vital care within a reasonable time. Our study shows that with judicious oversight and monitoring, the practice of overlapping surgery is not associated with higher complication rates or a higher incidence of life-threatening adverse events.

Conclusions

In this single-center review of neurosurgical procedures performed by senior surgeons, we were unable to identify an association between overlapping surgery and overall complications or life-threatening complications including death. There remains a significant need for further inquiry into the subject of overlapping surgery and its impact on patient outcomes, preferably in the setting of a prospective, multicenter multispecialty study.

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Conception and design: Schmidt, Guan. Acquisition of data: Guan. Drafting the article: Schmidt, Guan, Brock, Karsy. Critically revising the article: Schmidt, Couldwell, Schmidt, Kestle, Jensen, Dailey. Reviewed submitted version of manuscript: Schmidt, Guan. Approved the final version of the manuscript on behalf of all authors: Schmidt. Statistical analysis: Guan.

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