JAMA Surgery | Original Investigation

Association of Overlapping Surgery With Patient Outcomes in a Large Series of Neurosurgical Cases

Brian M. Howard, MD; Christopher M. Holland, MD, PhD; C. Christina Mehta, PhD, MSPH; Ganzhong Tian, MSPH; David P. Bray, MD; Jason J. Lamanna, PhD; James G. Malcolm, PhD; Daniel L. Barrow, MD; Jonathan A. Grossberg, MD

Invited Commentary
Supplemental content

IMPORTANCE Overlapping surgery (OS) is common. However, there is a dearth of evidence to support or refute the safety of this practice.

OBJECTIVE To determine whether OS is associated with worsened morbidity and mortality in a large series of neurosurgical cases.

DESIGN, SETTING, AND PARTICIPANTS A retrospective cohort study was completed for patients who underwent neurosurgical procedures at Emory University Hospital, a large academic referral hospital, between January 1, 2014, and December 31, 2015. Patients were operated on for pathologies across the spectrum of neurosurgical disorders. Propensity score weighting and logistic regression models were executed to compare outcomes for patients who received nonoverlapping surgery and OS. Investigators were blinded to study cohorts during data collection and analysis.

MAIN OUTCOMES AND MEASURES The primary outcome measures were 90-day postoperative mortality, morbidity, and functional status.

RESULTS In this cohort of 2275 patients who underwent neurosurgery, 1259 (55.3%) were female, and the mean (SD) age was 52.1 (16.4) years. A total of 972 surgeries (42.7%) were nonoverlapping while 1303 (57.3%) were overlapping. The distribution of American Society of Anesthesiologists score was similar between nonoverlapping surgery and OS cohorts. Median surgical times were significantly longer for patients in the OS cohort vs the nonoverlapping surgery cohort (in-room time, 219 vs 188 minutes; skin-to-skin time, 141 vs 113 minutes; both $P < .001$). Overlapping surgery was more frequently elective (93% vs 87%; $P < .001$). Regression analysis failed to demonstrate an association between OS and complications, such as mortality, morbidity, or worsened functional status. Measures of baseline severity of illness, such as admission to the intensive care unit and increased length of stay, were associated with mortality (intensive care unit: odds ratio [OR], 25.5; 95% CI, 6.22-104.67; length of stay: OR, 1.03; 95% CI, 1.00-1.05), morbidity (intensive care unit: OR, 1.85; 95% CI, 1.43-2.40; length of stay: OR, 1.06; 95% CI, 1.04-1.08), and unfavorable functional status (length of stay: OR, 1.03; 95% CI, 1.02-1.05).

CONCLUSIONS AND RELEVANCE These data suggest that OS can be safely performed if appropriate precautions and patient selection are followed. Data such as these will help determine health care policy to maximize patient safety.

JAMA Surg. doi:10.1001/jamasurg.2017.4502
Published online November 8, 2017.

Author Affiliations: Department of Neurosurgery, Emory University School of Medicine, Atlanta, Georgia (Howard, Bray, Malcolm, Barrow, Grossberg); Carolina Neurosurgery and Spine Associates, Concord, North Carolina (Holland); Department of Biostatistics and Bioinformatics, Rollins School of Public Health, Emory University, Atlanta, Georgia (Mehta, Tian); Emory University School of Medicine, Atlanta, Georgia (Lamanna).

Corresponding Author: Brian M. Howard, MD, Department of Neurosurgery, Emory University School of Medicine, 1365 Clifton Rd NE, Ste B6200, Atlanta, GA 30322 (bhowar5@emory.edu).

© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017

Surgeons routinely schedule operations for 2 patients such that portions of each procedure are conducted concomitantly. This phenomenon, known as *simultaneous*, *concurrent*, or *overlapping surgery* (OS),[1,2] is an established practice that the press[3-7] and Senate Finance Committee[1] have recently questioned. Media and congressional criticism of OS is based on concerns about informed consent, patient safety and education, medical ethics, and hospital billing.[1,4,5,8-11]

Misconception outside of the medical community regarding OS has driven much of the apprehension surrounding its practice. Until recently, the definition of OS was ambiguous and led to confusion among medical practitioners, patients, and the general population. The American College of Surgeons defines operations as concurrent "when 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" and as overlapping "when the key or critical elements of the first operation have been completed, and ... a second operation is started in another operating room while a qualified practitioner performs noncritical components of the first operation."[2]

While several opinion pieces support OS as safe if appropriate precautions are followed, to our knowledge, a paucity of data exists in this area.[1,2,8,9,11,12] The few recently published studies that evaluate the safety of OS stress the need for more widespread analyses from varied institutions and the importance of mid-term and long-term follow-up.[10,13-15] Therefore, we systematically analyzed whether OS was associated with mortality, morbidity, and change in functional status in a series of 2275 neurosurgical cases. We hypothesized that OS was not associated with such negative outcomes.

Key Points

Question Is overlapping surgery associated with increased morbidity and mortality and worsened outcome measures compared with nonoverlapping surgery?

Findings In this retrospective cohort study that included 2275 neurosurgical cases, no difference between overlapping and nonoverlapping surgery was identified for mortality, morbidity, or worsened functional status at discharge and follow-up.

Meaning These data suggest that overlapping surgery can be safely done without risking patient safety in a large series of mostly complex neurosurgical cases.

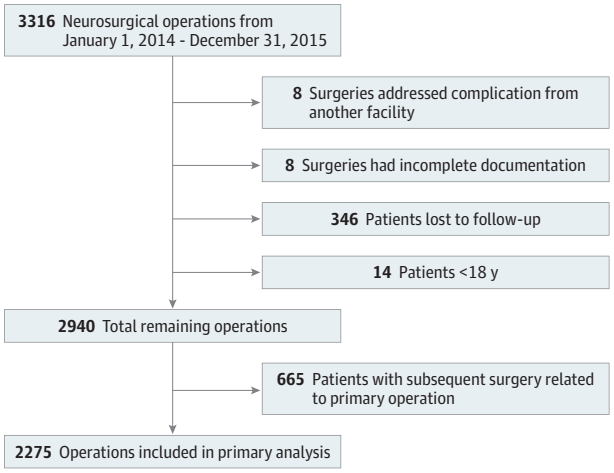
Methods

All neurosurgical operations (n = 3316) performed at Emory University Hospital from January 1, 2014, through December 31, 2015, were retrospectively identified from a centralized surgical database. Patients were excluded if surgery addressed a complication from a referring institution (n = 8), documentation was incomplete (n = 8), the patient was younger than 18 years (n = 14), or the patient was lost to follow-up at 90 days (n = 346). Of the remaining 2940 surgeries, 1103 (37.5%) were from 438 patients who underwent more than 1 operation during the study period (range, 2-12). To minimize confounding of outcomes by subsequent surgeries, only the first surgery from each unique patient was used for primary analysis. Therefore, an additional 665 surgeries were removed from the initial analysis. After exclusion, 2275 surgeries were analyzed (**Figure 1**). The Emory University Institutional Review Board approved this study, and informed consent was waived because data were deidentified.

Two main study groups were defined. *Nonoverlapping surgery* (NOS) was defined as surgery without any portion of the operation occurring concomitantly with another operation performed by the same attending surgeon. *Overlapping surgery* was defined as an operation for which any portion of the surgery, from the time the patient entered until the patient exited the operating room, overlapped with another operation for which the same surgeon was responsible. Overlapping surgery was further divided into 2 subgroups: overlapping in-room time (OS-R), when the preparation phase of surgery for a second patient occurred simultaneously with the emergence phase of surgery for the first patient, and overlapping skin-to-skin time (OS-StS), when any portion of the operative time ran concomitantly with that of another patient operated on by a single surgeon. In accordance with departmental policy, the critical portion of the surgery did not overlap with that of another case performed by an individual surgeon in any of the OS-StS cases (**Figure 2**).

Demographic data and parameters of surgery were extracted from the electronic surgical management system. All relevant information regarding baseline health status, hospital course, and follow-up within the 90-day global period was collected. Indicators were created for having multiple, related surgeries, unplanned return to the operating room or need for an invasive procedure (eg, external ventricular drain placement) within 90 days, unplanned admission within 30 days after surgery, and surgical site infection. Data were extracted by 5 investigators who were blinded to study cohorts during data collection and analysis. The primary investigator (B.M.H.) independently scored the modified Rankin Scale (mRS) for 50 patients per extractor to assure consistency (concordance, 189 of 200 [94.5%]).

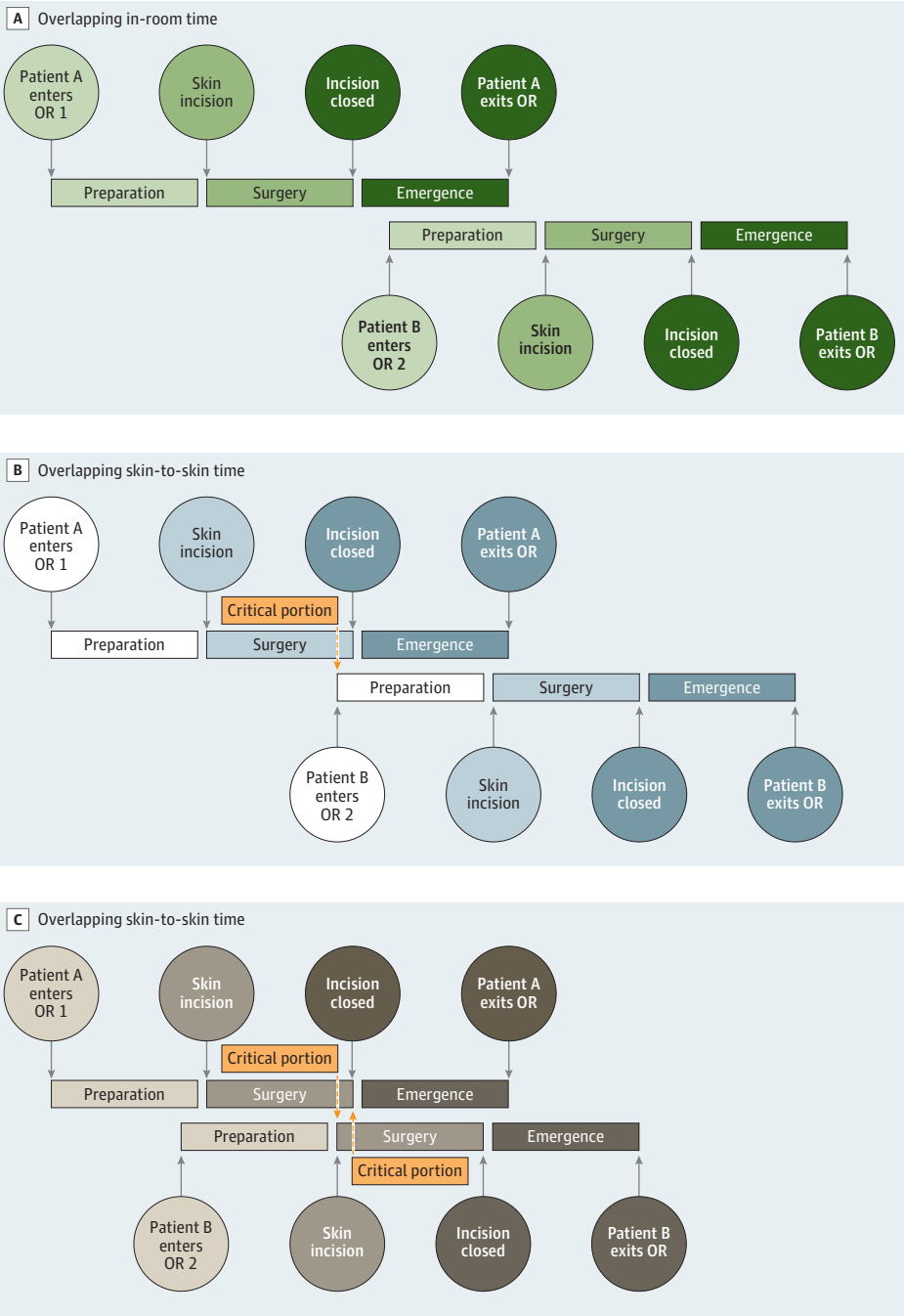
Figure 1. Flow Diagram Depicting Inclusion and Exclusion Criteria for Study Cohort



© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017

Figure 2. Schematic Representation of Various Permutations of Overlapping Surgery



A, Two patients in the overlapping in-room time cohort, in which emergence from anesthesia for patient A is concomitant with the preparatory phase of surgery for patient B. The operative, or skin-to-skin, portion of surgery does not overlap for either patient. B, The first scenario for patients in the overlapping skin-to-skin time cohort. As the surgical portion of the case is ending for patient A, patient B enters a separate operating room (OR) for the preparatory phase of surgery. Patients similar to patient A were included in the overlapping skin-to-skin time cohort for subgroup analysis, while those like patient B were included in the overlapping in-room time group. C, The second scenario for patients in the overlapping skin-to-skin time cohort. As the surgical portion of the case is ending for patient A, patient B enters the surgical phase of surgery. Note that although the surgical portions of the operations overlap, the critical portions do not.

Primary outcomes were 90-day mortality, morbidity, and functional status as measured by the mRS at baseline and at 90-day follow-up (dichotomized as "good" for scores ≤2 or as "unchanged poor or worse" for scores ≥3 that remained unchanged from baseline or for patients whose mRS score worsened between baseline and follow-up). Clinical measures evaluated were skin-to-skin time, total operating room time, unexpected intensive care unit (ICU) admission, ICU length of stay (LOS), total LOS, discharge location (ie, home, acute rehabilitation facility, or other), baseline mRS score (dichotomized into ≤2 vs ≥3), American Society of Anesthesiologists (ASA) score (considered as an ordinal variable and dichotomized into low to standard risk [≤2] vs higher risk [≥3]), and unexpected 30-day readmission. Morbidity was graded using the Clavien-Dindo scale[16] and dichotomized into none vs any (Clavien-Dindo score, ≥1). Patients who died were excluded from morbidity and functional status outcomes.

Data were analyzed with SAS version 9.4 (SAS Institute). Normally distributed, continuous variables are reported as mean and standard deviation. Nonparametric continuous data

© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017

Table 1. Demographic and Summary Data for All Patients and by Study Group

Variable	No. (%) Overall Unweighted (n = 2275)	Overall Weighted (n = 2607)	Nonoverlapping Surgery Unweighted (n = 972)	Nonoverlapping Surgery Weighted (n = 1306)	Overlapping Surgery Unweighted (n = 1303)	*P* Value Unweighted	*P* Value Weighted
Type of overlap							
No overlap	972 (42.7)	1307 (50.1)	972 (100)	1306 (100)	0	NA	NA
In-room overlap	231 (10.2)	231 (8.9)	0	0	231 (17.7)	NA	NA
Skin-to-skin overlap	1072 (47.1)	1072 (41.1)	0	0	1072 (82.3)	NA	NA
Patient characteristics							
Sex							
Female	1259 (55.3)	1518 (57.9)	505 (52.0)	764 (58.5)	754 (57.9)	.005	.76
Male	1016 (4.7)	1092 (41.9)	467 (48.0)	543 (41.6)	549 (42.1)		
Age, mean (SD), y	52.1 (16.4)	52 (17.5)	51.9 (16.6)	51.9 (19.0)	52.2 (52.2)	.69	.66
ASA score							
1-2	685 (30.1)	841 (32.3)	273 (28.1)	429 (32.9)	412 (31.6)	.07	.51
≥3	1590 (70.0)	1769 (67.9)	699 (71.9)	878 (67.2)	891 (68.4)		
mRS score at baseline							
0-2	1768 (77.7)	2115 (81.1)	713 (73.4)	1060 (81.2)	1055 (81.0)	<.001	.95
3-5	506 (22.2)	496 (19.0)	258 (26.5)	248 (19.0)	248 (19.0)		
Surgery characteristics							
Surgical staff							
Cosurgeon present	451 (19.8)	627 (24.1)	148 (15.2)	324 (24.8)	303 (23.3)	<.001	.38
Fellow present	439 (19.3)	473 (18.1)	225 (23.1)	258 (19.8)	214 (16.4)	<.001	.03
Resident present	2080 (91.4)	2372 (91.0)	896 (92.2)	1188 (91.0)	1184 (91.0)	.27	.96
Urgency							
Elective	2054 (90.3)	2427 (93.1)	842 (86.6)	1215 (93.0)	1212 (93.0)	<.001	.97
Emergent/urgent	221 (9.7)	182 (7.0)	130 (13.4)	91 (7.0)	91 (7.0)		
Admission status							
Day surgery	350 (15.4)	435 (16.7)	134 (13.8)	219 (16.8)	216 (16.6)	.07	.91
Admitted	1925 (84.6)	2175 (83.4)	838 (86.2)	1088 (83.3)	1087 (83.4)		
Surgery category							
CSF diversion	188 (8.3)	156 (6.0)	109 (11.2)	77 (6.0)	79 (6.1)	<.001	.98
Functional	527 (23.2)	601 (22.9)	222 (22.8)	296 (22.7)	305 (23.4)		
Other	151 (6.6)	144 (5.6)	81 (8.3)	73 (5.7)	70 (5.4)		
Peripheral nerve	233 (10.2)	293 (11.2)	87 (9.0)	147 (11.1)	146 (11.2)		
Spine	71 (3.1)	87 (3.3)	27 (2.8)	43 (3.3)	44 (3.4)		
Tumor	813 (35.7)	977 (37.6)	334 (34.4)	498 (38.4)	479 (36.8)		
Vascular	292 (12.8)	354 (13.5)	112 (11.5)	174 (13.2)	180 (13.8)		

Abbreviations: ASA, American Society of Anesthesiologists; CSF, cerebrospinal fluid; mRS, modified Rankin Scale; NA, not applicable.

are presented as median and first and third quartiles (Q1, Q3). *t* Tests, Wilcoxon rank sum, and χ^2 tests were used to compare demographic and clinical data for bivariate analyses as appropriate.

Propensity score (PS) weighting adjusted for observed significant differences between the NOS and OS groups on surgery category, primary surgeon, and other baseline factors assessed prior to the primary surgeon's NOS/OS decision. The amount of variation in outcomes attributable to individual surgeons was assessed by intraclass correlation coefficient (0.0405, 0.0718, and 0.0975 for mortality, morbidity, and change in functional status, respectively). An intraclass correlation coefficient greater than 0.2 suggests correlation between the outcomes of interest by cluster (primary surgeon) that should be accounted for in additional analyses. Because the threshold was not met, independence between primary surgeon and outcomes was assumed.

A logistic regression model with NOS/OS as the dependent variable was fit with primary surgeon, surgery category, ASA score, dichotomized baseline mRS score, whether a cosurgeon was present, sex, planned ambulatory surgery status (outpatient vs admitted), age at surgery, and case urgency (elective vs emergent/urgent) as independent variables. The predicted probabilities of OS from the PS model (ie, the PS score) were used to create average treatment effect for treated (ATT) weights. Improvement in the distribution of baseline covariates by NOS/OS group after ATT PS weighting was confirmed (**Table 1**).

© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017

Bivariate analyses were computed both before and after ATT PS weighting for study group (NOS/OS) comparisons. Multivariable logistic regression models were used to evaluate the association between each outcome (mortality, morbidity, and change in function) and study group. Double robust PS methods were used so that observations were weighted by ATT PS weight, and the model also included logit(PS score) as a covariate. Backward selection (P = .20) was used to find the most parsimonious model after forcing study group and logit(PS score). Firth penalized likelihood method was implemented when independent variable cell sizes were zero or close to zero. Evaluated independent variables included total in-room time and skin-to-skin time, presence of a resident, dichotomized resident level, presence of a fellow, postoperative ICU admission, ICU LOS, overall LOS, surgical site infection, unplanned readmission within 30 days, multiple dependent surgeries, and disposition. Adjusted odds ratios (ORs) with 95% CIs are reported for each model. Model fit was assessed. Subanalyses assessed the association between subtypes of OS (OS-R vs OS-StS) with each of the 3 outcomes using the same logistic regression methods described above. A bootstrap was performed using 10 000 replicate samples of the original data set to refit the mortality model for each sample to get an estimate of the effect of OS. Significance was set at $P < .05$, and all P values were 2-tailed.

Results

Baseline demographic data are presented in Table 1, both before and after PS weighting was applied to the NOS group. The cohort included 1259 female patients (55.3%), and the mean (SD) age was 52.1 (16.4) years. Of 2275 operations, 972 (42.7%) were NOS while 1303 (57.3%) were OS (1072 OS-StS [82.3%]; 231 OS-R [17.7%]). Most patients underwent elective surgery (2054 [90.3%]) and had higher ASA scores (1590 [69.9%]), and there was a relatively high proportion of patients with poor baseline mRS score (≥3; 506 [22.2%]). Significant differences were observed between NOS and OS groups at baseline on sex, surgery category, case urgency, cosurgeon presence, and mRS score at baseline. After ATT PS weighting, no significant differences were observed on the baseline covariates.

Clinical data assessed during and after surgery are presented in **Table 2**. Residents were present in 2080 surgeries (91.4%; 1338 [58.8%] covered by upper-level residents), while fellows were present in 439 surgeries (19.3%). A cosurgeon was present in 451 surgeries (19.8%). Median in-room time was 206 minutes, and median skin-to-skin time was 130 minutes. Median overall LOS was 3 days. After surgery, 979 patients (43.0%) went to the ICU, 95 (4.2%) had a surgical site infection, 210 (9.2%) had an unplanned readmission within 30 days, 158 (6.9%) had an unexpected return to the operating room or invasive procedure, and 108 (4.7%) had subsequent related/dependent surgeries. Of the patients with more than 1 surgery, 330 (75.3%) had subsequent surgeries that were not a result of a complication from their first operation, while 108 (24.7%) had more than 1 operation related to the first (range, 2-5). Significant differences were observed between the NOS and OS groups on presence of a fellow, in-room and skin-to-skin operating times, unexpected return to the operating room, related/dependent surgeries, admission to the ICU, disposition, overall LOS, and ICU LOS. After ATT PS weighting, significant differences were still observed on in-room and skin-to-skin operating times and presence of a fellow. eTables 1 and 2 in the Supplement describe baseline characteristics and outcomes for OS subgroups (OS-R and OS-StS).

As described in Table 2, 53 deaths were observed during the follow-up period. Of the remaining 2222 patients, 324 (14.6%) experienced morbidity and 459 (20.7%) experienced the same poor or worse mRS score at follow-up compared with baseline. Of those who suffered morbidity, 212 (65.4%) were severe (Clavien-Dindo score ≥3).

eTable 3 in the Supplement shows bivariate analysis results for mortality, morbidity, and change in function. Patients who died were almost uniformly admitted to the ICU (n = 51 [96%]), had a poor disposition (n = 52 [98%]), and had a poor mRS score at discharge (n = 52 [98%]). Compared with OS, NOS was associated with mortality (n = 31 vs 22; P = .02) but not morbidity (n = 148 vs 176; P = .19) or change in function (n = 201 vs 258; P = .47).

Table 3 depicts multivariate model results for mortality. After adjusting for relevant covariates, mortality and study group were not associated (OS vs NOS: OR, 1.62; 95% CI, 0.84-3.14). Similarly, the observed 95% CI for the OR of OS/NOS from the 10 000 bootstrap samples was 0.81 to 3.38. Longer overall LOS (OR, 1.03; 95% CI, 1.00-1.05; P = .02) and admission to the ICU (OR, 25.5; 95% CI, 6.22-104.67; $P < .001$) were significantly associated with increased odds of mortality. Table 3 also demonstrates multivariate model results for morbidity. After adjusting for relevant covariates, morbidity and study group were not associated (OS vs NOS: OR, 0.86; 95% CI, 0.68-1.08). Presence of morbidity was inversely associated with discharge mRS score and associated with ICU admission, unplanned readmission, multiple dependent surgeries, longer total in-room time, and overall LOS. Table 3 also describes multivariate model results for change in function. After adjusting for relevant covariates, change in function and study group were not associated (OS vs NOS: OR, 0.87; 95% CI, 0.71-1.06). Worsening change in function was associated with having a resident present, poor discharge disposition, and increasing overall LOS (Table 3).

Because outcomes among patients who underwent more than 1 surgery could be influenced by repeated operations, sensitivity analyses were also performed. The final models for each outcome were rerun among patients with only a single surgery. The adjusted results for all outcomes were similar (eTable 4 in the Supplement). Mortality was not associated with study group (OS vs NOS: OR, 1.64; 95% CI, 0.83-3.30). Morbidity was not associated with study group (OS vs NOS: OR, 0.81; 95% CI, 0.64-1.04). Change in function was not associated with study group (OS vs NOS: OR, 0.86; 95% CI, 0.71-1.06).

Table 3 describes multivariate analysis results for association of type of overlap (OS-StS vs OS-R) with each outcome. Type of overlap was not associated with mortality (OS-StS vs OS-R: OR, 2.09; 95% CI, 0.51-8.54), morbidity (OS-StS vs OS-R: OR, 1.43; 95% CI, 0.76-2.68), or change in function (OS-StS vs OS-R: OR, 0.78; 95% CI, 0.55-1.12).

© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017

Table 2. Surgical and Outcomes Data Presented by Study Group

Variable	No. (%) Overall Unweighted (n = 2275)	Overall Weighted (n = 2610)	Nonoverlapping Unweighted (n = 972)	Nonoverlapping Weighted (n = 1307)	Overlapping Unweighted (n = 1303)	*P* Value Unweighted	*P* Value Weighted
Operative time, median (Q1-Q3), min							
In-room overlap	206 (135-292)	211 (138-291)	188 (125-284)	203 (129-286)	219 (146-296)	<.001	<.001
Skin-to-skin overlap	130 (65-196)	135 (67-198)	113 (57-187)	129 (61-193)	141 (71-202)	<.001	.004
Length of stay, median (Q1-Q3), d							
ICU LOS	1 (1-5)	1 (1-4)	2 (1-8)	1 (1-5)	1 (1-3)	<.001	.05
Overall LOS	3 (1-6)	3 (1-6)	3 (1-8)	3 (1-6)	3 (1-6)	<.001	.20
Discharge location							
Good disposition (home or AR)	2113 (92.8)	2486 (95.2)	876 (90.1)	1249 (95.6)	1237 (95.0)	<.001	.47
Poor disposition	162 (7.1)	125 (4.8)	96 (10.0)	58 (4.4)	66 (5.1)		
Mortality	53 (2.3)	38 (1.5)	31 (3.2)	16 (1.2)	22 (1.7)	.02	.25
mRS score at discharge							
0-2	1654 (72.7)	1926 (73.8)	681 (70.1)	953 (72.9)	973 (74.7)	.02	.31
3-5	621 (27.3)	684 (26.2)	291 (29.9)	354 (27.1)	330 (25.3)		
mRS score at follow-up vs baseline							
0-2	1762 (79.3)	2024 (78.6)	739 (78.6)	1001 (77.4)	1023 (80.0)	.47	.14
Unchanged poor (3-5) or worse	459 (20.7)	550 (21.4)	201 (21.4)	292 (22.6)	258 (20.0)		
Morbidity within 90 d							
No	1898 (85.4)	2188 (85.0)	793 (84.3)	1083 (83.8)	1105 (86.3)	.19	.08
Yes	324 (14.6)	386 (15.0)	148 (15.7)	210 (16.2)	176 (13.7)		
Severity of morbidity							
Clavien-Dindo score of 1 or 2	112 (34.6)	147 (38.1)	52 (35.1)	87 (41.4)	60 (34.1)	.84	.14
Clavien-Dindo score of 3 or 4	212 (65.4)	239 (61.9)	96 (64.9)	123 (58.6)	116 (65.9)		
30-d Readmission							
No	2064 (90.7)	2366 (91.0)	875 (90.0)	1177 (90.1)	1189 (91.3)	.32	.30
Yes	211 (9.3)	244 (9.0)	97 (10.0)	130 (9.9)	114 (8.7)		
Unexpected return to OR or invasive procedure within 90 d						.006	.06
No	2117 (93.1)	2437 (93.4)	888 (91.4)	1208 (92.4)	1229 (94.3)		
Yes	158 (6.9)	173 (6.6)	84 (8.6)	99 (7.6)	74 (5.7)		
Surgical site infection							
No	2180 (95.8)	2506 (96.0)	928 (95.5)	1254 (95.9)	1252 (96.1)	.47	.87
Yes	95 (4.2)	104 (4.0)	44 (4.5)	53 (4.1)	51 (3.9)		
Multiple related surgeries							
No	2167 (95.3)	2505 (96.0)	910 (93.6)	1248 (95.5)	1257 (96.5)	.002	.23
Yes	108 (4.7)	105 (4.0)	62 (6.4)	59 (4.5)	46 (3.5)		

Abbreviations: AR, acute rehabilitation facility; ICU, intensive care unit; LOS, length of stay; mRS, modified Rankin Scale; OR, operating room; Q1, first quartile; Q3, third quartile.

Discussion

Surgeons, particularly in academic and tertiary care settings, often conduct operations on separate patients, portions of which overlap. In a 2017 high-profile malpractice suit, the overlapping nature of surgery was determined not have had a role in the patient's complication,[17] but the case's details brought widespread criticism of the practice by the lay press.[3-7,18] This case served as the basis for an inquiry by the Senate Finance Committee[1] and, rightfully, evoked self-scrutiny by the medical community.[2,8,9,11,12] In the wake of the media spotlight, several opinion pieces published in prominent journals defended the purported advantages of OS, but nearly all of these articles emphasized the need for systematic and widespread evaluation of safety and outcomes, given the near absolute lack of evidence to support the practice.[8,9,11,12,19] To our knowledge, only 4 studies have been published to date in which out-

© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017

Table 3. Multivariable Logistic Regression (MLR) for Covariates Associated With Mortality, Morbidity, and Unchanged Poor or Worse Modified Rankin Scale (mRS) Score at 90 Days vs Baseline[a]

Variable	Estimate (SE)	OR (95% CI)	*P* Value
MLR for covariates associated with mortality			
All surgeries			
OS (reference, NOS)	0.48 (0.34)	1.62 (0.84-3.14)	.15
Admitted to ICU (reference, no)	3.24 (0.72)	25.5 (6.22-104.67)	<.001
Overall LOS, d	0.03 (0.01)	1.03 (1.00-1.05)	.02
OS only			
OS-StS (reference, OS-R)	0.74 (0.72)	2.09 (0.51-8.54)	.30
Admitted to ICU (reference, no)	3.02 (0.84)	20.55 (3.94-107.20)	<.001
Overall LOS, d	0.04 (0.01)	1.04 (1.01-1.07)	.01
MLR for covariates associated with morbidity			
All surgeries			
OS (reference, NOS)	−0.16 (0.12)	0.86 (0.68-1.08)	.59
Discharge mRS score 0-2 (reference, 3-5)	−0.56 (0.13)	0.57 (0.44-0.74)	<.001
Admitted to ICU (reference, no)	0.62 (0.13)	1.85 (1.43-2.40)	<.001
30-d Readmission (reference, no)	4.02 (0.19)	55.70 (38.12-81.37)	<.001
Multiple related surgeries (reference, no)	0.93 (0.26)	2.53 (1.54-4.18)	<.001
Total in-room time, min	0.002 (0.00)	1.00 (1.00-1.00)	<.001
Overall LOS, d	0.06 (0.01)	1.06 (1.04-1.08)	<.001
OS only			
OS-StS (reference, OS-R)	0.36 (0.32)	1.43 (0.76-2.68)	.26
Discharge mRS score 0-2 (reference, 3-5)	−1.37 (0.24)	0.25 (0.16-0.41)	<.001
Admitted to ICU (reference, no)	0.60 (0.24)	1.82 (1.13-2.91)	.01
30-d Readmission (reference, no)	4.26 (0.29)	70.80 (40.08-125.09)	<.001
Multiple related surgeries (reference, no)	1.84 (0.43)	6.27 (2.70-14.59)	<.001
Total in-room time, min	0.00 (0.00)	1.00 (1.00-1.00)	.04
Overall LOS, d	0.07 (0.02)	1.07 (1.04-1.11)	<.001
MLR for covariates associated with unchanged poor (3-5) or worse mRS score at 90 d vs baseline			
All cases			
OS (reference, NOS)	−0.15 (0.10)	0.87 (0.71-1.06)	.15
Resident present (reference, no)	0.69 (0.22)	2.06 (1.35-3.13)	.001
Good disposition (reference, bad)	−2.16 (0.28)	0.12 (0.07-0.20)	<.001
Overall LOS, d	0.03 (0.01)	1.03 (1.02-1.05)	<.001
OS only			
OS-StS (reference, OS-R)	−0.25 (0.18)	0.78 (0.55-1.12)	.17
Resident present (reference, no)	0.70 (0.32)	2.02 (1.09-3.74)	.03
Good disposition (reference, bad)	−2.30 (0.38)	0.10 (0.05-0.21)	<.001
SSI (reference, no)	0.70 (0.32)	2.01 (1.07-3.80)	.03

Abbreviations: ICU, intensive care unit; LOS, length of stay; NOS, nonoverlapping surgery; OR, odds ratio; OS, overlapping surgery; OS-R, overlapping in-room time; OS-StS, overlapping skin-to-skin time; SSI, surgical site infection.

[a] Model included logit(propensity score) and used average treatment effect for treated weights.

comes for overlapping or concurrent surgery have been evaluated.[10,13-15] In each, OS was not associated with increased risk of complication, but none of the studies examined outcomes beyond 30 days. In this study, complications and outcomes were compared between large cohorts of neurosurgical patients who underwent NOS and OS through the 90-day postoperative global period. Consequently, this study not only adds meaningfully to the small but growing body of literature regarding the safety of OS but also is the first to examine outcomes and complications over the protracted postoperative period. Moreover, to our knowledge, the study presented herein is the first to evaluate the subset of procedures for which the operative, or skin-to-skin, time was overlapping as a distinct study group.

The analysis included diverse metrics to assess functional outcomes, complications, and resource use for cases involving NOS and OS. Regression modeling failed to demonstrate any statistically significant difference between the OS-R and OS-StS cohorts and the NOS group for mortality, overall and severe morbidity (including major organ system failure), ICU LOS, overall LOS, discharge location, functional status at discharge and within the 90-day global period, unexpected readmission within 30 days, and unplanned return to the operating room or invasive neurosurgical procedure within 90 days. In sum, these data suggest that OS can be safely performed without risking patient safety in a large series of mostly complex neurosurgical cases.

Instead, proxy measures for baseline severity of illness, such as being admitted to the ICU and overall LOS, were asso-

© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017

ciated with mortality, overall morbidity, and unfavorable functional status. Not unexpectedly, 30-day readmission was strongly associated with morbidity, as was having to undergo an unexpected subsequent operation. Age was independently assessed for association with outcomes because it was accounted for in the propensity score model. These data are generally consistent with previous reports.[13,15]

A commonly cited concern is that OS may lead to increased anesthesia and operative time for patients, which, in turn, may lead to complications, such as respiratory failure and wound infections.[1,9,10,12,15] Both OS-R and OS-StS cases were significantly longer than NOS cases in this study. Longer in-room time was associated with morbidity, but not mortality or follow-up mRS score. More importantly, skin-to-skin time was not associated with mortality, morbidity, or worsened functional status. An article published in 2016[13] in which outcomes were compared between NOS and OS cases demonstrated that longer surgical time was associated with complications, both minor and severe. Despite longer total in-room and skin-to-skin time in the OS-R and OS-StS cohorts, SSI and major morbidity were no different between the NOS and OS groups, consistent with a previous report.[15]

Limitations

This study has limitations. Most prominently, the analysis was retrospective. Although PS weighting mitigated bias to the best extent possible, to completely account for unrecognized influences and associations that may affect adverse events is impossible. Propensity score weighting eliminated the differences in baseline characteristics between the NOS and OS groups for factors chosen prior to the decision to schedule surgery as overlapping or not; however, differences in presence of a fellow and operative and in-room time remained after weighting. Moreover, that surgery was completed solely at a single academic neurosurgical referral center may limit generalizability of the results. However, analyses from centers and practices of varying types are of crucial importance to develop robust and substantive literature that ultimately supports or refutes the safety of OS. Interrater reliability for post hoc mRS score extraction was not formally evaluated. In addition, 346 patients (15.2%) were lost to follow-up, and while we cannot be certain of the fate of those patients, follow-up was equally likely in each of the 3 study groups in the regression analysis, tempering bias.

Perhaps the most important partiality is that of the surgeon. The American College of Surgeons, multiple editorials, and organizational position statements emphasize that the responsibility to safely conduct and oversee OS rests entirely with the attending surgeon.[2,8,9,11,19] Surgeons must use their experience, keen intuition, and respect for their own ability and limitations to carefully select patients for OS. Patients who underwent OS in 2 publications in which NOS and OS were compared were healthier at baseline,[13,15] while patients in our OS-StS cohort were more likely to have a baseline ASA score of 1 or 2, although this was not statistically significant (P = .07). Cases of OS-R and OS-StS were more likely to involve a cosurgeon, and OS was more likely to be ambulatory surgery. Although difficult to prove, these data suggest that surgeons effectively manage their operating room schedules such that these factors combine to make OS safe and effective.

Conclusions

These data suggest that overlapping neurosurgery is safe and has the potential to benefit patients by maximizing efficiency and making highly sought-after specialists available to a greater number of patients. By carefully training the next generation of surgeons through a system of supervision and progressive autonomy, OS may also be a key factor in maintaining a competent surgical workforce for the future. Data such as these will help determine health care standards and policies that have the potential to broadly affect the delivery of surgical care in the United States. An evidence-based approach to policy surrounding OS is crucial not only to maximize patient safety but also to make highly specialized surgical care available to as many patients as possible.

ARTICLE INFORMATION

Accepted for Publication: July 30, 2017.

Published Online: November 8, 2017. doi:10.1001/jamasurg.2017.4502

Author Contributions: Dr Howard had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Howard, Holland, Barrow, Grossberg.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Howard, Holland, Mehta.
Critical revision of the manuscript for important intellectual content: Howard, Holland, Tian, Bray, Lamanna, Malcolm, Barrow, Grossberg.
Statistical analysis: Howard, Mehta, Tian, Malcolm.
Administrative, technical, or material support: Holland, Lamanna, Barrow, Grossberg.
Study supervision: Howard, Holland, Barrow, Grossberg.

Conflict of Interest Disclosures: None reported.

REFERENCES

1. Senate Finance Committee. Concurrent and overlapping surgeries: additional measures warranted. https://www.finance.senate.gov/imo/media/doc/Concurrent%20Surgeries%20Report%20FINAL%20.pdf. Accessed January 15, 2017.

2. American College of Surgeons. Statements on principles. https://www.facs.org/about-acs/statements/stonprin. Accessed February 9, 2017.

3. Abelson J, Saltzman J. Surgeons urged to better govern dual bookings. *Boston Globe*. April 14, 2016. http://edition.pagesuite.com/popovers/article_popover.aspx?guid=79b35938-3cca-42ef-b84b-d9d16b8b2364. Accessed January 15, 2017.

4. Abelson J, Saltzman J. Surgeons must tell patients of double-booked surgeries, new guidelines say. *Boston Globe*. April 13, 2016. https://www.bostonglobe.com/metro/2016/04/13/surgery/Jn7LbOHq3VUGeZGBgjiwOM/story.html. Accessed January 15, 2017.

5. Abelson J, Saltzman J, Kowalczyk L. Clash in the name of care. *Boston Globe*. October 25, 2015:A1, A8.

6. Abelson J, Saltzman J, Kowalczyk L. A new wave of scrutiny for simultaneous surgeries. *Boston Globe*. December 20, 2015:A1, A20.

7. Twedt S. Senate committee looks at policies on surgeons performing more than one surgery at once. *Pittsburgh Post-Gazette*. March 28, 2016. http://www.post-gazette.com/business/healthcare-business/2016/03/28/Senate-committtee-looks-at-hospital-policies-regarding-concurrent-surgeries/stories/201603270074. Accessed January 15, 2017.

8. Langerman A. Concurrent surgery and informed consent. *JAMA Surg*. 2016;151(7):601-602.

9. Mello MM, Livingston EH. Managing the risks of concurrent surgeries. *JAMA*. 2016;315(15):1563-1564.

10. Hyder JA, Hanson KT, Storlie CB, et al. Safety of overlapping surgery at a high-volume referral center. *Ann Surg*. 2017;265(4):639-644.

© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017

11. American Association of Neurological Surgeons; American Board of Neurological Surgery; Congress of Neurological Surgeons; Society of Neurological Surgeons. Position statement on intraoperative responsibility of the primary neurosurgeon. http://www.aans.org/pdf/Legislative/Neurosurgery%20Position%20Statement%20on%20Overlapping%20Surgery%20FINAL.pdf. Accessed February 9, 2017.

12. Hoyt DB. Overlapping surgery: safety data and ongoing concerns. *Ann Surg*. 2017;265(4):645-646.

13. Guan J, Brock AA, Karsy M, et al. Managing overlapping surgery: an analysis of 1018 neurosurgical and spine cases [published online December 2, 2016]. *J Neurosurg*.

14. Zhang AL, Sing DC, Dang DY, et al. Overlapping surgery in the ambulatory orthopaedic setting. *J Bone Joint Surg Am*. 2016;98(22):1859-1867.

15. Zygourakis CC, Keefe M, Lee J, et al. Comparison of patient outcomes in 3725 overlapping vs 3633 nonoverlapping neurosurgical procedures using a single institution's clinical and administrative database. *Neurosurgery*. 2017;80(2):257-268.

16. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004;240(2):205-213.

17. Saltzman J. Double surgery did not cause man's quadriplegia, jury finds. *Boston Globe*. January 30, 2017. https://www.bostonglobe.com/metro/2017/01/30/surgeon-failed-inform-patient-about-double-booked-surgery-jury-finds/xzWz0hrRNCDeaOvYetugzK/story.html. Accessed February 9, 2017.

18. Saltzman J, Abelson J, Kowalczyk L. MGH files sought in federal inquiry. *Boston Globe*. November 15, 2015:A1, A15.

19. Beasley GM, Pappas TN, Kirk AD. Procedure delegation by attending surgeons performing concurrent operations in academic medical centers: balancing safety and efficiency. *Ann Surg*. 2015;261(6):1044-1045.

© 2017 American Medical Association. All rights reserved.

Downloaded From: by a Emory University User on 11/08/2017