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Ali S. Farooqi

Austin J. Borja

Rashad Jabarkheel

Gregory Glauser

Krista Strouz

See next page for additional authors

Authors

Ali S. Farooqi, Austin J. Borja, Rashad Jabarkheel, Gregory Glauser, Krista Strouz, Scott McClintock, and Neil R. Malhotra

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Ali S. Farooqi[1], Austin J. Borja[1], Rashad Jabarkheel[1], Gregory Glauser[1], Krista Strouz[2,3], Scott D. McClintock[3], Neil R. Malhotra[1,2]

■ OBJECTIVE: **The American College of Surgeons (ACS) updated its guidelines on overlapping surgery in 2016. The objective was to examine differences in postoperative outcomes after overlapping surgery either pre-ACS guideline revision or post-guideline revision, in a coarsened exact matching sample.**

■ METHODS: **A total of 3327 consecutive adult patients undergoing single-level posterior lumbar fusion from 2013 to 2019 were retrospectively analyzed. Patients were separated into a pre-ACS guideline revision cohort (surgery before April 2016) or a post-guideline revision cohort (surgery after October 2016) for comparison. The primary outcomes were proportion of cases performed with any degree of overlap, and adverse events including 30-day and 90-day rates of readmission, reoperation, emergency department visit, morbidity, and mortality. Subsequently, coarsened exact matching was used among overlapping surgery patients only to assess the impact of the ACS guideline revision on overlapping outcomes, and controlling for attending surgeon and key patient characteristics known to affect surgical outcomes.**

■ RESULTS: **After the implementation of the ACS guidelines, fewer cases were performed with overlap (22.0% vs. 53.7%; $P < 0.001$). Patients in the post-ACS guideline revision cohort experienced improved rates of readmission and reoperation within 30 and 90 days. However, when limited to overlapping cases only, no differences were observed in overlap outcomes pre-ACS versus post-ACS guideline revision. Similarly, when exact matched on risk-associated patient characteristics and attending surgeon, overlapping surgery patients pre-ACS and post-ACS guideline revision experienced similar rates of 30-day and 90-day outcomes.**

■ CONCLUSIONS: **After the ACS guideline revision, no discernable impact was observed on postoperative outcomes after lumbar fusion performed with overlap.**

INTRODUCTION

Overlapping surgery is the practice in which an attending surgeon manages multiple cases, with at least some portion of the operations occurring simultaneously. In the extreme form of this practice (concurrent surgery), the procedures overlap during the critical operative steps. The practice of overlapping surgery was recently brought into public attention after a Spotlight report by *Boston Globe* in 2015.[1] In response, the American College of Surgeons (ACS) released guideline revisions (Table 1), stating that "a primary attending surgeon's involvement in concurrent or simultaneous surgeries on 2 different patients in 2 different rooms is inappropriate."[2] On the

Key words
- Lumbar spine
- Outcomes
- Overlapping surgery
- Patient safety
- Spinal fusion

Abbreviations and Acronyms
ACS: American College of Surgeons
ASA: American Society of Anesthesiologists
BMI: Body mass index
CCI: Charlson Comorbidity Index
CEM: Coarsened exact matching
CI: Confidence interval
ED: Emergency department
OR: Odds ratio

From the [1]Department of Neurosurgery, Perelman School of Medicine at the University of Pennsylvania; Philadelphia, Pennsylvania; [2]McKenna EpiLog Fellowship in Population Health at the University of Pennsylvania, Philadelphia, Pennsylvania; and [3]West Chester University, The West Chester Statistical Institute and Department of Mathematics, West Chester, Pennsylvania, USA

To whom correspondence should be addressed: Neil R. Malhotra, M.D. [E-mail: neil.malhotra@pennmedicine.upenn.edu]

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other hand, nonconcurrent overlapping surgeries were deemed appropriate, insofar as they do not "negatively affect the seamless and timely flow of either procedure."[2] In accordance with the updated ACS guidelines, numerous health systems revised their surgical protocols. However, few studies have evaluated the impact of the ACS guideline revision.

Across all surgical services, 15% of elective surgeries and up to 34% of neurosurgeries may be performed with some degree of overlap.[3,4] At 1 institution, the frequency of overlap and case involvement of resident assistant surgeons decreased after the guideline revision, whereas surgery wait times increased.[5] Moreover, the rate of complications remained equivalent despite reduced overlapping cases. Nonetheless, there exists a paucity of studies examining the impact of the ACS guideline revision among spine surgery populations. Further, given the significant variability in surgical risk and complication rate among different spinal procedures, procedure-specific studies are warranted to assess the impact of the guideline revision on outcomes after overlapping surgery.

Lumbar fusions are a high-volume spine surgery with appreciable short-term complication rates, making them an enticing procedure to study institutional trends.[6,7] Here, at an institution in which concurrent surgery is not permitted, we sought to examine the impact of the 2016 ACS guideline revision across a large population of patients undergoing single-level posterior-only lumbar fusion. Our objective was to compare the proportion of operations performed with any amount of nonconcurrent overlap between time periods, then to use coarsened exact matching (CEM) (which uses patient-level characteristics and attending surgeon as covariates for 1:1 matching) to tightly control for confounding variables and evaluate any differences in adverse postoperative outcomes before or after the ACS guideline revision.

Table 1. American College of Surgeons Guideline Revisions. Major Changes within the Revised American College of Surgeons Statement on Principles (Updated April 12, 2016)[2]

American College of Surgeons Statement on Principles language after revision (April 12, 2016)
The "critical" or "key" portions of an operation are those stages when essential technical expertise and surgical judgment are necessary to achieve an optimal patient outcome. The critical or key portions of an operation are determined by the primary attending surgeon. Concurrent or simultaneous operations occur 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. A primary attending surgeon's involvement in concurrent or simultaneous surgeries on 2 different patients in 2 different rooms is inappropriate.
"Overlapping or sequenced" operations for surgeons: The practice of the primary surgeon initiating and participating in another operation when he or she has completed the critical portions of the first procedure and is no longer an essential participant in the final phase of the first operation. These are by definition surgical procedures where key or critical portions of the procedure are occurring at different times. The first and most common scenario is when the key or critical elements of the first operation have been completed, and there is no reasonable expectation that the primary attending surgeon will need to return to that operation. In this circumstance, a second operation is started in another operating room while a qualified practitioner performs noncritical components of the first operation…In this situation, a qualified practitioner must be physically present in the operating room of the first operation. The second and less common scenario is when the key or critical elements of the first operation have been completed and the primary attending surgeon is performing key or critical portions of a second operation in another room. In this scenario, the primary attending surgeon must assign immediate availability in the first operating room to another attending surgeon. The patient needs to be informed in either of these circumstances. The performance of overlapping procedures should not negatively affect the seamless and timely flow of either procedure.

METHODS

Ethics Committee Approval

This study was approved by the institutional review board of the present institution. The institutional review board determined that this study posed minimal risk to patients and granted a waiver of informed consent. All ethical guidelines and rules were followed to protect patient privacy.

Sample Selection

This was a retrospective study at a multihospital 1659-bed university health center. Overall, 3799 consecutive adult patients undergoing single-level posterior-only lumbar fusion over a 6-year period (2013–2019) were enrolled in this study. This study period was selected to have an equivalent amount of time and include a sufficient number of patients for analysis and to minimize confounding from other intangible variables such as turnover in surgical teams and other changes in preoperative or postoperative care policies. Posterior-only open and endoscopic surgeries, with and without concomitant interbody devices, were included. Patient exclusion criteria included any revision surgery at the same vertebral level ($n = 156$) and nonroutine operations (significantly increased body mass index [BMI, calculated as weight in kilograms divided by the square of height in meters; value >70], emergent surgeries, noninpatient operations, unclean wound closure, or nongeneral anesthesia; total $n = 80$). Furthermore, any patients who underwent surgery within 6 months of the ACS guideline revision (April 12–October 12, 2016) were removed from

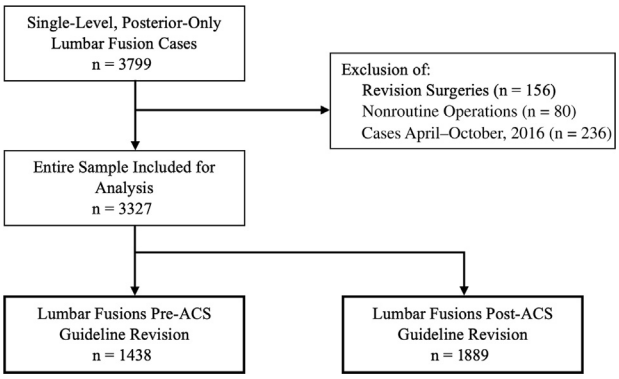

Figure 1. Flowchart showing patient selection for this study. ACS, American College of Surgeons.

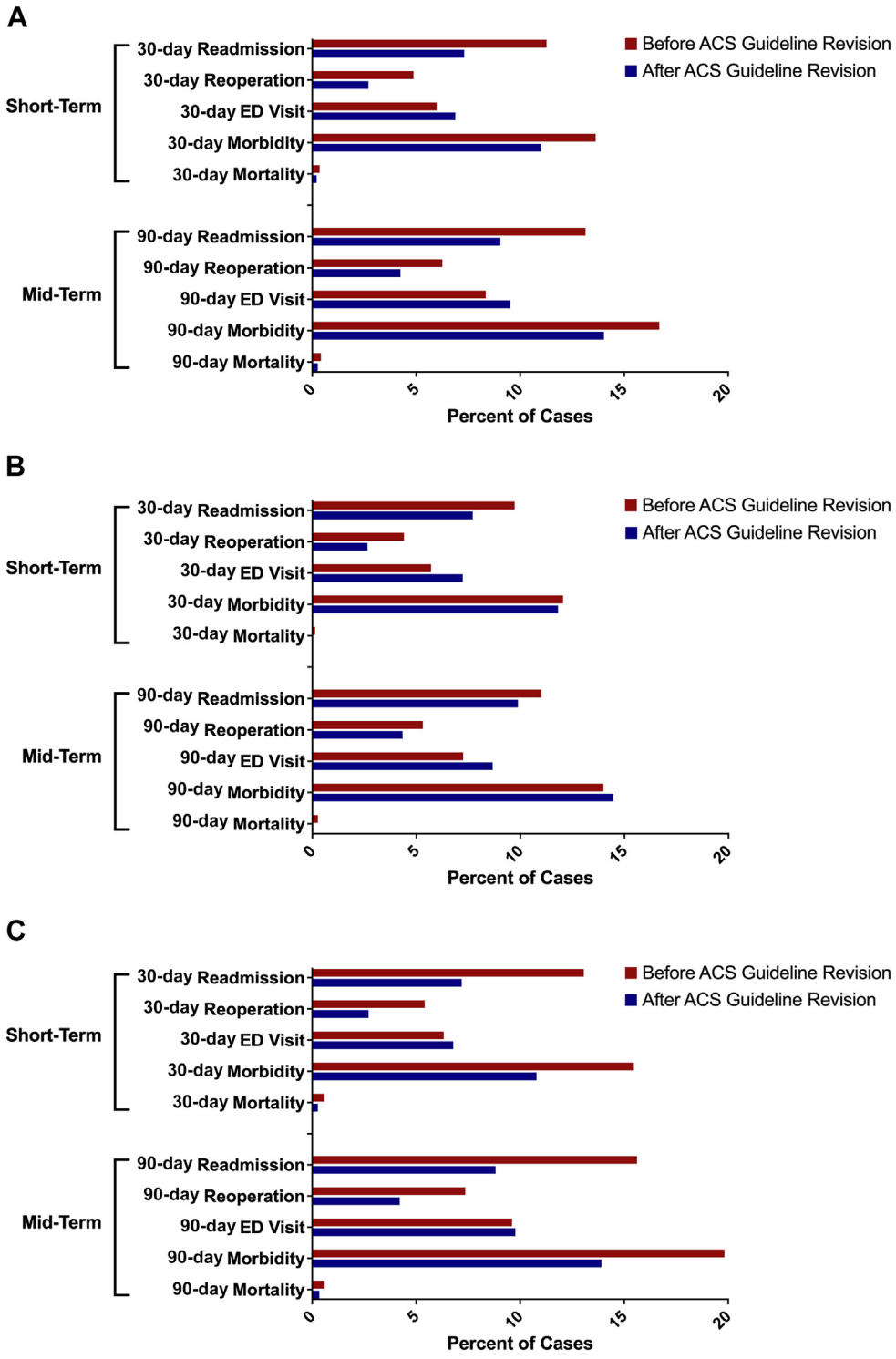

Figure 2. Rate of adverse outcomes either pre–American College of Surgeons (ACS) guideline revision (*red bars*) or post–American College of Surgeons guideline revision (*blue bars*) among (**A**) all patients in the present sample ($n = 3327$), (**B**) only patients who underwent lumbar fusion with any amount of nonconcurrent overlap ($n = 1187$), and (**C**) only patients who underwent lumbar fusion without any overlap ($n = 2140$). ED, emergency department.

Table 2. Frequency of adverse events. Frequency of Events Breakdown by Time Period: Pre— American College of Surgeons Guideline Revision (Before April 12, 2016) or Post—American College of Surgeons Guideline Revision (After October 12, 2016)

	Entire Sample (n = 3327)			Overlapping Surgery Only (n = 1187)			Nonoverlapping Surgery Only (n = 2140)		
outcome	Pre-ACS Guideline Revision (n = 1438), n (%)	Post-ACS Guideline Revision (n = 1889), n (%)	*P* Value	Pre-ACS Guideline Revision (n = 772), n (%)	Post-ACS Guideline Revision (n = 416), n (%)	*P* Value	Pre-ACS Guideline Revision (n = 666), n (%)	Post-ACS Guideline Revision (n = 1474), n (%)	*P* Value
30-day readmission	162 (11.3)	138 (7.3)	**<0.001**	75 (9.7)	32 (7.7)	0.25	87 (13.1)	106 (7.1)	**<0.001**
30-day reoperation	70 (4.9)	51 (2.7)	**<0.001**	34 (4.4)	11 (2.7)	0.13	36 (5.4)	40 (2.7)	**0.002**
30-day emergency department visit	86 (6.0)	130 (6.9)	0.30	44 (5.7)	30 (7.2)	0.38	42 (6.3)	100 (6.8)	0.68
30-day morbidity	196 (13.6)	208 (11.0)	**0.022**	93 (12.1)	49 (11.8)	0.81	103 (15.5)	159 (10.8)	**0.002**
30-day mortality	5 (0.4)	4 (0.2)	0.45	1 (0.1)	0 (0)	0.46	4 (0.6)	4 (0.3)	0.25
90-day readmission	189 (13.1)	171 (9.1)	**<0.001**	85 (11.01)	41 (9.9)	0.51	104 (15.6)	130 (8.8)	**<0.001**
90-day reoperation	90 (6.3)	80 (4.2)	**0.009**	41 (5.31)	18 (4.3)	0.43	49 (7.7)	62 (4.2)	**0.002**
90-day emergency department visit	120 (8.3)	180 (9.4)	0.24	56 (7.3)	36 (8.7)	0.49	64 (9.6)	144 (9.8)	0.91
90-day morbidity	240 (16.7)	265 (14.0)	**0.034**	108 (14.0)	60 (14.5)	0.96	132 (19.8)	205 (13.9)	**<0.001**
90-day mortality	6 (0.4)	5 (0.3)	0.45	2 9 (0.3)	0 (0)	0.29	4 (0.6)	5 (0.3)	0.39

First, the difference in rates between time periods was assessed among the entire sample (N = 3327). Subsequently, the difference in rates between time periods was evaluated only in patients who underwent lumbar fusion with any amount of nonconcurrent overlap (n = 1187), then only in patients who underwent lumbar fusion without any overlap (n = 2140). Bold values denote significance at $P < 0.05$.

ACS, American College of Surgeons.

analysis (n = 236) to allow for departmental adjustment to the revised guidelines. This buffer period was based on the senior author's experience with protocol implementation and adoption. Patients included for analysis (n = 3327) were separated into a pre-ACS guideline revision cohort (surgery performed before April 2016; n = 1438) or a post-ACS guideline revision cohort (surgery performed after October 2016; n = 1889) (Figure 1).

To assess the impact of the ACS guideline revision on outcomes after overlapping surgery, the entire sample was limited to surgery with any degree of nonconcurrent overlap (n = 1187); concurrent surgeries (those with overlap during the critical steps) are not performed at the present institution. Of the surgeries with overlap, 772 were performed before the ACS guideline revision, whereas 416 were performed after the ACS guideline revision.

To assess institutional trends, the entire sample was limited to nonoverlapping surgery (i.e., without any overlap; n = 2140). Of these cases of nonoverlapping surgery, 666 were performed before the ACS guideline revision, whereas 1474 were performed after the ACS guideline revision.

CEM and Same-Surgeon Limit

CEM was used to exact match subjects 1:1 on key risk-associated patient characteristics and isolate the impact of the ACS guideline revision on outcomes.[8] Patients were matched on American Society of Anesthesiologists (ASA) grade, income, BMI, Charlson Comorbidity Index, smoking history, insurance, age, gender, race/ethnicity, and previous surgical history, as described by previous work from the authors.[9-11] A binary approach was used to match income (above vs. below the median value), race/ethnicity (white vs. nonwhite), insurance (private vs. nonprivate), and previous surgical history (presence vs. absence). A ternary approach was applied to BMI, CCI, and ASA grade, assigned as low, medium, or high clusters. Matching for age was performed by decade. Exact matching on each value was performed for all remaining variables. At the present institution, the critical portions of neurosurgical cases are defined at the discretion of the operating surgeon. Hence, to account for any differences among supervising surgeons, exact-matched cohorts were limited to pairs in which both patients shared the same attending surgeon. Unmatched patients were removed from the matched analysis.

Statistical Analysis

Patient demographic data and outcome data were extracted from our institution's electronic health record via the EpiLog tool, a nonproprietary data acquisition software created to streamline workflow and support quality improvement.[12] The primary outcomes collected and reported were proportion of surgery

Table 3. Characteristics in Overlapping Surgery Patients, Pre—American College of Surgeons (ACS) versus Post-ACS Guidelines. Characteristics of Coarsened Exact-Matched Patients with Any Degree of Nonconcurrent Overlap, Who Underwent Lumbar Fusion Either Pre-ACS Guideline Revision (Before April 12, 2016) or Post-Guideline Revision (After October 12, 2016)

	Overlapping Surgery Patients After Exact Match on Risk-Associated Characteristics			Nonconcurrent Overlapping Surgery Patients After Exact Match and Same-Surgeon Limit		
Characteristic	Pre-ACS Guideline Revision (n = 665)	Post-ACS Guideline Revision (n = 665)	*P* Value	Pre-ACS Guideline Revision (n = 289)	Post-ACS Guideline Revision (n = 289)	*P* Value
Gender, n (%)			1.00			1.00
Male	273 (41.05)	273 (41.05)		128 (44.29)	128 (44.29)	
Female	392 (58.95)	392 (58.95)		161 (55.71)	161 (55.71)	
Race/ethnicity, n (%)			1.00			1.00
White	577 (86.77)	577 (86.77)		263 (91)	263 (91)	
Nonwhite	88 (13.23)	88 (13.23)		26 (9)	26 (9)	
Age (years), mean (range)	60.1 (18—88)	60.3 (19—88)	0.95	60.50 (18—88)	60.58 (19—83)	0.99
American Society of Anesthesiologists grade, mean (range)	2.28 (1—3)	2.28 (1—3)	1.00	2.26 (1—3)	2.26 (1—3)	1.00
Charlson Comorbidity Index, mean (range)	2.20 (0—11)	2.29 (0—13)	0.24	2.15 (0—10)	2.27 (0—10)	0.25
Tobacco use, n (%)			1.00			1.00
Yes	54 (8.12)	54 (8.12)		22 (7.61)	22 (7.61)	
No	611 (91.88)	611 (91.88)		267 (92.39)	267 (92.39)	
Number of lifetime previous surgeries, mean (range)	0.44 (0—17)	0.49 (0—18)	0.92	0.38 (0—7)	0.49 (0—10)	0.79
Number of surgeries 90-days before index operation, mean (range)	0.057 (0—2)	0.042 (0—2)	0.39	0.045 (0—2)	0.045 (0—2)	0.68
Insurance type, n (%)			0.23			0.76
Commercial	18 (2.71)	27 (4.06)		12 (4.15)	11 (3.81)	
Medicare	283 (42.56)	285 (42.86)		131 (45.33)	130 (44.98)	
Medicaid	27 (4.06)	25 (3.76)		7 (2.42)	9 (3.11)	
Managed case	256 (38.50)	224 (33.68)		98 (33.91)	89 (30.80)	
Self-pay	1 (0.15)	1 (0.15)		1 (0.35)	0 (0)	
Blue Cross	80 (12.03)	103 (15.49)		40 (13.84)	(17.30)	

First, patients were exact matched on key risk-associated patient characteristics. Subsequently, exact-matched cohorts were limited to pairs in which both patients shared the same attending surgeon.
ACS, American College of Surgeons.

performed with any degree of overlap, as well as adverse postoperative events including 30-day and 90-day rates of readmission for any reason, reoperation, emergency department (ED) visit for any reason, overall morbidity (occurrence of any of the 3 previous adverse events), and all-cause mortality. χ^2 testing was performed to compare proportion of lumbar fusion performed with overlap and adverse postsurgical events between time cohorts.

Subsequently, to assess the impact of the ACS guideline revision on adverse events after overlapping surgery, CEM was used among overlapping surgery patients only, to control for key patient characteristics/attending surgeon and to isolate the time period. Patients who underwent surgery before the ACS guideline revision were exact matched to patients who underwent surgery after the ACS guideline revision, using numerous covariates known to independently affect outcomes. Outcomes between exacted matched subgroups, without and with the same-surgeon limit, were compared by a McNemar test.

To determine whether any reported outcome differences reflected the ACS guideline revision or institutional trends, an additional CEM analysis was performed among nonoverlapping surgery patients only, to exact match patients who underwent

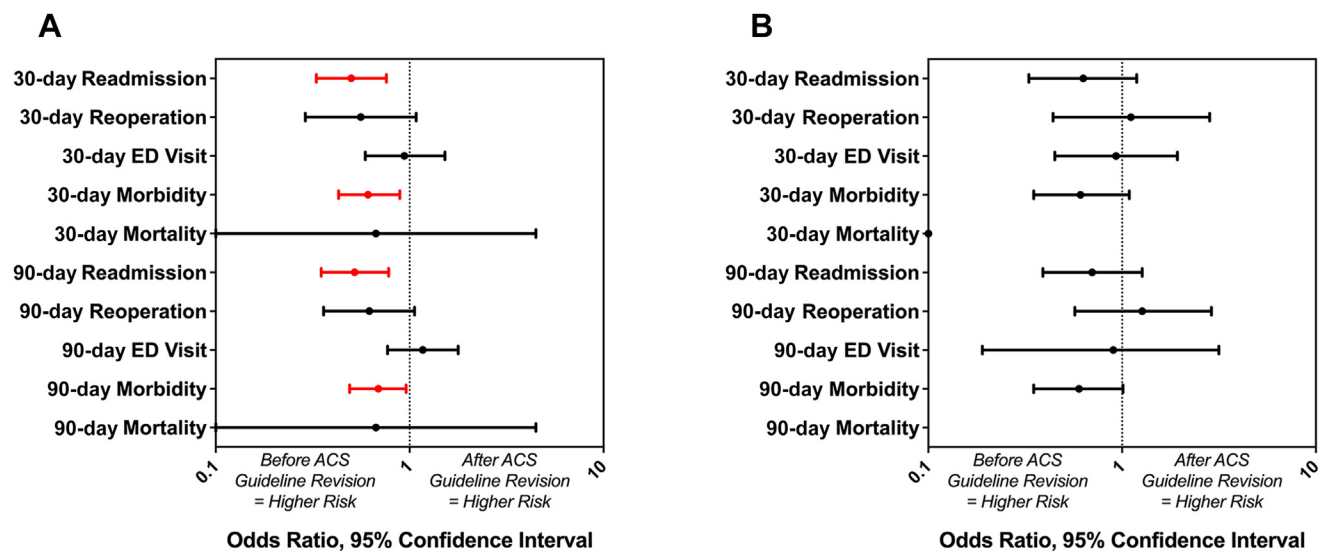

Figure 3. Outcomes in overlapping surgery patients, pre–American College of Surgeons (ACS) versus post-ACS guidelines. Forest plots showing the impact of time period (either pre-ACS guideline revision or post-ACS guideline revision) on outcomes among coarsened exact-matched patients who underwent lumbar fusion with any degree of nonconcurrent overlap. (**A**) First, patients were exact matched on key risk-associated patient characteristics. (**B**) Subsequently, exact-matched cohorts were limited to pairs in which both patients shared the same attending surgeon. Odds ratio <1 indicates that the event was more likely in the pre-guideline revision cohort. Odds ratio >1 indicates that the outcome was more likely in the post-guideline revision cohort. *Red values* denote significance at $P < 0.05$.

surgery before the ACS guideline revision to patients who underwent surgery after the ACS guideline revision.

Matches were generated by the MatchIt programming package in R Statistics (2017; R Foundation for Statistical Computing, Vienna, Austria). All other analysis was performed by SAS version 9.4 (SAS Institute Inc., Cary, North Carolina, USA). Statistical outcomes are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance for all analyses was defined as $P < 0.05$.

RESULTS

Outcomes: Entire Sample of Single-Level Lumbar Fusion Cases

A total of 1438 lumbar fusions (both with and without overlap) were performed before the ACS guideline revision, and 1889 (56.8%) were performed after the ACS guideline revision. Significantly fewer cases were performed with some amount of overlap after the ACS guideline revision (22.0%) compared with before the ACS guideline revision (53.7%) ($P < 0.001$).

Comparing postoperative outcomes between time periods across the entire sample (Figure 2A, Table 2), 30-day and 90-day rates of readmissions, reoperations, and morbidity declined after the guideline revision. No significant differences in 30-day and 90-day ED visits or mortality were observed between time cohorts.

Outcomes: All Overlapping Cases Only

Among the entire sample, 1187 surgeries were performed with any amount of overlap. Of these surgeries, 772 were performed before the ACS guideline revision, whereas 416 were performed after the ACS guideline revision. Across these overlapping cases only (Figure 2B, Table 2), no significant differences in 30-day and 90-day outcomes were observed between time cohorts.

Outcomes: Overlapping Cases Only, After Exact Matching

After exact matching of overlapping surgery patients on risk-producing patient characteristics, patients within the pre-ACS guideline revision ($n = 665$; 46.2% match rate) and post-ACS guideline revision ($n = 665$) subgroups shared a similar age, CCI, and ASA grade (Table 3).

Comparing postoperative outcomes between these subgroups (Figure 3A, Table 4), patients after the ACS guideline revision experienced lower rates of 30-day readmission (5.4% vs. 10.2%; OR, 0.50; 95% CI, 0.33–0.76; $P = 0.001$) and morbidity (8.3% vs. 12.6%; OR, 0.61; 95% CI, 0.43–0.89; $P = 0.009$) than did patients before the ACS guideline revision. At 90 days postoperatively, patients after the ACS guideline revision experienced lower rates of readmission (6.9% vs. 12.0%; OR, 0.52; 95% CI, 0.35–0.78; $P = 0.001$) and morbidity (12.0% vs. 15.9%; OR, 0.69; 95% CI, 0.49–0.96; $P = 0.028$) than did patients before the ACS guideline revision. The time period subgroups did not have significantly different rates of 30-day and 90-day reoperations, ED visits, mortality.

Outcomes: Overlapping Cases Only, After Exact Matching and Same-Surgeon Limit

After exact matching of overlapping surgery patients on risk-producing patient characteristics, then limiting to matched pairs sharing the same attending surgeon, patients within the pre-ACS guideline revision ($n = 289$; 20.1% match rate) and post-ACS

Table 4. Overlapping Surgery Patient Outcomes. Outcomes Among Coarsened Exact-Matched Patients with Any Degree of Nonconcurrent Overlap, Who Underwent Lumbar Fusion Either Pre—American College of Surgeons Guideline Revision (Before April 12, 2016) or Post— American College of Surgeons Guideline Revision (After October 12, 2016)

	Overlapping Surgery Patients After Exact Match on Risk-Associated Characteristics				Overlapping Surgery Patients After Exact Match and Same-Surgeon Limit			
Outcome	Pre-ACS Guideline Revision (n = 665), n (%)	Post-ACS Guideline Revision (n = 665), n (%)	OR (95% CI)*	*P* Value†	Pre-ACS Guideline Revision (n = 289), n (%)	Post-ACS Guideline Revision (n = 289), n (%)	OR (95% CI)*	*P* Value†
30-day readmission	68 (10.23)	36 (5.41)	0.50 (0.33—0.76)	**0.001**	26 (9.00)	17 (5.88)	0.63 (0.33—1.19)	0.15
30-day reoperation	26 (3.91)	15 (2.26)	0.56 (0.29—1.08)	0.08	9 (3.11)	10 (3.46)	1.11 (0.44—2.83)	0.82
30-day ED visit	36 (5.41)	34 (5.11)	0.94 (0.59—1.52)	0.81	15 (5.19)	14 (4.84)	0.93 (0.45—1.93)	0.85
30-day morbidity‡	84 (12.63)	55 (8.27)	0.61 (0.43—0.89)	**0.009**	34 (11.76)	22 (7.61)	0.61 (0.35—1.09)	0.09
30-day mortality	3 (0.45)	2 (0.30)	0.67 (0.08—4.48)	0.69	2 (0.69)	0 (0)	N/A	N/A
90-day readmission	80 (12.03)	46 (6.92)	0.52 (0.35—0.78)	**0.001**	29 (10.03)	21 (7.27)	0.70 (0.39—1.27)	0.24
90-day reoperation	36 (5.41)	23 (3.46)	0.62 (0.36—1.06)	0.08	11 (3.81)	14 (4.84)	1.27 (0.57—2.89)	0.56
90-day ED visit	49 (7.37)	56 (8.42)	1.17 (0.77—1.78)	0.46	21 (7.27)	19 (6.57)	0.90 (0.45—1.70)	0.75
90-day morbidity	106 (15.94)	80 (12.03)	0.69 (0.49—0.96)	**0.028**	42 (14.53)	27 (9.34)	0.60 (0.35—1.01)	0.51
90-day mortality	3 (0.45)	2 (0.30)	0.67 (0.08—4.48)	0.69	2 (0.69)	0 (0)	N/A	N/A

First, patients were exact matched on key risk-associated patient characteristics. Subsequently, exact matched cohorts were limited to pairs in which both patients shared the same attending surgeon.

ACS, American College of Surgeons; OR, odds ratio; CI, confidence interval; ED, emergency department; N/A, not available.

*Odds ratio <1 indicates that the event was more likely in the pre-guideline revision cohort. Odds ratio >1 indicates that the outcome was more likely in the post-guideline revision cohort.

†Significant *P* values (<0.05) are in bold.

‡Morbidity refers to the presence of any of the studied morbidity outcomes, including readmission, reoperation, and emergency department evaluation.

guideline revision (n = 289) subgroups shared a similar age, CCI, and ASA grade (Table 3).

Comparing postoperative outcomes between these subgroups (Figure 3B, Table 4), no significant differences in 30-day and 90-day outcomes were observed.

Outcomes: All Nonoverlapping Cases Only

Among the entire sample, 2140 surgeries were performed without any overlap. Of these surgeries, 666 were performed pre-ACS guideline revision, whereas 1474 were performed post-ACS guideline revision. Across these nonoverlapping surgeries only (Figure 2C, Table 2), patients after the ACS guideline revision had lower rates of 30-day and 90-day readmissions, reoperations, and morbidity than did patients before the ACS guideline revisions. No significant differences in 30-day and 90-day ED visits or mortality were observed between time cohorts.

Outcomes: Nonoverlapping Cases, After Exact Matching

After exact matching of nonoverlapping surgery patients on risk-producing patient characteristics, patients within the pre-ACS guideline revision (n = 429; 64.4% match rate) and post-ACS guideline revision (n = 429) subgroups shared a similar age, CCI, and ASA grade (Table 5).

Comparing postoperative outcomes between these subgroups (Figure 4, Table 6), patients after the guideline revision experienced significantly lower rates of 30-day readmission (5.8% vs. 11.7%; OR, 0.46), reoperation (2.1% vs. 4.4%; OR, 0.44), and morbidity (9.6% vs. 14.7%; OR, 0.60) than did patients before the ACS guideline revision. At 90 days postoperatively, patients after the ACS guideline revision experienced significantly lower rates of readmission (7.0% vs. 13.8%; OR, 0.46), reoperation (0.9% vs. 2.1%; OR, 0.46), and morbidity (13.5% vs. 18.7%; OR, 0.65) than did patients before ACS guideline revision. The time period subgroups did not have significantly different rates of 30-day and 90-day ED visits or mortality.

DISCUSSION

After the ACS guideline revision, there was a significant reduction of lumbar fusion surgeries performed with overlap (from 54% to 22%) at this multihospital academic center. Patients after the ACS guideline revision experienced lower rates of readmission and reoperation within 30 and 90 days. However, when exclusively analyzing overlapping cases, there was no difference in outcomes among overlapping surgery patients pre-ACS versus post-ACS guideline revision. Similarly, after exact matching and limiting to matched pairs sharing the same attending surgeon, overlapping

Table 5. Characteristics in Nonoverlapping Surgery Patients, Pre—American College of Surgeons (ACS) versus Post-ACS Guidelines. Characteristics of Coarsened Exact-Matched Patients without Any Overlap, Who Underwent Lumbar Fusion Either Pre-ACS Guideline Revision (Before April 12, 2016) or Post-Guideline Revision (After October 12, 2016)

	Nonoverlapping Surgery Patients After Exact Match on Risk-Associated Characteristics		
Characteristic	**Pre-ACS Guideline Revision (n = 429)**	**Post-ACS Guideline Revision (n = 429)**	***P* Value**
Gender, n (%)			1.00
Male	159 (37.06)	159 (37.06)	
Female	270 (62.94)	270 (62.94)	
Race/ethnicity, n (%)			1.00
White	356 (82.98)	356 (82.98)	
Nonwhite	73 (17.02)	73 (17.02)	
Age (years), mean (range)	60.31 (15—88)	60.43 (19—83)	0.92
American Society of Anesthesiologists grade, mean (range)	2.29 (1—3)	2.29 (1—3)	1.00
Charlson Comorbidity Index, mean (range)	2.33 (0—11)	2.38 (0—10)	0.59
Tobacco use, n (%)			1.00
Yes	33 (7.69)	33 (7.69)	
No	396 (92.31)	396 (92.31)	
Number of lifetime previous surgeries, mean (range)	0.54 (0—17)	0.65 (0—18)	0.75
Number of surgeries 90-days before index operation, mean (range)	0.077 (0—2)	0.067 (0—2)	0.87
Insurance type, n (%)			0.74
Commercial	14 (3.26)	21 (4.90)	
Medicare	190 (44.29)	193 (44.99)	
Medicaid	21 (4.90)	18 (4.20)	
Managed Case	159 (37.06)	150 (34.97)	
Self-pay	0 (0)	0 (0)	
Blue Cross	45 (10.49)	47 (10.96)	

Patients were exact matched on key risk-associated patient characteristics.
ACS, American College of Surgeons.

surgery patients pre-ACS and post-ACS guideline revision experienced similar rates of 30-day and 90-day outcomes. These findings imply that the updated ACS guidelines did not have a discernable impact on outcomes related to overlapping surgery.

The observed reduction of overlapping lumbar fusion cases is consistent with studies into the impact of more restrictive policy changes at other academic centers. Guan et al.[5] found that the percentage of overall neurosurgical cases performed with overlap was reduced from 46% to 27% at a single academic medical center after the ACS guideline publication, following an institutional policy addressing overlapping and concurrent surgery. Nonetheless, these investigators' study found no change in the overall rate of complications or serious complications after the change in institutional policy. Taken together with the present study, these findings suggest that the ACS guideline revision had a widespread impact in reducing the number of overlapping procedures performed, but not on outcomes. In addition, the subsequent reduction of overlap may lead to greater health care inefficiency, including increased wait times for surgery and decreased resident involvement, as highlighted in other studies.[5,13]

Our selected outcomes measures were an intentional component of study design. They are easily interpretable by patients and providers, and they may be incorporated into quality assessment and reimbursement models for hospital systems. A difference in adverse postoperative outcomes was observed across the entire sample but not among overlapping surgery patients. This finding may reflect surgeons selecting healthier patients for overlap, consistent with previous studies that have shown that patients selected for overlapping procedures have fewer comorbidities and a lower ASA score.[4,14] For this reason, the present study used CEM to address any baseline differences within time period cohorts.

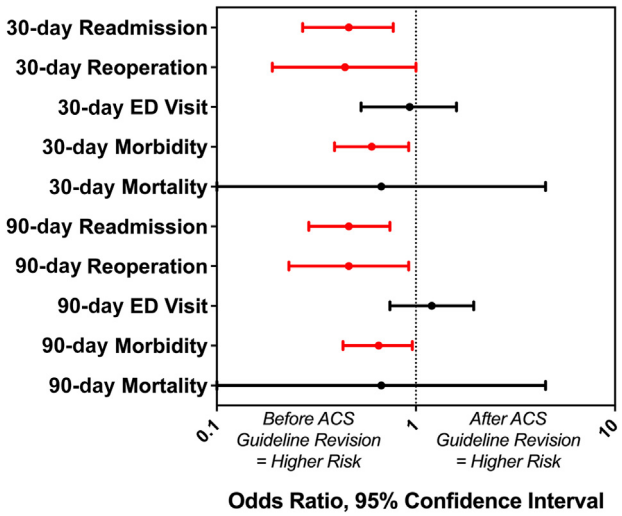

Figure 4. Outcomes in nonoverlapping surgery patients, pre–American College of Surgeons (ACS) versus post-ACS guidelines. Forest plots showing the impact of time period (either pre-ACS guideline revision or post-ACS guideline revision) on outcomes among patients who underwent lumbar fusion without any overlap and exact matched on key risk-associated patient characteristics. Odds ratio <1 indicates that the event was more likely in the pre-guideline revision cohort. Odds ratio >1 indicates that the outcome was more likely in the post-guideline revision cohort. *Red values* denote significance at $P < 0.05$.

Subsequently, matched overlapping surgery patients before and after the ACS guideline revision were limited to the same attending surgeon and subsequently showed equivalent 30-day and 90-day outcomes. This finding indicates that the ACS guideline revision did not affect outcomes after overlapping surgeries when performed by the same surgeon. However, across the entire sample, patient outcomes seemed to improve in the time period after the ACS guideline revision. These results may reflect an institutional trend of decreasing rates of adverse short- and mid-term outcomes in the time period after the ACS guideline revision, regardless of the presence or absence of overlap.

Limitations

This study must be interpreted within its limitations. First, this retrospective analysis may be subject to sampling bias because of the use of a single university-wide electronic medical record. It is possible that some adverse postoperative events were managed at other health care institutions. This limitation was mitigated by a long duration of follow-up (mean, 53.9 months and 17.53 months for exact-matched patients pre-ACS and post-ACS guideline revision, respectively). All patient encounters at outside hospitals were documented during each follow-up visit.

Another limitation is that there may have been confounding variables that were not controlled via CEM, such as specific operative techniques used or surgical indication. Nevertheless, our intent was to examine the impact of this major policy change across an entire single-level lumbar fusion population, consisting of procedures that all showed a comparable degree of surgical trauma. Further, the exclusion criteria and matching characteristics used herein were carefully selected based on existing literature that has correlated them to adverse postsurgical events.[15-26] We believe that we have sufficiently accounted for confounding variables and isolated the true impact of the ACS guideline revision on outcomes.

Further, outcomes may have been affected by differences in surgeon and surgical team experience over the course of the study period. Nonetheless, we addressed this challenge by limiting the exact-matched pairs of overlapping cases to those with the attending neurosurgeon. In addition, this study did not evaluate differences in specific short-term or long-term operative complications such as increased operative time, blood loss, durotomy, infection, or neurologic impairment. Future studies should evaluate differences in specific short-term and long-term complications to establish the safety of overlapping surgery more thoroughly.

This single-institution study examined only single-level posterior lumbar fusions. Although this situation may limit generalizability, this was an intentional aspect of the study design to limit confounding and preserve internal validity, and the results may be immediately applicable to many patients undergoing overlapping

Table 6. Nonoverlapping Surgery Patient Outcomes. Outcomes of Coarsened Exact-Matched Patients without Any Overlap, Who Underwent Lumbar Fusion Either Pre—American College of Surgeons Guideline Revision (Before April 12, 2016) or Post—American College of Surgeons Guideline Revision (After October 12, 2016)

	Nonoverlapping Surgery Patients After Exact Match on Risk-Associated Characteristics			
Outcome	**Pre-ACS Guideline Revision (n = 429), n (%)**	**Post-ACS Guideline Revision (n = 429), n (%)**	**Odds Ratio (95% Confidence Interval)***	***P* Value†**
30-day readmission	50 (11.66)	25 (5.83)	0.46 (0.27—0.77)	**0.002**
30-day reoperation	19 (4.43)	9 (2.10)	0.44 (0.19—1.02)	**0.049**
30-day ED visit	28 (6.53)	26 (6.06)	0.93 (0.53—1.60)	0.78
30-day morbidity‡	63 (14.69)	41 (9.56)	0.60 (0.39—0.92)	**0.02**
30-day mortality	3 (0.70)	2 (0.47)	0.67 (0.08—4.48)	0.69
90-day readmission	59 (13.75)	30 (6.99)	0.46 (0.29—0.74)	**0.001**
90-day reoperation	27 (6.29)	13 (3.03)	0.46 (0.23—0.92)	**0.02**
90-day ED visit	38 (8.86)	44 (10.26)	1.20 (0.74—1.95)	0.46
90-day morbidity	80 (18.65)	58 (13.52)	0.65 (0.43—0.96)	**0.03**
90-day mortality	3 (0.70)	2 (0.47)	0.67 (0.08—4.48)	0.69

ACS, American College of Surgeons; ED, emergency department.
*Odds ratio <1 indicates that the event was more likely in the pre-guideline revision cohort. Odds ratio >1 indicates that the outcome was more likely in the post-guideline revision cohort.
†Significant *P* values (<0.05) are in bold.
‡Morbidity refers to the presence of any of the studied morbidity outcomes, including readmission, reoperation, and ED evaluation.

spinal fusions. Future multicenter studies among other spine surgery populations are warranted to corroborate the present results.

CONCLUSIONS

After the 2016 ACS guideline revision, the large multihospital academic medical center studied herein experienced a reduction in the proportion of lumbar fusions performed with overlap. Overall, we observed an institutional trend of improved 30-day and 90-day adverse postsurgical outcomes after the ACS guideline revision. However, no discernable differences in outcomes were observed among overlapping surgeries. After controlling for key risk-producing patient characteristics and attending surgeon among the overlapping surgery cases, exact-matched time period subgroups did not show significantly different 30-day and 90-day outcomes. These findings suggest that the ACS guideline revisions had no discernable impact on adverse postoperative events after overlapping surgeries but did change the frequency of overlapping spinal fusion surgeries.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Ali S. Farooqi: Conceptualization, Methodology, Writing — original draft, Writing — review & editing, Formal analysis, Data curation. **Austin J. Borja:** Methodology, Writing — original draft, Writing — review & editing, Visualization, Software, Formal analysis, Data curation. **Rashad Jabarkheel:** Writing — original draft, Writing — review & editing. **Gregory Glauser:** Writing — original draft, Writing — review & editing. **Krista Strouz:** Methodology, Software, Formal analysis, Data curation. **Scott D. McClintock:** Writing — review & editing, Methodology, Software, Supervision. **Neil R. Malhotra:** Conceptualization, Methodology, Software, Validation, Investigation, Resources, Data curation, Writing — original draft, Writing — review & editing, Supervision, Project administration, Funding acquisition.

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