



Review

Does overlapping surgery result in worse surgical outcomes? A systematic review and meta-analysis



Rajshri M. Gartland^{a,*}, Kristin Alves^b, Níssia C. Brasil^c, Matthew Mossanen^d,
Elizabeth Mort^e, Cameron D. Wright^a, Carrie C. Lubitz^a, Collin May^f

^a Department of Surgery, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA

^b Department of Orthopedic Surgery, Harvard Medical School, Boston, MA, USA

^c Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, MA, USA

^d Department of Surgery, Division of Urology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA

^e Lawrence Center for Quality and Safety, Massachusetts General Hospital and Massachusetts General Physicians' Organization, Boston, MA, USA

^f Department of Orthopedic Surgery, Boston Children's Hospital, Harvard Medical School, Boston, MA, USA

ARTICLE INFO

Article history:

Received 17 October 2018

Received in revised form

25 November 2018

Accepted 29 November 2018

Meeting presentation: This paper was presented as podium presentation at the 99th Annual New England Surgical Society meeting on September 22, 2018 in Portland, Maine.

Keywords:

Overlapping surgery

Concurrent surgery

Mortality

Complications

Operative time

Patient safety

ABSTRACT

Background: The practice of overlapping surgery impacts patients, providers, and policy-makers. While several studies have examined the relationship between overlapping surgery and clinical outcomes, a combined analysis of all available data has not been performed. We aimed to evaluate the impact of overlapping surgery on 30-day mortality, morbidity, and length of surgery.

Methods: A systematic literature review revealed all relevant studies examining outcomes of overlapping versus non-overlapping surgery as of March 2018. A pooled meta-analysis with stratification by study quality grade was performed, and heterogeneity and publication bias were assessed.

Results: A total of 14 sets of analyses met inclusion and exclusion criteria. Meta-analysis revealed no significant differences in 30-day mortality (OR = 0.84; $p = 0.277$) or overall morbidity (OR = 0.96; $p = 0.632$) between patients who underwent overlapping versus non-overlapping surgery. The standardized mean difference for length of surgery between the groups indicated a small statistically significant increase in length of surgery for the overlapping surgery group (SMD = 0.079, $p < 0.05$).

Conclusion: While further study is warranted, current literature suggests that overlapping surgery is not associated with increased risk of mortality or morbidity.

© 2018 Elsevier Inc. All rights reserved.

Brief summary

Meta-analysis of the current literature examining the risks of overlapping surgery versus non-overlapping surgery demonstrated no statistically significant difference in 30-day mortality, overall morbidity, and 30-day unplanned reoperation rates between the two groups. There was a small statistically significant increased standardized mean difference for length of surgery for the overlapping surgery group. While further studies are necessary to better define optimal patient, setting, and procedure type for safe and efficacious overlapping surgery, these findings suggest that

overlapping surgery, if performed under established guidelines, may be performed without increased risk to patient safety.

Introduction

The practice of surgeons performing overlapping surgery is an important topic for patients, physicians, and policy-makers. While surgeons performing operations in two separate rooms with some degree of overlap constitutes a longstanding common practice, the issue was catapulted to national attention when the *Boston Globe* investigative Spotlight series released "Clash in the name of care," highlighting the practice in detail as it was being performed by the Massachusetts General Hospital Orthopedic Department.¹ The article raised patient concerns over the safety of the practice and a lack of transparency around its use. In fact, in one survey of over 1400 patients, only 4% knew of overlapping surgeries, though the

* Corresponding author. Department of Surgery, Massachusetts General Hospital, 55 Fruit Street, GRB 425, Boston, MA, 02114, USA.

E-mail address: rgartland@mgh.harvard.edu (R.M. Gartland).

Abbreviations

CMS	Centers for Medicare and Medicaid Services
ACP	American College of Physicians
SMD	standardized mean difference
OR	odds ratio

majority (95%) felt surgeons should disclose if simultaneous surgery is to be performed.²

For hospitals, physicians, and patients, overlapping surgeries may improve utilization of operating room resources, decrease wait times for surgery and accordingly improve access to specialty care, and reduce healthcare costs.³ In academic settings, overlapping surgeries may also provide valuable educational opportunities for trainees.⁴ In a survey of surgical specialists, 63% of respondents felt that eliminating overlapping surgeries would be a detriment to residency training.⁵ Despite these potential advantages, the evidence base to support the safety of the practice is thin and historically patients have not been consistently and reliably educated about the practice. Understandably then, policy makers and the public have scrutinized overlapping surgeries citing concerns that such practices may put patients at undue risk for negative clinical outcomes such as surgical complications, or even death. In 2016, the Senate Finance Committee recognized the importance of exploring the issue and queried 20 hospitals.⁶ Less than half of hospitals outlined institutional policies. Their report entitled “Concurrent and Overlapping Surgeries: Additional Measures Warranted,” thus stipulated the importance of defining critical portions of operations, disclosing the practice to patients, and designating a back-up surgeon. Additionally, the report recognized that the true incidence and impact of overlapping surgery remains unknown, and that “there is a limited amount of information upon which to draw conclusions.”

As a result, the topic of overlapping surgeries remains controversial⁷ and has become increasingly studied.⁸ Of note, there is an important distinction between overlapping and concurrent surgery. While *concurrent* surgery occurs when a single surgeon is responsible for the critical portions of two or more simultaneous surgeries, a practice that violates the Centers for Medicare and Medicaid Services (CMS) billing requirements and is *not* condoned by the American College of Surgeons, *overlapping* surgery does not involve overlap of the critical portions and is more commonly performed.³ Over the last several years, physicians have examined the association of these surgeries with adverse clinical outcomes in a variety of fields including neurosurgery,^{9–15} head and neck surgery,¹⁶ orthopedic surgery,^{17–19} cardiothoracic surgery,²⁰ pediatric surgery,²¹ and overall surgery.^{22–24} However, no effort has been made to combine and collectively analyze the results of all available studies in the surgical literature. Meta-analysis offers an opportunity to statistically evaluate diverse studies and estimate the effect on clinical outcomes. In this work, a systematic review of the literature and meta-analysis was performed examining overlapping surgery and its impact on adverse clinical outcomes as defined by 30-day mortality, morbidity, and length of surgery.

Material and methods

Literature search strategy

The Population, Intervention, Comparator, Outcomes, Timing (PICOT) format was employed to build the study question. The study population included patients undergoing any surgical

procedure in the United States, the intervention was overlapping surgical procedure versus non-overlapping surgical procedure, assessing whether there is any difference in 30-day mortality, 30-day morbidity, and length of surgery. Surgeries taking place in both inpatient and ambulatory settings were included. Studies with no outcome measure assessed, studies with no comparison group, studies with surgery taking place exclusively at an outpatient surgery center or children’s hospital, studies with overlapping data, and studies evaluating or intending to evaluate “concurrent” surgery rather than overlapping surgery were excluded. Our *a priori* hypothesis was that there was no difference in these outcomes between patients undergoing overlapping versus patients undergoing non-overlapping surgical procedures.

A comprehensive literature search was performed with the assistance of a clinical librarian using PubMed, MEDLINE via OVID, and EMBASE databases from inception of the databases to March 1, 2018. The search was performed utilizing appropriate Medical Subject Headings terms including “concurrent,” “overlap,” “simultaneous,” “surgical procedures, operative” and “surgery” with expanded terms included. Keywords were used to indicate outcomes of interest, including generic terms such as “patient outcomes,” “adverse outcomes,” “morbidity,” “mortality,” “complications,” “readmission,” “reoperation,” “length of stay,” and “surgery duration.”

The obtained reference list was scanned for publication titles related to overlapping versus non-overlapping surgery. Papers with potentially relevant titles were selected for further review of the abstracts. All articles relevant to the subject were retrieved, and their bibliographies manually reviewed to identify any additional studies of interest. If the abstract had a subject matter involving overlapping or concurrent surgery, whether it was the primary focus or a secondary focus of the paper, the paper was selected for further review if full text was available.

After the initial assessment for inclusion, articles were sifted to isolate studies that had quantitative outcomes versus editorial assessments of overlapping surgery. For the meta-analysis, studies were required to have an analysis of overlapping surgery versus non-overlapping surgery with outcomes including mortality, complications, or length of surgery assessed. Thirty-day reoperation rates were also noted.

Data extraction and quality assessment

Data and study quality grade were extracted independently by three investigators (NCB, MM, CM) and conflicts were adjudicated by a third investigator (RMG). For the selected studies, information on all available variables was extracted and entered into a Microsoft Excel database. Study quality was assessed using the American College of Physicians (ACP) Grading System for the Quality of Evidence and Strength of Recommendations on a 3-point scale (low, moderate, high).²⁵ Studies demonstrated heterogeneity in the complications reported, thus, only composite measures of complications were used for the meta-analysis. Studies with sufficient statistical data to assess intervention effect sizes estimates were selected for the meta-analysis. Only adjusted results were used in the meta-analysis when any risk adjustment was performed. When a study performed no risk adjustment, the results of univariate analysis were used in the meta-analysis.

Statistical analysis

The meta-analysis was performed using a fixed-effects model when there was no statistically significant heterogeneity and a random-effects model when there was significant heterogeneity; statistical heterogeneity among studies was defined as I^2 statistic

greater than 50%. Heterogeneity in outcomes was expected across studies as a consequence of diversity of primary clinical outcome reported, different surgical procedures, different health care settings, and definitions of overlapping surgery across studies.

The Q test was used to assess heterogeneity and I^2 statistic to measure the relative degree of inconsistency across studies. Publication bias was assessed across all studies through visual inspection using the Funnel Plot analysis, as well as with the Begg's and Egger's regression methods for statistical assessment. Sub-group analysis was performed to examine effect estimates according to study quality grade (ACP "moderate" quality grade studies were denoted as Higher (H) quality and ACP "low" quality grade studies denoted as Low (L) quality). Cumulative analysis was used to assess outliers. Metameters were calculated considering a 95% confidence interval and $p \leq 0.05$. Statistical analysis was performed using Comprehensive Meta Analysis V 3.0.

This study was reported based on Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines.²⁶

Results

Study identification and characteristics

A flow diagram detailing the search strategy and identification of studies used in the meta-analysis is demonstrated in Fig. 1. The first search of the literature identified 3268 records. After exclusion of duplicates (1113), the search resulted in 2155 records. The search was narrowed based on eligibility criteria and resulted in 33 full texts to be assessed for final eligibility. Eleven studies were included in the quantitative analysis. Two sets of results were reported for three studies^{18,20,22} given that two sets of analyses were provided. One study had data extracted from an abstract and conference presentation.²⁰ During systematic review, the lead author

was contacted to obtain a copy of the paper, but a reply was not received by the time the analysis was performed.

The primary characteristics of the 11 studies (with 14 sets of analyses) included in the meta-analysis are summarized in Table 1. All studies were retrospective cohort studies and all studies examined cases during time periods after 2009. Ten of 14 analyses provided risk-adjusted results.

Outcomes

The overall pooled odds ratio (OR) for the outcome of 30-day mortality was 0.84 (95% CI 0.61–1.15, $p = 0.277$), indicating no significant difference in odds of mortality for those undergoing overlapping versus non-overlapping surgery (Fig. 2a). Stratified analysis by ACP study quality grade was performed (Fig. 2b); the higher (H) quality grade studies also demonstrated no significant difference in mortality between the overlapping and non-overlapping groups (OR 0.97, 95% CI 0.77–1.22, $p = 0.79$). The mortality estimate had high heterogeneity among studies, with an I^2 value of 86%. Nine studies (11 sets of analysis) reported on overall morbidity; both pooled (Fig. 3a) and stratified analysis (Fig. 3b) demonstrated no statistically significant difference in rate of complications between the overlapping and non-overlapping surgery groups (pooled OR 0.96, 95% CI 0.81–1.14, $p = 0.632$, $I^2 = 73\%$).

Length of surgery was available for 9 sets of analyses included in the meta-analysis. As shown in Fig. 4a, the standardized mean difference (SMD) for length of surgery between the overlapping and non-overlapping surgery groups indicated a small statistically significant increase in length of surgery for the overlapping surgery group (SMD = 0.095, $p < 0.005$, $I^2 = 46\%$), also evident after stratification based on study quality grade (Fig. 4b).

In addition to these outcomes, five studies assessed 30-day unplanned reoperation rates. On pooled analysis, there was no

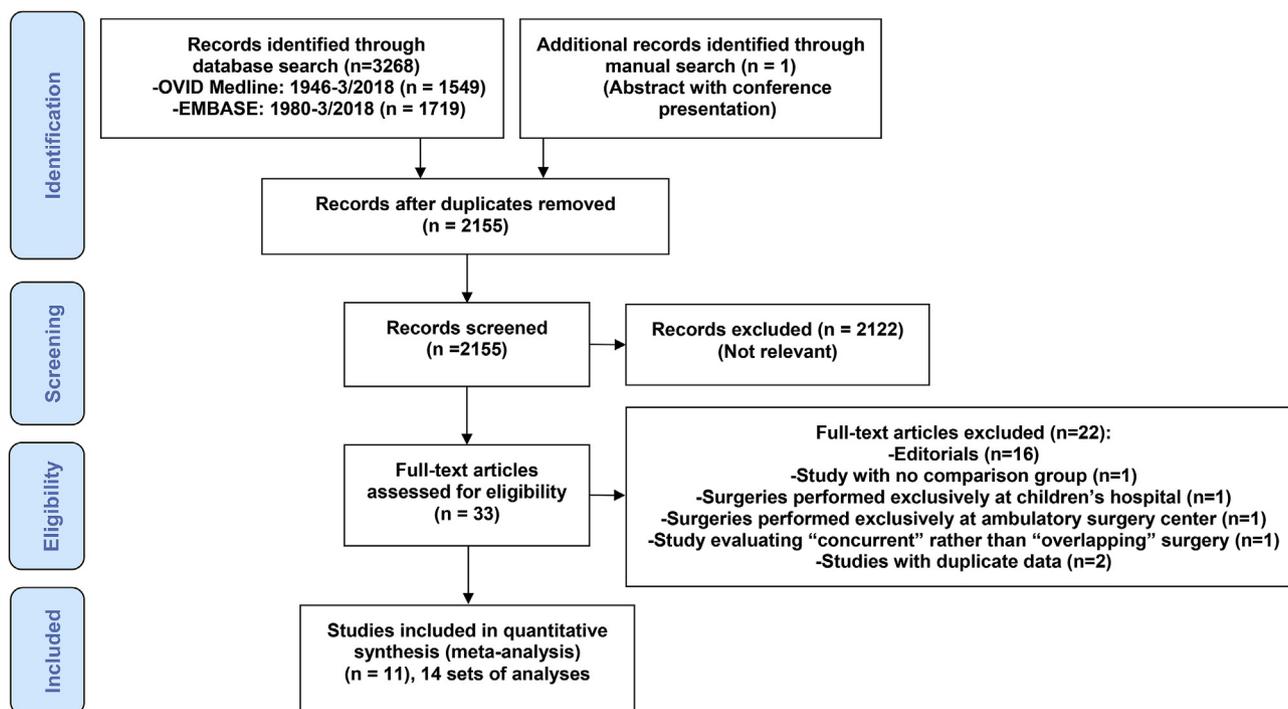


Fig. 1. Flow chart demonstrating systematic literature review process. This flow diagram illustrates the search strategy and identification of studies used in the meta-analysis. The first search of the literature identified 3268 records. After exclusion of duplicates (1113), the search resulted in 2155 records. The search was narrowed based on eligibility criteria and resulted in 33 full texts to be assessed for final eligibility. Eleven studies and with 14 sets of analyses were included in the quantitative analysis.

Table 1
Characteristics of included studies.

Study	Type of study	Study Period	Study population	Overlapping surgery definition	Overlapping cases, n	Non-overlapping, n	Setting	Risk adjustment	Outcomes included in meta-analysis					ACP Quality Grade ⁱ
									30-day mortality	Overall 30-day morbidity	30-day unplanned readmission	30-day unplanned reoperation	Length of surgery	
Bohl et al. (2018) ⁹	RC	7/2013-5/2016	patients undergoing neurosurgical procedures	surgeries with any degree of overlap	8429	6443	academic hospital	procedure type, patient demographics, clinical indicators, procedure characteristics, resident postgraduate year	unadjusted only	NG	unadjusted only	✓	✓	++
Guan et al. (2017) ¹⁰	RC	5/12/14-5/12/15	patients undergoing nonurgent neurosurgical procedures	2 patients under the care of a single lead surgeon under anesthesia at the same time for any duration	475	543	academic hospital	surgery type, surgery duration, BMI, ASA, intraoperative blood loss, neurological co-morbidities	unadjusted only	✓	NG	NG	unadjusted only	+
Hamilton et al. (2018) ¹⁷	RC	2006–2016	patients undergoing primary hip and knee arthroplasties	surgeries with >30 min of overlap, with no overlap of critical portion of case	9914	7002	academic high-volume practice	univariate analysis only	NG	unadjusted only	NG	unadjusted only	NG	+
Howard et al. (2018) ¹¹	RC	1/1/2014-12/31/2015	patients undergoing neurosurgical procedures	surgeries with any degree of overlap	1303	972	academic hospital	propensity score weighting, adjustments for patient demographics, surgeon, clinical indicators, procedure	Overlapping vs non-overlapping OR 1.64 (0.84–3.14)	Overlapping vs nonoverlapping OR 0.86 (0.68–1.08)	NG	NG	NG	++
Hyder et al. (2017) (UHC subset) ²²	RC	01/2013-09/2015	patients undergoing index, elective, nontransplant surgery	surgery by one surgeon with overlap between incision and closure (no overlap in critical portions)	10614	16111	UHC hospitals	surgeon, case-mix, and patient-level predicted risk estimates	✓	unadjusted only	NG	NG	✓	++
Hyder et al. (2017) (NSQIP subset) ²²	RC	01/2011-12/2014	patients undergoing inpatient and outpatient noncardiac nontransplant surgery	surgery by one surgeon with overlap between incision and closure (no overlap in critical portions)	3712	5637	UHC NSQIP hospitals	surgeon, case-mix, and patient-level predicted risk estimates	✓	✓	NG	NG	unadjusted only	++
Mooney et al. (2017) ¹²	RC	3/2003-1/2007	patients undergoing microsurgical clipping of ruptured saccular aneurysms	surgeries with any degree of overlap	123	118	Academic neurologic institute	univariate analysis only	unadjusted only	unadjusted only	NG	NG	unadjusted only	+
Ponce et al. (2018) ²⁴	RC	1/1/2014-12/31/2015	patients undergoing operations across 13 surgical specialties	surgeries with any degree of overlap, with no overlap of critical portions of case	11213	8295	2 academic hospitals	limited adjustment for patient demographic characteristics and case complexity	✓	✓	✓	NG	unadjusted only	+

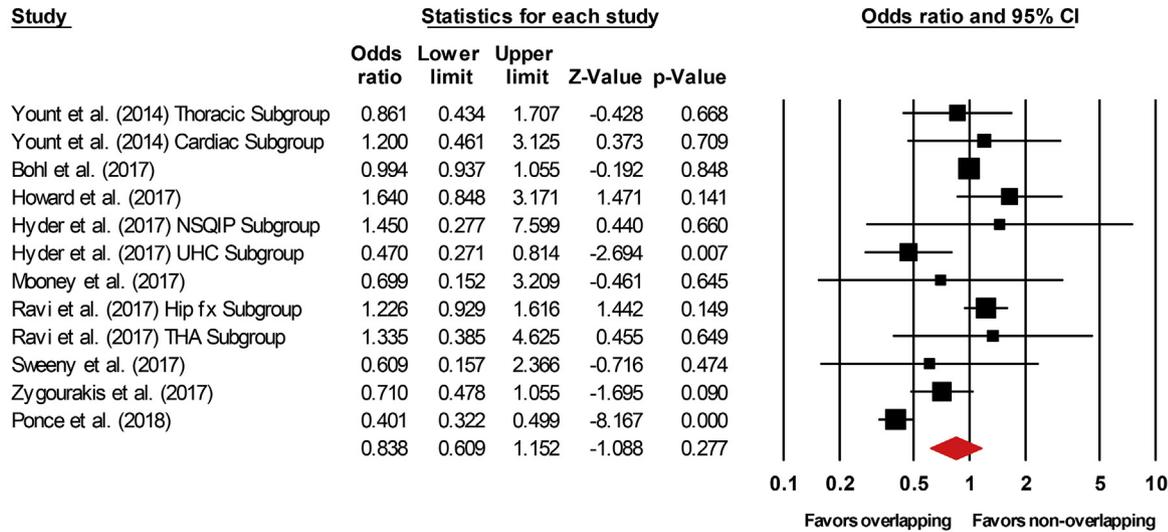
Ravi et al. (2018) (HIP subset) ¹⁸	RC	4/1/2009-3/31/2014	patients >60 years old undergoing acute surgical procedure for a hip fracture	surgeries with >30 min of overlapping operating room entry-exit time	960	37048	Hospitals included within several health administrative databases from Ontario, Canada	matching with respect to surgeon, age, sex, hospital, and procedure; only odds of complications based on duration of overlap, further adjusted for patient, surgeon, hospital and case characteristics	✓		NG	NG	✓	++
Ravi et al. (2018) (THA subset) ¹⁸	RC	4/1/2009-3/31/2014	patients >40 years old who received a primary elective total hip arthroplasty for arthritis	surgeries with >30 min of overlapping operating room entry-exit time	1560	51309	Hospitals included within several health administrative databases from Ontario, Canada	matching with respect to surgeon, age, sex, hospital, and procedure; only odds of complications based on duration of overlap, further adjusted for patient, surgeon, hospital and case characteristics	✓		NG	NG	✓	++
Sweeny et al. (2017) ¹⁶	RC	1/2010-2/2015	patients undergoing microvascular free tissue transfer of head and neck	2 surgeries with same first start time or surgeries with at least 60 min of overlap	542	773	2 academic hospitals	univariate analysis only	unadjusted only		NG	NG	unadjusted only	+
Yount et al. (2014) (cardiac subset) ²⁰	RC	7/2011-7/2013	patients undergoing cardiac surgery	2 surgeries with same surgeon overlapping more than 10 min	719	659	academic hospital	risk, case type, surgeon	✓	✓	NG	unadjusted only	✓	++
Yount et al. (2014) (thoracic subset) ²⁰	RC	7/2011-7/2013	patients undergoing thoracic surgery	2 surgeries with same surgeon overlapping more than 10 min	1005	677	academic hospital	univariate analysis only	unadjusted only		NG	unadjusted only	unadjusted only	+
Zygourakis et al. (2017) ¹⁴	RC	6/2/12-12/31/15	patients undergoing neurosurgical procedures	surgeries with ≥1 min of overlapping procedure time	3725	3633	academic hospital	surgeon, procedure type	✓	NG	✓	✓	✓	++

RC: retrospective cohort; NG: not given.

† Grade of evidence:²⁵

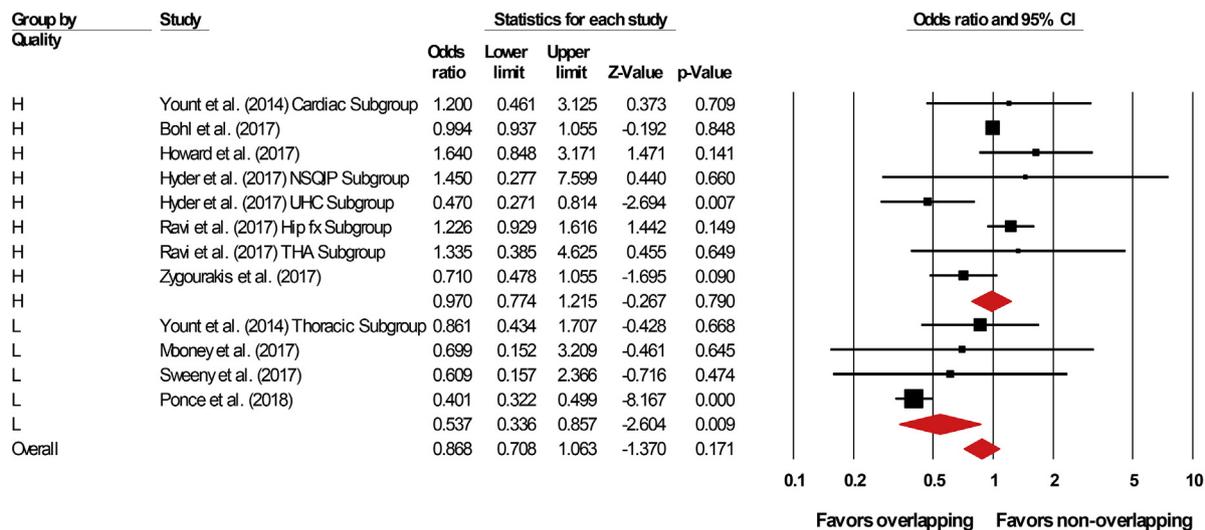
+ indicates low, ++ indicates moderate, +++ indicates high.

30-day Mortality



a

30-day Mortality



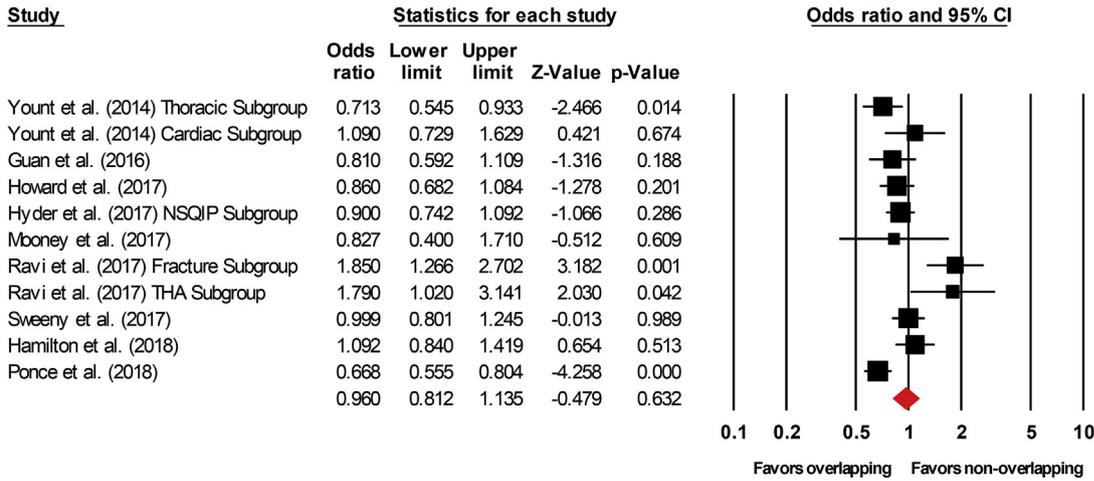
H: higher, L: low

b

Fig. 2. a. Forest plot of meta-analysis of 30-day mortality in overlapping versus non-overlapping groups. The overall pooled odds ratio (OR) for the outcome of 30-day mortality indicated no significant difference in odds of mortality for those undergoing overlapping versus non-overlapping surgery (OR 0.84, 95% CI 0.61–1.15, p = 0.277).

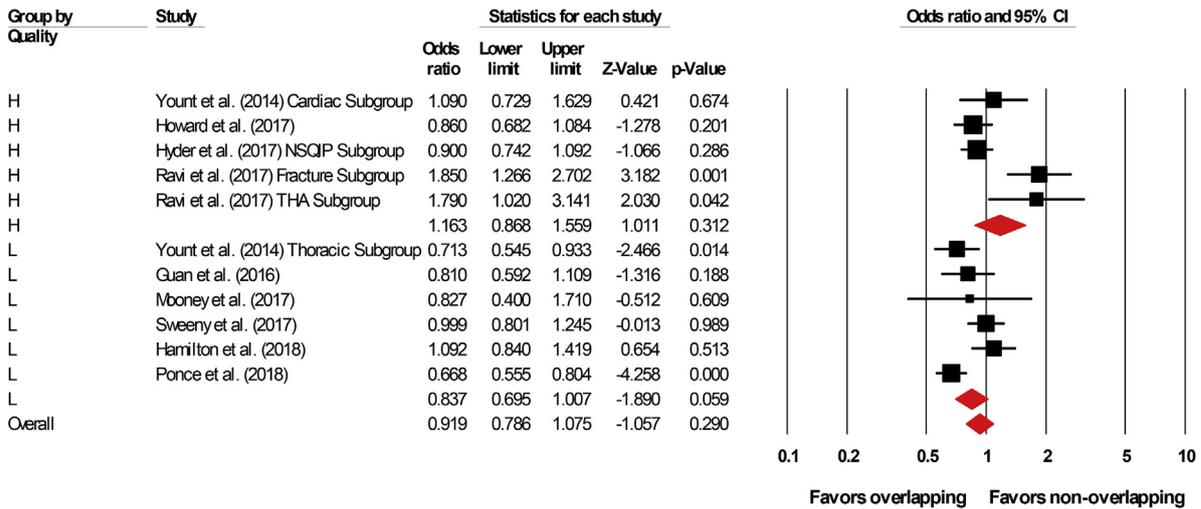
b. Stratified Forest plot of meta-analysis of 30-day mortality in overlapping versus non-overlapping groups. Given that the choice of whether or not to perform overlapping surgery may be dependent on case and patient characteristics, stratified analysis by study quality grade was performed. As demonstrated in Fig. 2b, the higher quality grade studies that attempted to control for patient and case characteristics also demonstrated no significant difference in mortality between the overlapping and non-overlapping groups (Higher quality grade studies OR 0.97, 95% CI 0.77–1.22, p = 0.79).

Overall morbidity



a

Overall morbidity



b

H: higher, L: low

Fig. 3. a. Forest plot of meta-analysis of overall morbidity in overlapping versus non-overlapping groups. Nine studies with 11 sets of analysis reported on overall morbidity. Pooled analysis demonstrated no statistically significant difference in odds of complications between the overlapping and non-overlapping surgery groups (OR 0.96, 95% CI 0.81–1.14, $p = 0.632$).

b. Stratified Forest plot of meta-analysis of overall morbidity in overlapping versus non-overlapping groups. Stratified analysis by quality score also demonstrated no significant difference in odds of complications between the overlapping and non-overlapping surgery groups (Higher quality grade studies OR 1.16, 95% CI 0.87–1.56, $p = 0.312$).

statistically significant difference in reoperation rates between the overlapping and non-overlapping groups (OR 0.89, 95% CI 0.77–1.03, $p = 0.107$, $I^2 = 31\%$), demonstrated in Fig. 5.

Publication bias and sensitivity analysis

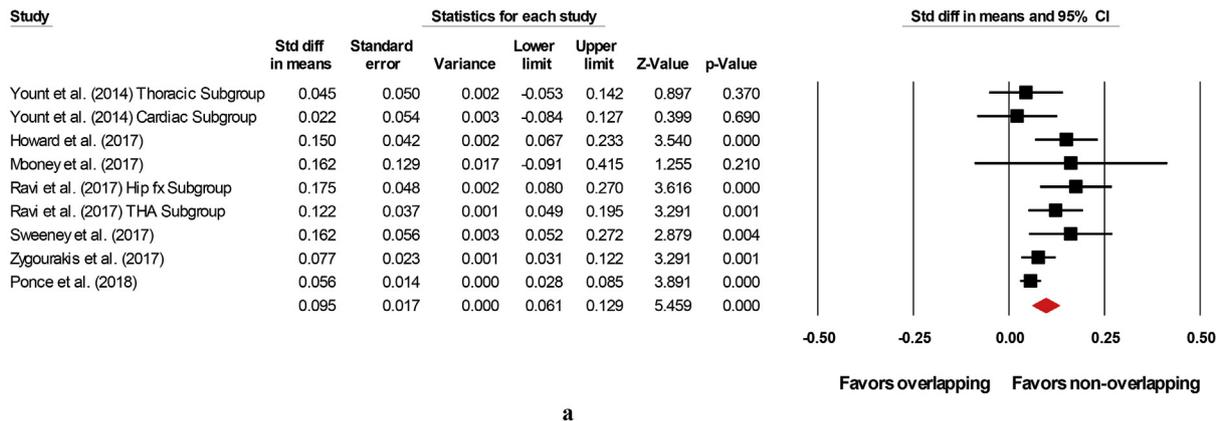
Visual inspection of the funnel plot for our primary outcome of 30-day mortality suggested a symmetric distribution of main

studies (Fig. 6). Begg's and Egger's tests confirmed that there was no significant publication bias. Sensitivity analyses were performed excluding studies with low quality scores, and this did not influence the results.

Discussion

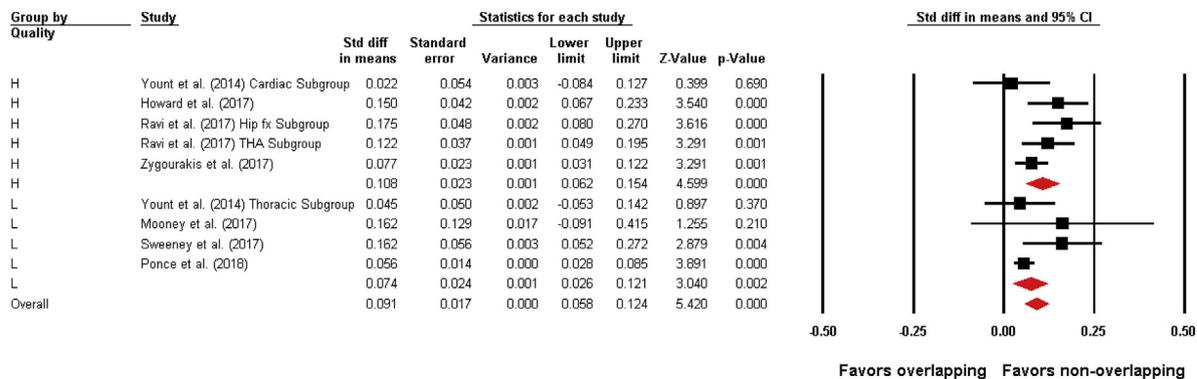
This meta-analysis, examining 14 sets of analyses from 2014 to

Length of surgery



a

Length of surgery



H: higher, L: low

b

Fig. 4. a. Forest plot of meta-analysis of length of surgery in overlapping versus non-overlapping groups. Length of surgery was available for 9 sets of analyses. The standardized mean difference for length of surgery between the overlapping and non-overlapping surgery groups indicated a small statistically significant increase in length of surgery for the overlapping surgery group (SMD = 0.095, $p < 0.005$). **b. Stratified Forest plot of meta-analysis of length of surgery in overlapping versus non-overlapping groups.** Stratified analysis by quality score also demonstrated a small statistically significant increase in length of surgery for the overlapping surgery group among the higher quality grade studies (SMD = 0.108, $p < 0.005$).

2018, totaling 193,514 patients, demonstrated no significant difference in 30-day mortality or overall morbidity between patients who underwent overlapping versus non-overlapping surgery, and revealed a small statistically significant increase in the SMD for length of surgery for the overlapping surgery group.

For the primary outcome of 30-day mortality, the pooled OR for the overlapping versus non-overlapping groups for all studies was 0.84 ($p = 0.277$), indicating no significant difference in odds of mortality for those undergoing overlapping versus non-overlapping surgery. This finding is in line with a recent meta-analysis evaluating the neurosurgical subset of studies.²⁷ Given that surgeons may be more likely to choose healthier patients undergoing less complex procedures when deciding which procedures to perform in an overlapping fashion, and given concern that studies of poor quality with minimal to no risk adjustment may have been responsible for the observed finding of no mortality difference, we performed a stratified analysis by ACP study quality grade. This stratified analysis demonstrated that higher quality grade studies alone also found no significant difference in mortality

between the overlapping and non-overlapping groups (OR 0.97, $p = 0.79$).

In addition, the odds of a significant complication or 30-day reoperation did not differ significantly between the overlapping and non-overlapping groups. The only outcome of interest that did show a significant difference was length of surgery. It was found that overlapping surgery led to a statistically significant increase in SMD for length of surgery. This finding potentially has sound theoretical basis, given that portions of overlapping surgeries are often performed by trainees, and thus likely to progress more slowly. It is also the case that when the attending surgeon is not in an operating room, and the critical portion of the procedure is reached, there may be a delay in awaiting the surgeon's arrival. These results may not be generalizable to the community setting where surgeons are often assisted by nurses or physician assistants.

While every attempt was made to comprehensively review the current literature, academic interest in the potential effects of overlapping surgery is a recent phenomenon, and thus this meta-analysis is limited by a relative paucity of studies rigorously

30-day Unplanned reoperation

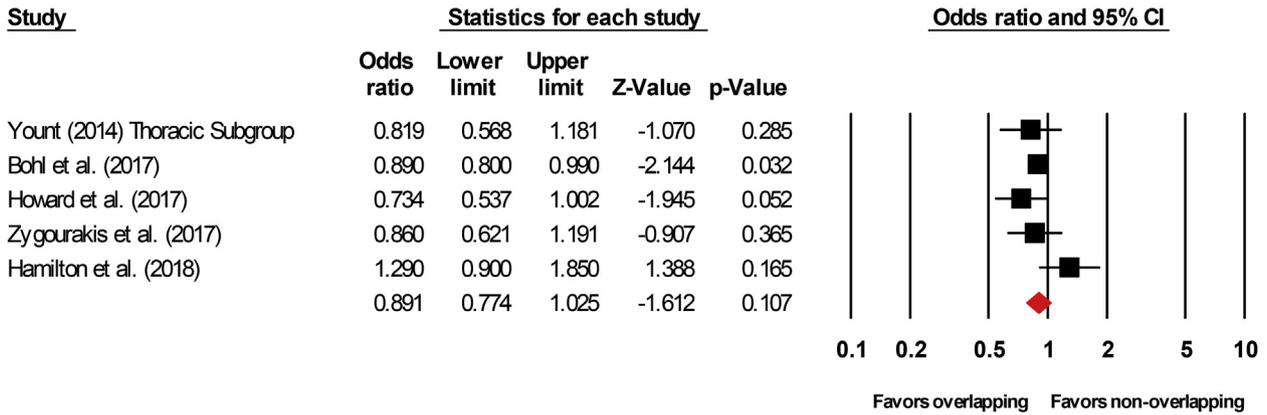


Fig. 5. Forest plot of meta-analysis of 30-day unplanned reoperations in overlapping versus non-overlapping groups. Five studies also assessed 30-day unplanned reoperation rates. On pooled analysis, there was no statistically significant difference in reoperation rates between overlapping and non-overlapping groups (OR 0.89, 95% CI 0.77–1.03, $p = 0.107$).

examining overlapping surgery. As the body of literature grows, it will be instructive to evaluate specialty and procedure-specific outcomes. Thirty-day mortality is a crude measure of quality given that the vast majority of procedures that are performed today, especially in the ambulatory setting, have no 30-day mortality. In order to better study this variable, studies exclusively featuring outpatient and/or pediatric populations were excluded since thirty-day mortality and morbidity are exceedingly low in these populations. In addition, patients who undergo surgery in these settings are seldom seen again in the hospital, and thus physicians

may underreport complications seen in the outpatient post-operative visit unless this data is prospectively collected.

In addition, all studies included in this review were non-randomized retrospective observational comparisons, with a potential for selection and reporting bias despite attempts at multivariate risk adjustment. While multiple studies confirmed that “overlapping” procedures refer to case overlap *without* concurrence of the critical portions of a case, no study captured which portions of the procedures were critical and the extent of surgeon presence for those portions. Moving forward, it will be

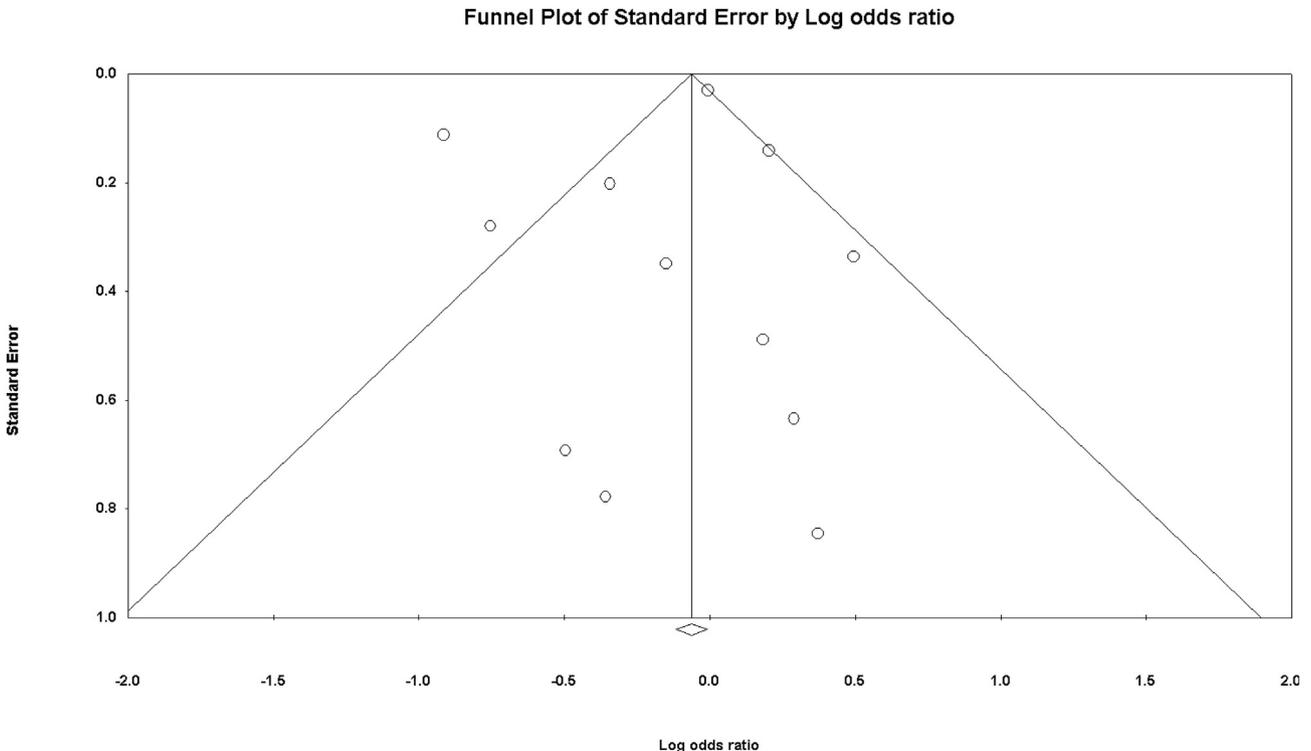


Fig. 6. Funnel Plot for Determining Publication Bias. Visual inspection of the funnel plot for our primary outcome of 30-day mortality suggested a symmetric distribution of main studies. This, in addition to the Begg's and Egger's tests, indicate no significant publication bias.

important to know if the *degree* of overlap is associated with increased odds of adverse outcomes. While this data was not uniformly available, Ravi et al. studied duration of overlap and found that for patients undergoing non-elective hip fracture repairs, risk of complications increased with every 10 min overlap in the overlapping surgery group.¹⁸ This statistically significant increased risk of complications with increased duration of overlap was not seen in the elective total hip arthroplasty group, suggesting that overlapping surgery may be safer in the elective setting when the entire surgical team can prepare to deliver care to multiple patients, and when the surgeon can potentially select his or her assistants accordingly.

Finally, the authors acknowledge that this systematic review and meta-analysis does not account for the full impact of overlapping surgeries, including the potential for decreased transparency between surgeons and patients as well as potential conflicts of interest.^{7,28} We can always improve our communication with patients in all aspects of medicine; this work provides physicians a summary of available evidence regarding safety of such practices, and may ultimately better and more transparently guide informed conversations with patients during pre-operative decision-making.

Despite its shortcomings, this study synthesizes the best available literature on clinical risks associated with overlapping surgery. To our knowledge, this is the first such analysis of the entire body of literature focused on overlapping surgery, and represents a step forward in evaluating the safety of this common practice. Given the lack of high-quality prospective evidence evaluating the impact of overlapping procedures and their outcomes, the conclusions of this systematic review and meta-analysis must be interpreted with caution. Patient safety is of utmost importance in any discussion of care delivery, and in the setting of overlapping surgery, and especially concurrent surgery, there is legitimate concern that the quest for efficiency and trainee autonomy may relegate patient safety to secondary status. Both CMS policy²⁹ and the American College of Surgeons guidelines³⁰ provide a framework for performing overlapping surgery, and within the confines of these principles it appears that overlapping surgery can be performed safely.

Conclusions

Meta-analysis of the current literature examining the risks of overlapping surgery versus non-overlapping surgery demonstrated no statistically significant difference in 30-day mortality, overall morbidity, and 30-day unplanned reoperation rates between the two groups. We found a statistically significant, but unlikely clinically relevant, increased SMD for length of surgery for the overlapping surgery group. These findings suggest that overlapping surgery, if performed under established guidelines, may be performed without increased risk to patient safety. Further studies are necessary to better define optimal patient, setting, and procedure type for safe and efficacious overlapping surgery.

Funding/support

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors would like to thank Dr. Michael Stoto, Professor of Biostatistics at the Harvard T.H. Chan School of Public Health, Alexander Wu, Doctor of Science candidate at the Harvard T.H. Chan School of Public Health, and Carol Mita, Research and Education

Librarian at the Countway Library of Medicine, for their assistance with this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amjsurg.2018.11.039>.

References

- Abelson J, Saltzman J, Kowalczyk L, et al. *Clash in the Name of Care*. Boston Globe; 2015. Available at: <http://apps.bostonglobe.com/spotlight/clash-in-the-name-of-care/story/>. Accessed August 1, 2017.
- Kent M, Whyte R, Fleishman A, et al. Public perceptions of overlapping surgery. *J Am Coll Surg*. 2017;224(5):771–778. e4.
- Langerman A. Concurrent surgery and informed consent. *JAMA Surgery*. 2016;151(7):601–602.
- 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.
- Cognetti DM, Nussenbaum B, Brenner MJ, et al. *Current State of Overlapping, Concurrent, and Multiple-room Surgery in Otolaryngology: A National Survey*. Otolaryngology - Head & Neck Surgery; 2017:998–1004.
- Concurrent and Overlapping Surgeries: Additional Measures Warranted*. United States Senate Finance Committee; 2016.
- Mello MM, Livingston EH. The evolving story of overlapping surgery. *JAMA*. 2017;318(3):233–234.
- Hoyt DB. Overlapping surgery: safety data and ongoing concerns. *Ann Surg*. 2017;265(4):645–646.
- Bohl MA, Mooney MA, Sheehy JP, et al. Overlapping surgeries are not associated with worse patient outcomes: retrospective multivariate analysis of 14872 neurosurgical cases performed at a single institution. *Neurosurgery*. 2018;83(1):53–59.
- Guan J, Brock AA, Karsy M, et al. Managing overlapping surgery: an analysis of 1018 neurosurgical and spine cases. *J Neurosurg*. 2017;127(5):1096–1104.
- Howard BM, Holland CM, Mehta CC, et al. Association of overlapping surgery with patient outcomes in a large series of neurosurgical cases. *JAMA Surg*. 2018;153(4):313–321.
- Mooney MA, Brigeman S, Bohl MA, et al. Analysis of overlapping surgery in patients undergoing microsurgical aneurysm clipping: acute and long-term outcomes from the Barrow Ruptured Aneurysm Trial. *J Neurosurg*. 2017:1–7. Epub Nov 3.
- Zygourakis CC, Lee J, Barba J, et al. Performing concurrent operations in academic vascular neurosurgery does not affect patient outcomes. *J Neurosurg*. 2017;127(5):1089–1095.
- 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.
- Zygourakis CC, Sizdahkhani S, Keefe M, et al. Comparison of patient outcomes and cost of overlapping versus nonoverlapping spine surgery. *World Neurosurg*. 2017;100:658–664.e8.
- Sweeny L, Rosenthal EL, Light T, et al. Effect of overlapping operations on outcomes in microvascular reconstructions of the head and neck. *Otolaryngol Head Neck Surg*. 2017;156(4):627–635.
- Hamilton WG, Ho H, Parks NL, et al. "Running two rooms" does not compromise outcomes or patient safety in joint arthroplasty. *J Arthroplasty*. 2018;33(7S):S8–S12.
- Ravi B, Pincus D, Wasserstein D, et al. Association of overlapping surgery with increased risk for complications following hip surgery: a population-based, matched cohort study. *JAMA Intern Med*. 2018;178(1):75–83.
- 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.
- Yount KW, Gillen JR, Kron IL, et al. AATS: attendings' performing simultaneous operations in academic cardiothoracic surgery does not increase operative duration or negatively affect patient outcomes [webcast]. Available at: http://webcast.aats.org/2014/files/Monday/20140428_750AM_810AM_Kenan_Yount.mp4. Accessed August 1, 2017.
- Hyder JA, Hanson KT, Storlie CB. *Assessing the Safety of Overlapping Surgery at a Children's Hospital*. 2018;268(2):e24–e27.
- 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.
- Liu JB, Berian JR, Ban KA, et al. Outcomes of concurrent operations: results from the American College of surgeons' national surgical quality improvement program. *Ann Surg*. 2017;266(3):411–420.
- Ponce BA, Wills BW, Hudson PW, et al. Outcomes with overlapping surgery at a large academic medical center. *Ann Surg*. 2018. Epub Feb 1, PubMed ID 29394167.
- Qaseem A, Snow V, Owens DK, et al. The development of clinical practice guidelines and guidance statements of the American College of Physicians: summary of methods. *Ann Intern Med*. 2010;153:194–199.
- Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic

- reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 2009;6(7), e1000097.
27. Self DM, Ilyas A, Stetler WR. Safety of running two rooms: a systematic review and meta-analysis of overlapping neurosurgical procedures. *World Neurosurgery.* 2018;116:e179–e186.
 28. Mello MM, Livingston EH. Managing the risks of concurrent surgeries. *JAMA.* 2016;315(15):1563–1564.
 29. September 14. *CMS Manual System–pub 100-04 Medicare Claims Processing.* Department of Health and Human Services; 2011. . Available at: <https://www.cms.gov/Regulations-and-Guidance/Guidance/Transmittals/downloads/R2303CP.pdf>. Accessed August 19, 2017.
 30. American College of Surgeons. Statements on principles. Available at: <https://http://www.facs.org/about-ac/s/statements/stoneprin>. Accessed August 18, 2017.