

Supplementary Online Content

Sun E, Mello MM, Rishel CA, et al. Association of overlapping surgery with perioperative outcomes. *JAMA*. doi:10.1001/jama.2019.0711

eAppendix 1. Parsing Text String to Identify Procedure Type

eAppendix 2. Identifying the Subgroup of High-Risk Patients

eAppendix 3. Estimating Adjusted Differences in Patient Characteristics Within Surgeon-Procedure Pairs

eTable 1. Diagnosis Codes Used to Identify Postoperative Complications

eTable 2. Comparison Between Sample Observations and Observations With Missing Data

eTable 3. Adjusted Differences in Covariates Between Overlapping and Non-Overlapping Cases

eTable 4. Full Regression Results, Main Statistical Model

eTable 5. Additional Sensitivity Analyses: Non-Emergent Cases and Alternative Definitions of Overlap

eTable 6. Sensitivity Analysis: Association Between Overlapping Surgery and Specific Postoperative Complications

eTable 7. Additional Sensitivity Analyses: CABG Subgroups

eTable 8. Additional Sensitivity Analysis: Multiple Imputation Approach for Missing Data

This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix 1. Parsing Text String to Identify Procedure Type

Most institutions in the Multicenter Perioperative Outcomes Group do not report surgical and/or anesthesia procedure codes (e.g., Current Procedural Terminology codes) that would readily identify the surgical procedure a patient received. However, for every case, the institutions do report a text descriptor (e.g., “L Total Knee Arthroplasty”, “L TKA”). Therefore, we parsed these text descriptors to identify our procedures of interest.

Surgical procedures were categorized using a combination of case-insensitive regular expression pattern matching applied to the raw text description of the surgical procedures. Regular expressions allow for the identification of many variants of keywords to include surgical procedures of interest and exclude procedures that contain disqualifying modifier text.¹ For example, a total knee arthroplasty may be described in many ways (e.g. “tka”, “total knee”, “arthroplasty, knee, total”, “knee replacement”, etc.). Additionally, procedures may contain additional text which indicates a variant of the procedure that should be excluded from the analysis. Some of these exclusion keywords are specific to the procedure category (e.g., for total knee replacements, “unicompartment”, “unicompartmental”, “arthroscopy”, etc.), while others are globally exclusive (e.g., “removal”, “I&D”, “cancelled”). Some procedures also contained conditional modifiers (e.g., “possible”, “with or without”, “w/wo”), in which case we required that relevant inclusion keywords occurred before the conditional text in the string in order to be included.

The specific combination of regular expressions for each procedure was chosen based upon manual examination of the data. Keywords were initially chosen to be very broad based upon knowledge of common descriptors, and were narrowed as appropriate to improve the sensitivity and specificity of the criteria. The data were also sorted by frequency of the surgical procedure and manually examined for the 1000 most common surgical procedure descriptions to ensure that no additional major variants were missed. Because the inclusion and exclusion criteria for each procedure type were a combination of many regular expression evaluations which would be difficult to interpret as written text, the complete MATLAB analysis code has been included as a separate file in the online content.

References

1. Kaur G. Usage of Regular Expressions in NLP. *International Journal of Research in Engineering and Technology*. 2014;3(1):168-174.

eAppendix 2. Identifying the Subgroup of High-Risk Patients

In one of our subgroup analyses, we restricted our analysis to patients at high risk for mortality or complications, hypothesizing that overlapping scheduling may have a larger effect on outcomes for this subset. To identify patients at high risk for these complications, we used two logistic regressions in which the outcomes were (1) in-hospital mortality and (2) in-hospital complication, and the independent variables were age, sex, comorbidities, and American Society of Anesthesiologist’s Physical Status Score. We used the results from each regression to obtain each patient’s predicted probability of in-hospital death and complications. We then defined high-risk patients as those in the top quartile of predicted probability for either outcome.

eAppendix 3. Estimating Adjusted Differences in Patient Characteristics Within Surgeon-Procedure Pairs

Our primary statistical approach addressed confounding by adjusting for observable factors (e.g., patient comorbidities) that could affect outcomes and by comparing outcomes for a given surgeon's overlapping and non-overlapping cases of the same type, as opposed to comparing outcomes across surgeons and hospitals. However, this approach could be confounded by unobservable differences between overlapping and non-overlapping cases performed by a given surgeon, e.g., if the surgeon preferentially chooses to perform low-risk cases with overlapping scheduling. As one way of addressing this issue, we examined whether there were differences in observable patient characteristics between overlapping and non-overlapping cases performed by a given surgeon, after adjusting for procedure. Similarity in observable patient factors between overlapping and non-overlapping cases (within surgeon-procedure pairs) might suggest that unobservable patient factors may also be balanced between overlapping and non-overlapping cases.

For patient age, sex, and each comorbidity included in the main models, we estimated a linear probability model in which the dependent variable was the patient characteristic itself and the independent variable of interest was case overlap. The model included fixed effects for each surgeon-procedure combination. Thus, this model tested for the significance of any differences in mean age, sex, and comorbidity incidence between overlapping and non-overlapping cases, within each given surgeon-procedure pair. The results of our analysis are presented in **Table S3** below.

eTable 1. Diagnosis Codes Used to Identify Postoperative Complications^a

	ICD-9 Codes	ICD-10 Codes
Surgical Site Infection	9985, 99851, 99859	K6811, T814XXA
Urinary Tract Infection	112.2, 5901*, 590.3, 5908*, 5950, 5953, 5990, 99664	B3742, B3749, N10, N12, N16, N2884, N2885, N2886, N3000, N3001, N3030, N3031, N390, T8351XA
Pneumonia	0391, 1124, 1179, 1363, 46619, 480*, 481, 482*, 483*, 4841, 4846, 4947, 485, 486, 4870, 507*, 5130, 5168, 99731, 99739	A420, A481, B250, B371, B440, B488, B49, B59, J1100, J120, J121, J122, J1281, J1289, J129, J13, J14, J150, J151, J1520, J15211, J15212, J1529, J153, J154, J155, J156, J157, J158, J159, J160, J168, J17, J180, J181, J189, J218, J690, J691, J698, J8409, J850, J851, J852, J95851, J95859, J9588, J9589
Sepsis	038*, 78552, 99591, 99592, 9980, 99859, 99931	A403, A409, A4101, A4102, A411, A412, A413, A414, A4150, A4151, A4152, A4153, A4159, A4189, A419, K6811, R6520, R6521, T80219A, T814XXA
DVT	4511*, 4512, 45181, 4519, 4534*, 4538, 4539	I8010, I80209, I80219, I803, I809, I82409, I82419, I82429, I82439, I82499, I824Y9, I824Z9, I8291
Pulmonary Embolism	4151*	I2690, I2692, I2699, T800XXA, T81718A, T8172XA, T82817A, T82818A
Venous Thromboembolism	4151*, 4511*, 4512, 45181, 4534*, 4538, 4539	I2690, I2692, I2699, I8010, I80209, I80219, I803, I82409, I82419, I82429, I82439, I82449, I82499, I824Y9, I824Z9, I8291, T800XXA, T81718A, T8172XA, T82817A, T82818A
Myocardial Infarction	410*0, 410*1	I2109, I2111, I2119, I2129, I213, I214
Stroke	997.02	I97811, I98921

^aICD-9 codes for each complication are based on references 23-25. These ICD-9 codes were mapped into ICD-10 codes based on the General Equivalence Mapping data found at <https://www.cms.gov/Medicare/Coding/ICD10/2016-ICD-10-CM-and-GEMs.html>. An asterisk (*) indicates that a wildcard was used for the given digit.

eTable 2. Comparison Between Sample Observations and Observations With Missing Data^a

	Sample Observations (N=66,430)	Observations with Missing Data (N=11,556)	Difference (95% CI)
<i>Patient Demographics</i>			
Age, mean (s.d.), years	59 (15)	58 (16)	1.3 (0.3 to 2.2)
Male, N (%)	34,515 (52)	6,195 (54)	-1.8 (-3.4 to 0.2)
<i>American Society of Anesthesiologists Physical Status Score</i>			
Numerical score, mean (s.d.)	2.6 (0.76)	2.6 (0.79)	0.02 (-0.04 to 0.08)
Emergency status, N (%)	4,254 (6.8)	1,178 (10.1)	-3.1 (-4.8 to -1.4)

^aOur final sample consisted of 66,430 observations and excluded 11,879 observations with missing data (missing diagnosis codes, missing surgery times, or missing mortality). Of these 11,879 observations, 11,556 (97%) had complete data on age, sex, and American Society of Anesthesiologist Physical Status Score. This table provides compares summary statistics for this set of patients and the patients in our final sample. The American Society of Anesthesiologists Physical Status Score consists of a numerical score and an indicator “E” for emergency surgery. The numerical score ranges from 1 to 6, with 1 signifying a healthy patient, 3 signifying a patient with severe systemic disease, 5 signifying a moribund patient who is not expected to survive without the operation, and 6 an organ harvest patient. 95% confidence intervals are adjusted for clustering at the surgeon level

eTable 3. Adjusted Differences in Covariates Between Overlapping and Non-Overlapping Cases^a

	Non-Overlapping	Overlapping	Difference (95% CI)
<i>Patient demographics</i>			
Age, mean years (s.e)	58.1 (0.05)	58.3 (0.25)	0.15 (-0.43 to 0.73)
Male, % (s.e.)	52.7 (0.1)	53.3 (0.6)	0.6 (-0.7 to 1.9)
Female, % (s.e.)	47.3 (0.1)	46.7 (0.6)	-0.6 (-1.9 to 0.7)
<i>American Society of Anesthesiologists Physical Status Score</i>			
Numerical Score, mean (s.e.)	2.7 (0.002)	2.7 (0.01)	0.02 (-0.8 to 0.5)
Emergency status, % (s.e.)	7.9 (0.1)	6.6 (0.7)	-1.4 (-3.0 to 0.2)
<i>Patient comorbidities, % (s.e)</i>			
AIDS/HIV	0.2 (0.01)	0.3 (0.1)	0.1 (-0.0 to 0.3)
Alcohol abuse	1.9 (0.03)	2.2 (0.2)	0.3 (-0.0 to 0.7)
Blood loss anemia	0.6 (0.01)	0.6 (0.01)	-0.0 (-0.2 to 0.1)
Arrhythmia	16.4 (0.1)	15.9 (0.5)	-0.5 (-1.7 to 0.7)
COPD	15.6 (0.1)	15.5 (0.4)	-0.1 (-1.1 to 0.8)
Coagulopathy	6.5 (0.1)	5.8 (0.3)	-0.7 (-1.5 to 0.1)
Congestive heart failure	8.1 (0.1)	8.2 (0.3)	0.0 (-0.6 to 0.7)
Iron deficiency anemia	1.8 (0.02)	2.0 (0.1)	0.3 (-0.1 to 0.6)
Depression	15.9 (0.8)	15.8 (0.4)	-0.1 (-1.2 to 0.9)
Diabetes, without complications	11.4 (0.1)	11.8 (0.4)	0.4 (-0.5 to 1.4)
Diabetes, with complications	2.6 (0.02)	2.5 (0.1)	-0.0 (-0.4 to 0.2)
Drug abuse	3.2 (0.04)	3.3 (0.2)	0.1 (-0.5 to 0.6)
Fluid/electrolyte disorder	17.6 (0.1)	18.0 (0.5)	0.4 (-0.7 to 1.6)

^aShown are the results of analyses comparing differences in patient characteristics between non-overlapping and overlapping surgeries performed by an individual surgeon, after adjusting for year, date, and time of surgery.

eTable 3. Adjusted Differences in Covariates Between Overlapping and Non-Overlapping Cases (cont.)^a

	Non-Overlapping	Overlapping	Difference (95% CI)
<i>Patient comorbidities, % (s.e.)</i>			
Hypertension, without complications	47.6 (0.1)	49.2 (0.7)	1.6 (0.0 to 3.1)
Hypertension, with complications	7.5 (0.04)	7.4 (0.3)	-0.0 (-0.7 to 0.5)
Hypothyroidism	11.2 (0.07)	11.1 (0.4)	-0.0 (-1.0 to 0.9)
Liver disease	3.0 (0.03)	3.1 (0.2)	0.1 (-0.2 to 0.5)
Lymphoma	1.1 (0.02)	1.2 (0.1)	0.0 (-0.2 to 0.3)
Metastatic cancer	7.1 (0.08)	6.8 (0.4)	-0.3 (-1.2 to 0.6)
Obesity	16.0 (0.1)	17.8 (0.5)	1.8 (-.6 to 3.0)
Other neurologic disorders	13.3 (0.1)	14.0 (0.4)	0.7 (-0.1 to 1.6)
Paralysis	5.5 (0.1)	5.4 (0.3)	-0.0 (-0.7 to 0.6)
Peptic ulcer disease	0.6 (0.01)	0.7 (0.1)	0.1 (-0.1 to 0.3)
Peripheral vascular disease	7.3 (0.1)	7.2 (0.4)	-0.0 (-0.9 to 0.8)
Psychosis	1.1 (0.02)	1.1 (0.1)	0.0 (-0.2 to 0.3)
PCD	3.6 (0.04)	4.0 (0.2)	0.4 (-0.2 to 0.9)
Renal failure	7.7 (0.0)	7.8 (0.3)	0.1 (-0.5 to 0.7)
Rheumatoid arthritis	3.6 (0.03)	3.6 (0.2)	-0.0 (-0.4 to 0.4)
Solid tumor	12.2 (0.1)	13.1 (0.4)	0.9 (0.0 to 1.8)
Valvular disease	7.5 (0.1)	7.0 (0.3)	-0.5 (-1.2 to 1.6)
Weight loss	3.7 (0.04)	4.2 (0.2)	0.5 (-0.1 to 1.0)
<i>Predicted Mortality/Complication Risk</i>			
Low Risk	65.2 (0.1)	65.2 (0.8)	0.0 (-1.8 to 1.8)
High Risk	34.7 (0.1)	34.7 (0.8)	0.0 (-1.8 to 1.8)

^aShown are the results of analyses comparing differences in patient characteristics between non-overlapping and overlapping surgeries performed by an individual surgeon, after adjusting for year, date, and time of surgery.

eTable 4. Full Regression Results, Main Statistical Model^a

	Mortality β (s.e.)	Complications β (s.e.)	Surgery Length β (s.e.)
<i>Year of surgery (baseline year in 2010)</i>			
2011	-0.000955 (0.00241)	-0.00101 (0.00912)	4.290* (2.239)
2012	0.00182 (0.00262)	-0.0125 (0.00878)	0.123 (2.843)
2013	-0.00436* (0.00249)	-0.0208** (0.00945)	2.984 (3.375)
2014	-0.00197 (0.00296)	-0.0316*** (0.00868)	1.393 (3.387)
2015	-0.00484* (0.00277)	-0.0394*** (0.00994)	0.0402 (3.562)
2016	-0.00800*** (0.00271)	-0.0496*** (0.0101)	0.0644 (3.660)
2017	-0.0109*** (0.00327)	-0.0554*** (0.0104)	0.791 (3.885)
2018	-0.00917** (0.00389)	-0.0567*** (0.0114)	3.519 (4.720)
<i>Day of surgery (baseline day is Sunday)</i>			
Monday	-0.0225** (0.00888)	-0.0353** (0.0139)	23.40*** (4.242)
Tuesday	-0.0206** (0.00936)	-0.0315** (0.0141)	22.92*** (4.007)
Wednesday	-0.0229** (0.00917)	-0.0300** (0.0148)	25.58*** (3.772)
Thursday	-0.0210** (0.00925)	-0.0271* (0.0144)	23.29*** (3.975)
Friday	-0.0212** (0.00955)	-0.0352** (0.0137)	20.91*** (3.965)
Saturday	-0.0115 (0.0106)	0.00329 (0.0180)	0.568 (3.480)
<i>Time of surgery (baseline group is 0300-0659)</i>			
0700-1059	-0.00601* (0.00360)	0.0110 (0.00921)	10.03*** (2.803)
1100-1459	-0.00413 (0.00360)	0.0218** (0.00948)	-10.83*** (2.825)
1500-1759	0.000549 (0.00420)	0.0298*** (0.0101)	-35.10*** (3.769)
1900-2159	0.0150 (0.0142)	0.0447** (0.0210)	-57.53*** (5.181)
2300-0159	0.0409** (0.0181)	0.00428 (0.0269)	-55.42*** (8.486)

^aFor mortality and complications, the coefficient shown is the percentage point change associated with the given variable. For surgery length, the coefficient shown is the associated change in surgery length (in minutes). Standard errors shown in parentheses were clustered at the surgeon level. Not shown are the fixed effects for each surgeon-procedure pair. *p<0.1, **p<0.05, ***p<0.01.

eTable 4. Full Regression Results, Main Statistical Model (cont.)^a

	Mortality	Complications	Surgery Length
<i>Sex (baseline group is female)</i>			
Male	-0.000258 (0.00115)	-0.0102*** (0.00310)	1.725* (0.905)
<i>Age (baseline group is 18-22)</i>			
23-27	-0.00603 (0.00782)	-0.0108 (0.0133)	-6.453 (3.994)
28-32	-0.00385 (0.00727)	-0.0199 (0.0125)	-11.06** (4.392)
33-37	-0.00270 (0.00744)	-0.0123 (0.0128)	-15.63*** (3.478)
38-42	-0.00266 (0.00729)	-0.0182 (0.0119)	-15.48*** (3.830)
43-47	0.00524 (0.00711)	-0.0135 (0.0128)	-10.34*** (3.698)
48-52	0.00409 (0.00742)	-0.00976 (0.0127)	-8.553** (3.797)
53-57	0.00375 (0.00719)	-0.0137 (0.0128)	-8.014** (4.034)
58-63	0.00296 (0.00731)	-0.00605 (0.0120)	-7.386* (4.371)
63-67	0.00476 (0.00755)	-0.000297 (0.0131)	-7.578* (4.412)
68-72	0.00722 (0.00759)	-0.00568 (0.0127)	-10.11** (4.709)
73-77	0.00716 (0.00755)	0.00780 (0.0127)	-14.12*** (4.454)
78-82	0.0191** (0.00859)	-0.00167 (0.0133)	-21.02*** (4.363)
83-87	0.0149 (0.0101)	0.0140 (0.0170)	-31.30*** (5.064)
88-90	0.0416*** (0.0141)	0.0309 (0.0237)	-44.50*** (5.366)

^aFor mortality and complications, the coefficient shown is the percentage point change associated with the given variable. For surgery length, the coefficient shown is the associated change in surgery length (in minutes). Standard errors shown in parentheses were clustered at the surgeon level. Not shown are the fixed effects for each surgeon-procedure pair. *p<0.1, **p<0.05, ***p<0.01.

eTable 4. Full Regression Results, Main Statistical Model (cont.)^a

	Mortality	Complications	Surgery Length
<i>Elixhauser comorbidities</i>			
AIDS/HIV	0.00439 (0.0189)	0.0131 (0.0460)	-1.222 (7.511)
Alcohol abuse	-0.00747 (0.00680)	-0.00180 (0.0104)	-9.742*** (2.818)
Blood loss anemia	-0.0164* (0.00892)	0.0412 (0.0271)	10.79** (4.823)
Arrhythmia	0.00524*** (0.00201)	0.0514*** (0.00592)	12.02*** (1.831)
COPD	0.00388** (0.00163)	-0.00697* (0.00381)	-1.530 (1.055)
Coagulopathy	0.0305*** (0.00512)	0.0112 (0.00782)	13.82*** (2.371)
Congestive heart failure	0.00960*** (0.00349)	0.0185* (0.0102)	-0.907 (1.825)
Iron deficiency anemia	-0.0115*** (0.00431)	0.0203* (0.0122)	1.370 (2.810)
Depression	-0.00792*** (0.00139)	0.00902** (0.00448)	2.811** (1.137)
Diabetes (with complications)	-0.000969 (0.00362)	-0.0122 (0.0109)	-3.581 (2.445)
Diabetes (without complications)	0.00149 (0.00187)	0.00882* (0.00454)	-3.941*** (1.118)
Drug abuse	-0.0127*** (0.00364)	0.0123 (0.0109)	4.099 (2.751)
Fluid/electrolyte disorders	0.0109*** (0.00224)	0.0942*** (0.00736)	17.40*** (2.276)
Hypertension (with complications)	-0.00280 (0.00477)	-0.0286** (0.0121)	1.019 (2.486)

^aFor mortality and complications, the coefficient shown is the percentage point change associated with the given variable. For surgery length, the coefficient shown is the associated change in surgery length (in minutes). Standard errors shown in parentheses were clustered at the surgeon level. Not shown are the fixed effects for each surgeon-procedure pair. *p<0.1, **p<0.05, ***p<0.01. COPD=Chronic obstructive pulmonary disease.

eTable 4. Full Regression Results, Main Statistical Model (cont.)^a

	Mortality	Complications	Surgery Length
<i>Elixhauser comorbidities</i>			
Hypertension (without complications)	-0.00361*** (0.00131)	0.00381 (0.00280)	2.059** (0.882)
Hypothyroidism	-0.00210 (0.00162)	-0.00787** (0.00382)	0.734 (1.213)
Liver disease	0.0270*** (0.00731)	0.0298*** (0.0102)	-7.693*** (2.101)
Lymphoma	-0.0143** (0.00556)	0.00470 (0.0131)	-15.64*** (4.234)
Metastatic cancer	0.0173*** (0.00396)	-0.00405 (0.00929)	-24.60*** (5.395)
Obesity	0.000273 (0.000958)	0.00448 (0.00332)	9.054*** (1.178)
Other neurological disorders	0.0110*** (0.00343)	0.0354*** (0.00563)	5.319** (2.515)
Paralysis	0.00665 (0.00590)	0.0821*** (0.0102)	2.890 (2.395)
Peptic ulcer disease	-0.0171*** (0.00530)	0.0564*** (0.0206)	-6.592* (3.577)
Peripheral vascular disease	-0.000494 (0.00365)	0.0130 (0.00900)	12.02* (6.585)
Psychosis	0.000705 (0.00727)	0.0404** (0.0173)	3.353 (3.465)
PCD	0.0100** (0.00466)	0.288*** (0.0285)	10.94*** (1.916)
Renal failure	0.00818* (0.00473)	0.0270*** (0.0102)	-2.947 (2.377)
Rheumatoid arthritis	0.00239 (0.00301)	0.0102 (0.00646)	0.678 (1.776)
Solid tumor	0.00421 (0.00325)	-0.00892 (0.00573)	22.81*** (4.766)
Valvular disease	0.00877*** (0.00311)	-0.0701*** (0.0106)	10.82*** (2.420)
Weight loss	0.0136** (0.00650)	0.142*** (0.0130)	5.853* (3.095)

^aFor mortality and complications, the coefficient shown is the percentage point change associated with the given variable. For surgery length, the coefficient shown is the associated change in surgery length (in minutes). Standard errors shown in parentheses were clustered at the surgeon level. Not shown are the fixed effects for each surgeon-procedure pair. *p<0.1, **p<0.05, ***p<0.01. PCD=pulmonary circulation disorder.

eTable 4. Full Regression Results, Main Statistical Model (cont.)^a

<i>American Society of Anesthesiologists Physical Status Score (baseline group is 1)</i>			
1E	0.00853 (0.0173)	0.0216 (0.0186)	8.473 (8.682)
2	-0.00307** (0.00153)	-0.00178 (0.00449)	13.45*** (2.460)
2E	0.00793 (0.00942)	0.0398** (0.0164)	-3.722 (5.441)
3	-0.00483** (0.00213)	0.0152*** (0.00473)	22.45*** (3.265)
3E	0.0244*** (0.00779)	0.0834*** (0.0128)	-7.752 (5.488)
4	0.0224*** (0.00398)	0.0789*** (0.0110)	22.47*** (3.377)
4E	0.120*** (0.0126)	0.206*** (0.0208)	-11.43* (5.928)
5	0.181* (0.105)	0.245** (0.105)	21.85* (12.09)
5E	0.197*** (0.0279)	0.236*** (0.0302)	-25.19** (11.47)
<i>Overlapping Case</i>	0.00253 (0.00206)	0.0104** (0.00499)	32.07*** (3.500)
<i>Constant</i>	0.0306** (0.0118)	0.105*** (0.0214)	134.1*** (6.812)
<i>R²</i>	0.099	0.198	0.455

^aFor mortality and complications, the coefficient shown is the percentage point change associated with the given variable. For surgery length, the coefficient shown is the associated change in surgery length (in minutes). Standard errors shown in parentheses were clustered at the surgeon level. Not shown are the fixed effects for each surgeon-procedure pair. *p<0.1, **p<0.05, ***p<0.01.

eTable 5. Additional Sensitivity Analyses: Non-Emergent Cases and Alternative Definitions of Overlap^a

	Adjusted In-Hospital Mortality, % (95% CI)				Adjusted In-Hospital Postoperative Complications, % (95% CI)				Adjusted Surgery Length, minutes (95% CI)			
	<i>Non-overlapping</i>	<i>Overlapping</i>	<i>Diff</i>	<i>p</i>	<i>Non-overlapping</i>	<i>Overlapping</i>	<i>Diff</i>	<i>p</i>	<i>Non-overlapping</i>	<i>Overlapping</i>	<i>Diff</i>	<i>p</i>
Primary analysis	1.6 (1.6 to 1.7)	1.9 (1.5 to 2.3)	0.3 (-0.2 to 0.7)	0.21	11.8 (11.7 to 12.0)	12.8 (11.9 to 13.7)	0.9 (-0.1 to 1.9)	.08	173 (173 to 175)	204 (199 to 209)	30 (24 to 37)	<0.001
Sensitivity analysis: non-emergent cases ^b	0.9 (0.8 to 0.9)	1.1 (0.8 to 1.4)	0.2 (-0.1 to 0.5)	0.21	9.5 (9.4 to 9.6)	10.4 (9.6 to 11.3)	1.0 (-0.0 to 2.0)	0.07	174 (172 to 175)	201 (195 to 208)	28 (21 to 35)	<0.001
Sensitivity analysis: cases with any overlap excluded from the control group	1.6 (1.5 to 1.7)	1.9 (1.5 to 2.3)	0.3 (-0.1 to 0.7)	0.17	11.8 (11.7 to 12.0)	12.8 (11.9 to 13.7)	0.9 (-0.1 to 2.0)	0.08	174 (173 to 176)	204 (199 to 209)	30 (23 to 36)	<0.001
Sensitivity analysis: overlapping case defined as ≥ 1 minute of overlap	1.6 (1.5 to 1.7)	1.9 (1.6 to 2.1)	0.3 (-0.0 to 0.6)	0.10	11.8 (11.7 to 12.0)	12.4 (11.8 to 12.9)	0.5 (-0.2 to 1.2)	0.14	174 (174 to 176)	187 (184 to 190)	12 (8.4 to 16.4)	<0.001

^a“Primary Analysis” refers to the main analysis; the results shown here are reproduced from the “Primary Analysis” row from Tables 2-4. Shown are the results for four sensitivity analyses. The first restricted our analysis to non-emergent cases (those started between 7:00am and 4:00pm and not designated as emergency by the anesthesiologist). The second sensitivity analysis altered the comparison group. In the primary analysis, “non-overlapping” cases included cases lasting ≥ 60 minutes that had 1-59 minutes of overlap; this sensitivity analysis excluded these patients from the “non-overlapping” group. Thus, for this analysis, the non-overlapping group consists of cases with zero overlap, while the overlapping group consists of cases meeting the main definition of overlap: ≥ 60 minutes or the entirety of the case for cases < 60 minutes. Results for the remaining cases (1-59 minutes of overlap, case > 60 minutes) are as follows: adjusted mortality 1.8% (95%CI 1.5, 2.0), difference vs. non-overlapping 0.2% (95%CI -0.1, 0.5; $p=0.19$); adjusted postoperative complications 11.9% (95%CI 11.3, 12.5), difference vs. non-overlapping 0.1% (95%CI -0.6, 0.8; $p=0.83$); adjusted surgery length 169 minutes (95%CI 165, 173), difference vs. non-overlapping -5 minutes (95%CI -10, -0.3; $p=0.038$). The third sensitivity analysis defined an overlapping case as having ≥ 1 minute of overlap, and the fourth used a multiple imputation analysis to examine the sensitivity of the results to alternate methods of adjusting for missing data.

^bSimilar estimates were obtained when emergent cases were restricted to those designated as emergency by the anesthesiologist, since some weekend or evening cases may reflect elective cases that were delayed.

eTable 6. Sensitivity Analysis: Association Between Overlapping Surgery and Specific Postoperative Complications^a

	In-Hospital Postoperative Complication, % (95% CI)							
	Unadjusted				Adjusted			
	<i>Non-Overlapping</i>	<i>Overlapping</i>	<i>Difference</i>	<i>p</i>	<i>Non-Overlapping</i>	<i>Overlapping</i>	<i>Difference</i>	<i>p</i>
Primary analysis: all complications combined	11.7 (10.1 to 13.3)	14.0 (10.8 to 17.0)	2.3 (-0.5 to 5.0)	0.10	11.8 (11.7 to 12.0)	12.8 (11.9 to 13.7)	0.9 (-0.1 to 1.9)	0.08
Specific complications								
Surgical site Infection	1.0 (0.9 to 1.1)	1.6 (1.4 to 1.8)	0.6 (0.4 to 0.8)	<0.001	1.0 (1.0 to 1.1)	1.1 (0.9 to 1.4)	0.1 (-0.2 to 0.4)	0.55
Urinary tract Infection	2.9 (2.8 to 3.0)	2.7 (2.4 to 3.1)	-0.1 (-0.5 to 0.3)	0.52	2.9 (2.8 to 3.0)	2.8 (2.4 to 3.1)	-0.2 (-0.6 to 0.3)	0.50
Pneumonia	3.1 (2.9 to 3.2)	4.2 (3.8 to 4.6)	1.1 (0.7 to 1.5)	<0.001	3.2 (3.1 to 3.2)	3.7 (3.2 to 4.3)	0.6 (-0.0 to 1.8)	0.05
Sepsis	2.6 (2.5 to 2.7)	3.7 (3.3 to 4.0)	1.1 (0.7 to 1.5)	<0.001	2.7 (2.6 to 2.7)	3.1 (2.8 to 3.4)	0.4 (0.0 to 0.8)	0.04
Thromboembolic event	2.1 (2.0 to 2.2)	2.4 (2.1 to 3.7)	0.3 (-0.0 to 0.6)	0.09	2.2 (2.1 to 2.2)	2.1 (1.8 to 2.4)	-0.1 (-0.0 to 0.2)	0.50
Myocardial infarction	2.6 (2.5 to 2.7)	3.1 (2.7 to 3.4)	0.5 (0.1 to 0.9)	0.01	2.6 (2.5 to 2.7)	3.1 (2.6 to 3.7)	0.5 (-0.0 to 1.1)	0.10
Stroke	0.3 (0.3 to 0.4)	0.7 (0.5 to 0.8)	0.3 (0.2 to 0.5)	<0.001	0.4 (0.3 to 0.4)	0.4 (0.2 to 0.6)	-0.0 (-0.3 to 0.2)	0.95
All minor complications	3.8 (3.6 to 4.0)	4.3 (3.8 to 4.7)	0.4 (-0.0 to 0.9)	0.07	3.9 (3.8 to 4.0)	3.8 (3.3 to 4.3)	-0.1 (-0.1 to 0.5)	0.71
All major complications	9.4 (9.1 to 9.6)	12.0 (11.3 to 12.6)	2.6 (1.9 to 3.3)	<0.001	9.5 (9.4 to 9.7)	10.7 (9.9 to 11.6)	1.2 (0.2 to 2.1)	0.02

^a“Adjusted” refers to analyses that compare a given surgeon’s overlapping vs. non-overlapping cases of the same procedure type, and that also adjust for the patient characteristics shown in Table 1. Thromboembolic events include deep venous thrombosis and pulmonary embolism. “Major” refers to a composite consisting of pneumonia, sepsis, thromboembolic event, myocardial infarction, or stroke. “Minor” refers to a composite consisting of surgical site or urinary tract infection. The p-values shown reflect whether the difference between the non-overlapping and overlapping groups is significantly different from zero.

eTable 7. Additional Sensitivity Analyses: CABG Subgroups^a

	Adjusted In-Hospital Mortality, % (95% CI)				Adjusted In-Hospital Postoperative Complications, % (95% CI)				Adjusted Surgery Length, minutes (95% CI)			
	<i>Non-overlapping</i>	<i>Overlapping</i>	<i>Diff</i>	<i>p</i>	<i>Non-overlapping</i>	<i>Overlapping</i>	<i>Diff</i>	<i>p</i>	<i>Non-overlapping</i>	<i>Overlapping</i>	<i>Diff</i>	<i>p</i>
Primary CABG analysis	2.2 (2.0 to 2.4)	4.0 (2.8 to 5.1)	1.8 (0.5 to 3.2)	0.009	30.2 (29.8 to 30.6)	34.5 (31.9 to 37.1)	4.3 (1.3 to 7.4)	0.007	290 (289 to 290)	304 (299 to 309)	14 (9 to 20)	<0.001
Sensitivity analysis: adjust for higher-risk procedure	2.2 (2.0 to 2.3)	4.0 (2.8 to 5.1)	1.8 (0.5 to 3.2)	0.009	30.2 (30.0 to 30.6)	34.6 (32.0 to 37.1)	4.4 (1.5 to 7.4)	0.004	290 (288 to 291)	304 (299 to 308)	14 (9 to 19)	<0.001

^aCABG=coronary artery bypass graft. “Primary CABG Analysis” refers to the initial exploratory subgroup analysis for CABG; the results shown here are reproduced from the “CABG” row in Tables 2-4. Shown are the results for a sensitivity analysis that separately adjusted for higher-risk CABG (redo procedure or CABG plus a valve procedure).

eTable 8. Additional Sensitivity Analysis: Multiple Imputation Approach for Missing Data^a

	Adjusted Difference, Mortality, % (95% CI)	Adjusted Difference, Complications, % (95% CI)	Adjusted Difference, Surgery Length, minutes (95% CI)
<i>Primary Analysis</i>	0.3 (-0.2 to 0.7)	0.9 (-0.1 to 1.9)	30 (24 to 37)
<i>Multiple Imputations Analysis</i>	0.3 (-0.02 to 0.7)	1.0 (0.0 to 2.0)	32 (26 to 38)

^aShown are the adjusted differences in mortality, complication rate, and surgery length from the primary analysis (reproduced from tables 2,3, and 4) and a multiple imputation analysis which used a Markov Chain Monte Carlo procedure to adjust for missing data.