



Research Paper

Incidence and impact of surgical site complications on length of stay and cost of care for patients undergoing open procedures



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ARTICLE INFO

Article history:

Received 21 December 2022

Received in revised form 25 April 2023

Accepted 10 May 2023

Available online 20 May 2023

ABSTRACT

Background: Surgical site complications (SSCs) can have serious and life-threatening consequences for patients; however, their frequency and impact on healthcare utilization across surgical procedures, particularly for non-infectious SSCs, are unknown. This study examined incidence of overall SSCs and non-infectious SSCs in patients undergoing open surgical procedures in the United States and their effect on length of stay (LOS) and costs.

Methods: This retrospective study utilizing 2019–2020 data from Medicare and Premier Health Database identified patients with SSCs during hospitalization or within 90 days of discharge. Propensity score matching was used to calculate incremental LOS and costs attributable to SSCs. Mean LOS and costs attributable to SSCs for the index admission, readmissions, and outpatient visits were summed by procedure and Charlson Comorbidity Index score to estimate the overall impact of an SSC on LOS and costs across healthcare settings.

Results: Overall and non-infectious SSC rates were 7.3 % and 5.3 % respectively for 2,696,986 Medicare and 6.7 % and 5.0 % for 1,846,254 Premier open surgeries. Total incremental LOS and cost per SSC were 7.8 days and \$15,339 for Medicare patients and 6.2 days and \$17,196 for Premier patients. Incremental LOS and cost attributable to non-infectious SSCs were 6.5 days and \$12,703 and 5.2 days and \$14,477 for Medicare and Premier patients respectively.

Conclusions: This study utilizing two large national databases provides strong evidence that SSCs, particularly non-infectious SSCs, are not uncommon in open surgeries and result in increased healthcare utilization and costs. These findings demonstrate the need for increased adoption of evidence-based interventions that can reduce SSC rates.

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Background

Several studies have examined the incidence of surgical site infections (SSIs) and their negative impact on patient outcomes and costs [1–5]; however, less attention has been paid to other common, non-infectious surgical site complications (SSCs) such as dehiscence, postoperative seroma, skin complications and non-healing wounds [6]. These complications can be serious and even life-threatening for patients and often result in increased health care utilization [6–10]. SSCs are among the most frequently occurring adverse outcomes for elective total joint arthroplasty, a common procedure for Medicare patients,

and have been associated with a statistically significant increase in post-discharge costs [6]. A study examining postoperative wound dehiscence in the Nationwide Inpatient Sample found that this SSC was associated with excess mortality, increase in length of stay (LOS) and excess hospital charges [8]. While these studies provide evidence of the negative consequences of SSCs, the overall incidence of SSCs across surgical procedures in the United States (U.S.) and the impact of SSCs, particularly non-infectious complications, on health care delivery are not well established [6]. The impact of underlying comorbidities on the risk of developing an SSC based on surgical category is also unknown. This information is crucial to determining where implementation of evidence-based interventions that have been shown to reduce SSIs and non-infectious SSCs and associated negative outcomes can provide the most benefit for both the patient and the health care system [6]. The objective of this study was to identify incidence of overall SSCs (including SSIs) as well as non-infectious SSCs in patients undergoing open surgical procedures in the U.S. in 2019–2020 by surgical category and

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comorbidity level and to examine the incremental impact of these SSCs on length of stay (LOS) and costs.

Methods

Study design. This retrospective analysis utilized methods similar to those described in the authors' previously published work on the incidence and impact of surgical site infections for patients undergoing open procedures [5]. Data were extracted from the Medicare Limited Data Set (LDS) and the Premier (now PINC AI™) Healthcare Database (PHD). PHD contains, service-level, all-payer data on inpatient discharges from member hospitals, which include geographically diverse non-profit, non-governmental, and community and teaching hospitals and health systems from both rural and urban areas in the United States [11]. Deidentified clinical and cost data are collected from over 8 million inpatient admissions a year, representing approximately 25 % of U.S. inpatient admissions, and also from outpatient visits to emergency departments and ambulatory surgery centers. Data are available to PINC AI™ members and external companies through data licensing [12]. The Medicare LDS contains deidentified inpatient, outpatient, home health, hospice, skilled nursing facility, and carrier beneficiary-level claims for Medicare patients. As this study utilized deidentified data, it was exempt from IRB review.

Study population. Patients who underwent common open surgical procedures in 2019–2020, including cardiac, general abdominal, obstetrical/gynecological, orthopedic, vascular, and skin/subcutaneous tissue/breast procedures and had a least one ICD-10 procedure code with the 1st and the 5th character equal to "0", designating an open procedure, were included in the analysis. The diagnostic-related group (DRG) assigned at discharge was used to determine the overall surgical category for each patient. As DRGs are used to identify similar patterns of resource use and assigned based on clinical coherence such as a common organ system or clinical specialty and not strictly on surgical approach, using DRGs alone was not sufficient to determine if a patient had an open procedure. Although the descriptions of several included DRGs indicate a closed procedure (i.e., percutaneous intracardiac), patients included in this analysis had at least one open procedure as indicated by an ICD-10 procedure code which are more granular than DRGs. By definition, the study excluded patients who only underwent percutaneous or laparoscopic procedures.

Measures. SSCs were identified using DRGs and ICD-10 diagnosis codes (Appendix – eTable 1). SSIs were identified using DRGs (856–858, 862–863) and ICD-10 codes for postoperative infections. Non-infectious SSCs included dehiscence, postoperative seroma, skin complications, and non-healing wounds. Dehiscence was identified with ICD-10 codes for wound disruption. Post-operative seroma was identified with ICD-10 codes for postprocedural seroma of the nervous system of musculoskeletal structure. Skin complications were defined as postprocedural complications explicitly in skin and subcutaneous tissue and were identified with ICD-10 codes for cellulitis and acute lymphangitis or post-procedural hemorrhage, hematoma, seroma, or other complication of skin and subcutaneous tissue. Non-healing wounds were indicated by ICD-10 codes for necrotizing fasciitis, nontraumatic hematoma, fat necrosis of breast, and other unspecified complications of surgical care.

SSCs were included in the analysis if they were documented during index hospitalization as a secondary diagnosis or were listed as a primary diagnosis for a readmission, outpatient visit, or professional provider's service (Medicare only) within 90 days of discharge. Charlson Comorbidity Index (CCI) scores were calculated for each patient based on the comorbidities documented during the index admission or in the two years prior. Levels of comorbidity were classified based on CCI score as none (0), mild (1–2), moderate (3–4), or severe (≥ 5). Costs represent the amount paid by Medicare for services rendered

or the estimated cost of care provided by Premier facilities calculated with relative value units or cost-to-charge ratios.

Statistical analysis. Patient demographics and comorbidities for patients with and without SSCs in both the Medicare and Premier populations were examined using counts and percentages. Overall and non-infectious SSC incidence rates were calculated for each surgical category as well as by CCI levels. As the primary study objective was to examine the overall impact of SSCs as well as non-infectious SSCs on length of stay (LOS) and costs, propensity scoring was used to create matched sets of Medicare and Premier patients with SSCs and control groups without SSCs during the index admission to determine the incremental effect of an SSC on index LOS and care costs [1]. Separate propensity score models were used to determine the incremental effect of a non-infectious SSC on index LOS and costs.

Propensity score matching allowed for the control of underlying risk factors that may make a patient more susceptible to SSC and also be independently associated with greater health care utilization and costs. Controlling for this relationship prevented an overestimation of the impact of SSC on LOS and cost. To perform the propensity score matching, we used a multi-level random-intercept logistic regression model to estimate the effect of SSC predictors on the odds of developing an SSC during the index admission with a binary indicator for SSC as the dependent variable. The hospital facility was included as a random intercept to account for within-hospital clustering. The following SSC risk factors were included in the model: surgical category [1]; type of admission (elective or non-elective) [13]; CCI score [14]; blood transfusion [15]; alcohol, drug, and/or nicotine use [4,16]; and comorbidities including chronic obstructive pulmonary disease (COPD) [17,18], peripheral vascular disease [19,20], congestive heart failure [19], rheumatic disease [20], hypertension [19], obesity [4,16,20], diabetes [4,16], blood disorders [19], asthma [21], and liver disease [19,22].

A propensity score was calculated from the model for each observation indicating the likelihood of developing an SSC during the index admission and used to match individual patients with SSCs 1:1 to a control group of patients without SSCs in the same surgical category. Matching criterion for the propensity scores was set to ≤ 0.01 to ensure patients were well matched in terms of observed characteristics and SSC risk. The distributions of the independent variables included in the regression model were compared between groups before and after matching to ensure that covariate balance was achieved. Differences in inpatient LOS and costs for the index hospitalization were calculated between each matched pair, with observed differences attributed to SSCs.

The additional LOS and cost due to an SSC readmission were calculated as the mean readmission LOS and cost for all patients who were readmitted with a primary diagnosis of SSC. The additional costs of SSC-related outpatient visits were calculated as the mean cost of outpatient visits with primary diagnosis of SSC within 90 days after discharge. To determine the overall impact of an SSC on LOS and cost in terms of prolonged hospitalization and SSC-related readmissions and outpatient visits, we calculated SSC-related LOS as the weighted average of incremental LOS due to index SSCs and LOS of SSC readmissions. We calculated the SSC-related cost as the weighted average of costs from index SSCs, SSC readmissions, and SSC outpatient visits. We used the percentages of index SSCs, SSC readmissions, and SSC outpatient visits in each cohort as the weights.

Observations with missing data or a cost of \$0 were excluded from the calculations. A two-way ANOVA was used to test if the surgical category and CCI had inter-group effects on increased LOS and costs due to SSC. The model indicated a statistically significant ($p < .0001$) effect for surgical category and CCI group, thus SSC-related LOS and costs were calculated by surgical category and CCI group. All statistical analyses were conducted using SAS (9.4; SAS Institute Inc., Cary, NC). A p -value of $< .05$ was considered statistically significant.

Table 1
Demographics of study population.

	Medicare (n = 2,696,986)	Premier (n = 1,846,254)
Age, mean (SD)	71.9 (10.4)	61.7 (17.2)
Age group, n (%)		
<18	119 (0.0)	26,802 (1.5)
18–35	16,972 (0.6)	154,755 (8.4)
36–50	77,956 (2.9)	233,378 (12.6)
51–64	329,526 (12.2)	498,948 (27.0)
≥65	2,272,413 (84.3)	932,371 (50.5)
Female, n (%)	1,473,013 (54.6)	1,011,156 (54.8)
Admission type, n (%)		
Elective	1,590,258 (59.0)	1,052,075 (57.0)
Emergency	786,925 (29.2)	551,557 (29.9)
Urgent	271,778 (10.1)	189,796 (10.3)
Trauma center	44,276 (1.6)	32,952 (1.8)
Newborn	17 (0.0)	318 (0.0)
Unknown	3732 (0.1)	19,556 (1.1)
Surgical category, n (%)		
Orthopedic	1,729,117 (64.1)	1,025,378 (55.5)
Cardiac	426,016 (15.8)	285,422 (15.5)
Abdominal	263,941 (9.8)	201,617 (10.9)
Vascular	167,245 (6.2)	92,964 (5.0)
Skin, subcutaneous tissue, breast	74,484 (2.8)	74,318 (4.0)
Obstetric/gynecological	36,183 (1.3)	166,555 (9.0)
Comorbidities, n (%)		
Peripheral vascular disease	581,827 (21.6)	261,319 (14.2)
Congestive heart failure	665,449 (24.7)	310,075 (16.8)
Chronic pulmonary disease	743,341 (27.6)	402,770 (21.8)
Rheumatic disease	165,519 (6.1)	73,543 (4.0)
Hypertension	1,868,868 (69.3)	791,509 (42.9)
Obesity	754,769 (28.0)	442,714 (24.0)
Alcohol use	95,520 (3.5)	52,083 (2.8)
Blood transfusion	218,810 (8.1)	233,526 (12.7)
Blood disorders ^a	1,481,464 (54.9)	678,916 (36.8)
Cocaine use	10,199 (0.4)	9205 (0.5)
Nicotine use	380,137 (14.1)	277,923 (15.1)
Chronic obstructive pulmonary disease	486,677 (18.1)	189,890 (10.3)
CCI, mean (SD) ^b	3.1 (3.1)	2.2 (2.7)

^a Blood disorders: coagulation defects, purpura and other hemorrhagic conditions.^b CCI = Charlson Comorbidity Index.

Results

The study population included 2,696,986 Medicare patients and 1,846,254 Premier patients who underwent common open surgical procedures from 2019 to 2020 (Table 1). The Medicare population was

older on average (71.9 vs. 61.7 years), underwent more orthopedic procedures (64.1 % vs. 55.5 %) and fewer obstetric/gynecological procedures (1.3 % vs. 9.0 %), and had more comorbidities compared to the Premier population as reflected by a higher CCI (3.1 vs. 2.2). The percentage of patients undergoing elective surgeries (~60 %) versus emergency (~30 %), urgent (~10 %), or trauma procedures (~2 %) was similar between the populations.

Overall and non-infectious SSC rates by surgical type and CCI score for Medicare and Premier patients are displayed in Fig. 1 and Tables 2–3. The overall SSC rate was 7.3 % in the Medicare population and 6.7 % in the Premier population, and the overall SSC rate for urgent and emergency surgeries in these populations was 10.5 % and 9.9 %, respectively. There was variation in overall SSC rates across surgical categories, with the highest rates occurring in patients undergoing skin, subcutaneous tissue, and breast surgeries in both the Medicare (22.5 %) and Premier (18.4 %) populations. The lowest SSC rates were observed in orthopedic procedures (5.4 %) for Medicare patients and obstetric/gynecological procedures (3.9 %) for Premier patients. Increases in SSC rates were observed with increased levels of comorbidities across surgical categories in both populations.

The non-infectious SSC rate was 5.3 % in the Medicare population and 5.0 % in the Premier population, and the non-infectious SSC rate for urgent and emergency surgeries in these populations was 7.9 % and 7.7 %, respectively. Similar to the findings in the overall SSC analysis, we observed variation in non-infectious SSC rates across surgical categories, with the highest rates occurring in patients undergoing skin, subcutaneous tissue, and breast surgeries in both the Medicare (20.1 %) and Premier (16.7 %) populations. The lowest SSC rates were observed in orthopedic procedures (4.1 %) for Medicare patients and obstetric/gynecological procedures (2.9 %) for Premier patients. Increases in non-infectious SSC rates were observed with increased levels of comorbidities across surgical categories in both populations.

SSC rates by SSC category are displayed in Table 4. The non-infectious SSC rate was approximately 5 % and the SSI rate was approximately 2 % in both the Medicare and Premier populations. Skin complications were the most frequently occurring non-infectious SSCs in the Medicare (61.6 %) and Premier (62.5 %) populations. Approximately 23 % of non-infectious SSCs in both populations were non-healing wounds and an additional 22–24 % of these non-infectious SSCs were dehiscent wounds. Less than 2 % of non-infectious SSCs were post-operative seromas.

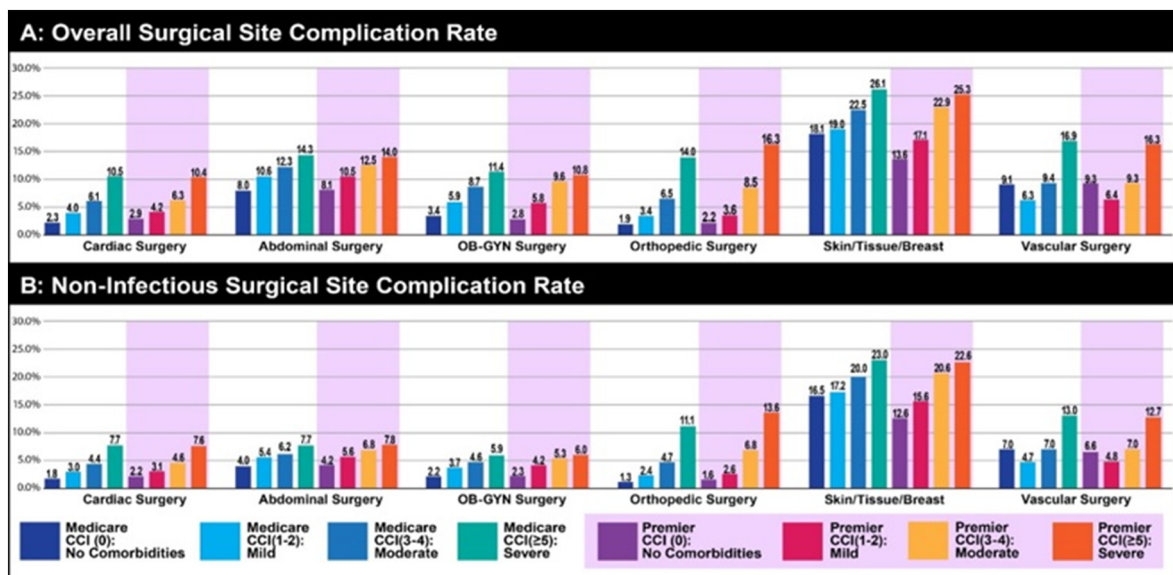


Fig. 1. Overall and non-infectious surgical site complication rates by Charlson Comorbidity Index and surgery type for Medicare and Premier patients.

Table 2

Overall and non-infectious surgical site complication rates by surgical type and Charlson Comorbidity Index score for Medicare patients.

Surgery category by procedure (DRG ^a) and comorbidity level, n (%)	Medicare					
	All surgeries			Urgent/emergency surgeries		
	Discharges	Overall SSCs	Non-infectious SSCs	Discharges	Overall SSCs	Non-infectious SSCs
Cardiac surgery	426,016 (15.80)	30,286 (7.11)	22,283 (5.23)	264,136 (24.95)	18,960 (7.18)	14,506 (5.49)
001–002: Heart transplant	4172 (0.98)	633 (15.17)	416 (9.97)	3058 (1.16)	487 (15.93)	318 (10.40)
003: ECMO or tracheostomy MV >96HR with OR proc.	24,007 (5.64)	3760 (15.66)	2565 (10.68)	16,392 (6.21)	2386 (14.56)	1681 (10.26)
004: Tracheostomy MV >96HR without OR proc	15,478 (3.63)	796 (5.14)	725 (4.68)	13,390 (5.07)	653 (4.88)	595 (4.44)
215: Other heart assist system implant	2685 (0.63)	296 (11.02)	225 (8.38)	2072 (0.78)	229 (11.05)	180 (8.69)
216–221: Cardiac valve and other cardiothoracic	64,866 (15.23)	3650 (5.63)	2446 (3.77)	18,097 (6.85)	1403 (7.75)	924 (5.11)
222–227: Cardiac defibrillator implant	29,957 (7.03)	1857 (6.20)	1729 (5.77)	24,185 (9.16)	1482 (6.13)	1379 (5.70)
228–229: Other cardiothoracic	10,410 (2.44)	757 (7.27)	535 (5.14)	5204 (1.97)	432 (8.30)	322 (6.19)
231–236: Coronary bypass	104,432 (24.51)	6447 (6.17)	3998 (3.83)	51,213 (19.39)	3415 (6.67)	2112 (4.12)
242–244: Permanent cardiac pacemaker implant	105,697 (24.81)	3290 (3.11)	3001 (2.84)	93,892 (35.55)	2858 (3.04)	2624 (2.79)
245: AICD generator	2772 (0.65)	186 (6.71)	172 (6.20)	2214 (0.84)	147 (6.64)	137 (6.19)
246–251: Percutaneous cardiovascular	2491 (0.58)	396 (15.90)	297 (11.92)	1855 (0.70)	309 (16.66)	229 (12.35)
258–259: Cardiac pacemaker device replacement	2740 (0.64)	131 (4.78)	120 (4.38)	2319 (0.88)	103 (4.44)	94 (4.05)
260–262: Cardiac pacemaker revision	6790 (1.59)	578 (8.51)	478 (7.04)	5611 (2.12)	458 (8.16)	377 (6.72)
265: AICD lead	571 (0.13)	47 (8.23)	40 (7.01)	316 (0.12)	34 (10.76)	29 (9.18)
266–267: Endovascular cardiac valve replacement	9540 (2.24)	738 (7.74)	596 (6.25)	1996 (0.76)	202 (10.12)	174 (8.72)
268–269: Aortic and heart assist	6431 (1.51)	696 (10.82)	442 (6.87)	2442 (0.92)	309 (12.65)	199 (8.15)
270–272: Other major cardiovascular	31,913 (7.49)	5917 (18.54)	4405 (13.80)	19,227 (7.28)	3999 (20.80)	3087 (16.06)
273–274: Percutaneous intracardiac	1064 (0.25)	111 (10.43)	93 (8.74)	653 (0.25)	54 (8.27)	45 (6.89)
No comorbidities (CCI = 0)	27,815 (6.53)	646 (2.32)	507 (1.82)	15,702 (5.94)	343 (2.18)	296 (1.89)
Mild (1 ≤ CCI ≤ 2)	113,293 (26.59)	4495 (3.97)	3313 (2.92)	63,248 (23.95)	2388 (3.78)	1837 (2.90)
Moderate (3 ≤ CCI ≤ 4)	105,697 (24.81)	6416 (6.07)	4669 (4.42)	64,393 (24.38)	3875 (6.02)	2934 (4.56)
Severe (CCI ≥ 5)	179,211 (42.07)	18,729 (10.45)	13,794 (7.70)	120,793 (45.73)	12,354 (10.23)	9439 (7.81)
Abdominal surgery	263,941 (9.79)	31,203 (11.82)	16,211 (6.14)	149,587 (14.13)	18,694 (12.50)	9958 (6.66)
326–328: Stomach, esophageal & duodenal	25,445 (9.64)	3201 (12.58)	1581 (6.21)	13,497 (9.02)	1759 (13.03)	926 (6.86)
329–331: Major small & large bowel	158,171 (59.93)	20,109 (12.71)	9648 (6.10)	82,689 (55.28)	12,113 (14.65)	5876 (7.11)
332–334: Rectal resection	1740 (0.66)	172 (9.89)	97 (5.57)	269 (0.18)	35 (13.01)	20 (7.43)
335–337: Peritoneal adhesiolysis	24,647 (9.34)	2472 (10.03)	1368 (5.55)	18,324 (12.25)	1612 (8.80)	925 (5.05)
338–343: Appendectomy	3363 (1.27)	311 (9.25)	156 (4.64)	2882 (1.93)	270 (9.37)	136 (4.72)
344–346: Minor small & large bowel	4574 (1.73)	486 (10.63)	321 (7.02)	2940 (1.97)	338 (11.50)	235 (7.99)
347–349: Anal & stomal	2305 (0.87)	162 (7.03)	141 (6.12)	1866 (1.25)	127 (6.81)	114 (6.11)
350–352: Inguinal & femoral hernia	11,300 (4.28)	580 (5.13)	435 (3.85)	9232 (6.17)	435 (4.71)	324 (3.51)
353–355: Hernia except inguinal & femoral	22,067 (8.36)	2417 (10.95)	1463 (6.63)	10,636 (7.11)	1045 (9.83)	638 (6.00)
356–358: Other digestive system OR procedure	10,329 (3.91)	1293 (12.52)	1001 (9.69)	7252 (4.85)	960 (13.24)	764 (10.54)
No comorbidities (CCI = 0)	41,178 (15.60)	3307 (8.03)	1650 (4.01)	22,826 (15.26)	1942 (8.51)	963 (4.22)
Mild (1 ≤ CCI ≤ 2)	77,597 (29.40)	8207 (10.58)	4197 (5.41)	44,019 (29.43)	4860 (11.04)	2483 (5.64)
Moderate (3 ≤ CCI ≤ 4)	53,618 (20.31)	6605 (12.32)	3340 (6.23)	29,939 (20.01)	3941 (13.16)	2092 (6.99)
Severe (CCI ≥ 5)	91,548 (34.69)	13,084 (14.29)	7024 (7.67)	52,803 (35.30)	7951 (15.06)	4420 (8.37)
OB-GYN surgery	36,183 (1.34)	2730 (7.54)	1518 (4.20)	5545 (0.52)	590 (10.64)	363 (6.55)
734–735: Pelvic evisceration, hysterectomy, vulvectomy	1585 (4.38)	161 (10.16)	88 (5.55)	160 (2.89)	19 (11.88)	8 (5.00)
736–743: Uterine and adnexal procs	24,755 (68.42)	1741 (7.03)	871 (3.52)	2902 (52.34)	311 (10.72)	131 (4.51)
744–745: D&C, conization, laparoscopy, tubal interruption	259 (0.72)	29 (11.20)	17 (6.56)	100 (1.80)	12 (12.00)	10 (10.00)
746–747: Vagina, cervix & vulva	3865 (10.68)	412 (10.66)	251 (6.49)	776 (13.99)	110 (14.18)	95 (12.24)
748: Female reproductive reconstructive	1988 (5.49)	59 (2.97)	41 (2.06)	105 (1.89)	7 (6.67)	6 (5.71)
749–750: Other female reproductive system	1145 (3.16)	144 (12.58)	89 (7.77)	349 (6.29)	45 (12.89)	36 (10.32)
770: Abortion w/D&C, aspiration curettage or hysterectomy	4 (0.01)	2 (50.00)	1 (25.00)	2 (0.04)	1 (50.00)	1 (50.00)
783–788: Cesarean section	2582 (7.14)	182 (7.05)	160 (6.20)	1151 (20.76)	85 (7.38)	76 (6.60)
No comorbidities (CCI = 0)	8772 (24.24)	295 (3.36)	192 (2.19)	1280 (23.08)	75 (5.86)	52 (4.06)
Mild (1 ≤ CCI ≤ 2)	10,013 (27.67)	588 (5.87)	371 (3.71)	1472 (26.55)	115 (7.81)	78 (5.30)
Moderate (3 ≤ CCI ≤ 4)	5129 (14.18)	448 (8.73)	236 (4.60)	766 (13.81)	89 (11.62)	58 (7.57)
Severe (CCI ≥ 5)	12,269 (33.91)	1399 (11.40)	719 (5.86)	2027 (36.56)	311 (15.34)	175 (8.63)
Orthopedic surgery	1729,117 (64.11)	94,113 (5.44)	70,466 (4.08)	521,661 (49.27)	48,858 (9.37)	38,587 (7.40)
239–241: Amputation except upper limb & toe	36,412 (2.11)	11,650 (31.99)	10,340 (28.40)	26,035 (4.99)	8557 (32.87)	7581 (29.12)
255–257: Upper limb & toe amputation	8496 (0.49)	2673 (31.46)	2337 (27.51)	6983 (1.34)	2188 (31.33)	1910 (27.35)
453–455: Anterior/posterior spinal fusion	94,658 (5.47)	4509 (4.76)	2354 (2.49)	7262 (1.39)	588 (8.10)	310 (4.27)
456–458: Spinal fusion with exclusions	13,691 (0.79)	1183 (8.64)	580 (4.24)	3757 (0.72)	447 (11.90)	227 (6.04)
459–460: Spinal fusion except cervical	93,453 (5.40)	4717 (5.05)	2457 (2.63)	9972 (1.91)	939 (9.42)	453 (4.54)
461–462: Multiple lower extremity major joint	11,162 (0.65)	247 (2.21)	189 (1.69)	399 (0.08)	32 (8.02)	27 (6.77)
466–467: Revision of hip or knee replacement	55,910 (3.23)	5283 (9.45)	3683 (6.59)	19,329 (3.71)	2324 (12.02)	1546 (8.00)
468: Revision of hip/knee replacement w/o cc/mcc	35,781 (2.07)	1473 (4.12)	1069 (2.99)	3054 (0.59)	179 (5.86)	119 (3.90)
469–470: Major hip/knee joint replacement/reattachment	730,537 (42.25)	17,925 (2.45)	13,283 (1.82)	122,372 (23.46)	473 (3.74)	3188 (2.61)
471–473: Cervical spinal fusion	62,022 (3.59)	2030 (3.27)	1397 (2.25)	10,349 (1.98)	502 (4.85)	359 (3.47)
474–476: Amputation, musculoskeletal system/connective tissue disorder	15,602 (0.90)	4616 (29.59)	4070 (26.09)	10,045 (1.93)	3113 (30.99)	2734 (27.22)
477–479: Biopsy of musculoskeletal system and connective tissue	8105 (0.47)	929 (11.46)	737 (9.09)	5675 (1.09)	696 (12.26)	557 (9.81)
480–482: Hip & femur except major joint	161,459 (9.34)	5786 (3.58)	3974 (2.46)	139,462 (26.73)	4704 (3.37)	3301 (2.37)
483: Major joint/limb reattachment of upper extremity	137,929 (7.98)	2009 (1.46)	1535 (1.11)	7572 (1.45)	219 (2.89)	156 (2.06)
485–489: Knee	18,196 (1.05)	1873 (10.29)	1373 (7.55)	7969 (1.53)	1057 (13.26)	799 (10.03)
492–494: Lower extremity/humerus except hip/foot/femur	69,534 (4.02)	5380 (7.74)	3567 (5.13)	47,267 (9.06)	3541 (7.49)	2398 (5.07)
495–499: Local excision/remove int fix dev except hip/femur	9310 (0.54)	1321 (14.19)	843 (9.05)	3293 (0.63)	664 (20.16)	446 (13.54)
500–502: Soft tissue	21,872 (1.26)	4187 (19.14)	3439 (15.72)	13,164 (2.52)	2827 (21.48)	2403 (18.25)

Table 2 (continued)

Surgery category by procedure (DRG ^a) and comorbidity level, n (%)	Medicare					
	All surgeries			Urgent/emergency surgeries		
	Discharges	Overall SSCs	Non-infectious SSCs	Discharges	Overall SSCs	Non-infectious SSCs
503–505: Foot	9847 (0.57)	1779 (18.07)	1569 (15.93)	6502 (1.25)	1342 (20.64)	1209 (18.59)
506: Major thumb or joint	882 (0.05)	124 (14.06)	110 (12.47)	724 (0.14)	107 (14.78)	98 (13.54)
507–508: Major shoulder or elbow joint	1045 (0.06)	131 (12.54)	103 (9.86)	651 (0.12)	96 (14.75)	80 (12.29)
509: Arthroscopy	13 (0.00)	1 (7.69)	1 (7.69)	7 (0.00)	1 (14.29)	1 (14.29)
510–512: Shoulder, elbow, or forearm	12,068 (0.70)	439 (3.64)	306 (2.54)	9018 (1.73)	315 (3.49)	225 (2.50)
513–514: Hand/wrist	4468 (0.26)	714 (15.98)	645 (14.44)	3676 (0.70)	623 (16.95)	575 (15.64)
515–517: Musculoskeletal system/connective tissue OR	37,114 (2.15)	1982 (5.34)	1137 (3.06)	10,836 (2.08)	770 (7.11)	466 (4.30)
518–520: Back and neck except spinal fusion	33,598 (1.94)	1635 (4.87)	843 (2.51)	8937 (1.71)	565 (6.32)	303 (3.39)
616–618: Low limb amputation for endocrine disorder	35,146 (2.03)	8929 (25.41)	8102 (23.05)	29,637 (5.68)	7511 (25.34)	6832 (23.05)
906: Hand procedures for injuries	1170 (0.07)	123 (10.51)	97 (8.29)	907 (0.17)	103 (11.36)	80 (8.82)
956: Limb reattachment, hip/femur trauma	9637 (0.56)	465 (4.83)	326 (3.38)	6807 (1.30)	275 (4.04)	204 (3.00)
No comorbidities (CCI = 0)	518,636 (29.99)	9701 (1.87)	6803 (1.31)	83,988 (16.10)	2561 (3.05)	1847 (2.20)
Mild (1 ≤ CCI ≤ 2)	609,940 (35.27)	20,928 (3.43)	14,501 (2.38)	159,510 (30.58)	7414 (4.65)	5309 (3.33)
Moderate (3 ≤ CCI ≤ 4)	275,610 (15.94)	17,953 (6.51)	12,998 (4.72)	104,789 (20.09)	8973 (8.56)	6845 (6.53)
Severe (CCI ≥ 5)	324,931 (18.79)	45,531 (14.01)	36,164 (11.13)	173,374 (33.23)	29,910 (17.25)	24,586 (14.18)
Skin, subcutaneous tissue, breast surgery	74,484 (2.76)	16,782 (22.53)	14,955 (20.08)	46,596 (4.40)	11,563 (24.82)	10,660 (22.88)
570–572: Skin debridement	22,507 (30.22)	5792 (25.73)	5276 (23.44)	16,978 (36.44)	4458 (26.26)	4119 (24.26)
573–578: Skin graft	8784 (11.79)	2008 (22.86)	1677 (19.09)	3373 (7.24)	885 (26.24)	775 (22.98)
579–581: Other skin, subcutaneous tissue & breast	37,658 (50.56)	8257 (21.93)	7470 (19.84)	24,979 (53.61)	6074 (24.32)	5645 (22.60)
582–583: Mastectomy for malignancy	2687 (3.61)	355 (13.21)	265 (9.86)	274 (0.59)	40 (14.60)	31 (11.31)
584–585: Breast biopsy, local excision, other breast	2848 (3.82)	370 (12.99)	267 (9.38)	992 (2.13)	106 (10.69)	90 (9.07)
No comorbidities (CCI = 0)	7903 (10.61)	1429 (18.08)	1303 (16.49)	5360 (11.50)	1076 (20.07)	1003 (18.71)
Mild (1 ≤ CCI ≤ 2)	19,966 (26.81)	3789 (18.98)	3426 (17.16)	12,335 (26.47)	2582 (20.93)	2413 (19.56)
Moderate (3 ≤ CCI ≤ 4)	16,181 (21.72)	3632 (22.45)	3240 (20.02)	10,126 (21.73)	2471 (24.40)	2275 (22.47)
Severe (CCI ≥ 5)	30,434 (40.86)	7932 (26.06)	6986 (22.95)	18,775 (40.29)	5434 (28.94)	4969 (26.47)
Vascular surgery	167,245 (6.20)	21,290 (12.73)	16,192 (9.68)	71,178 (6.72)	12,169 (17.10)	9686 (13.61)
020–021: Intracranial vascular w/PDX hemorrhage	1502 (0.90)	43 (2.86)	33 (2.20)	1387 (1.95)	38 (2.74)	29 (2.09)
022: Intracranial vascular w/PDX hemorrhage w/occ/mcc	39 (0.02)	1 (2.56)	1 (2.56)	29 (0.04)	1 (3.45)	1 (3.45)
034–036: Carotid artery stent	939 (0.56)	78 (8.31)	73 (7.77)	236 (0.33)	23 (9.75)	22 (9.32)
037–039: Extracranial	63,625 (38.04)	2184 (3.43)	1856 (2.92)	11,473 (16.12)	541 (4.72)	466 (4.06)
252–254: Other vascular	83,536 (49.95)	15,583 (18.65)	11,231 (13.44)	44,304 (62.24)	8883 (20.05)	6782 (15.31)
263: Vein ligation & stripping	413 (0.25)	71 (17.19)	57 (13.80)	242 (0.34)	49 (20.25)	39 (16.12)
264: Other circulatory system OR	17,191 (10.28)	3330 (19.37)	2941 (17.11)	13,507 (18.98)	2634 (19.50)	2347 (17.38)
No comorbidities (CCI = 0)	835 (0.50)	76 (9.10)	58 (6.95)	523 (0.73)	58 (11.09)	45 (8.60)
Mild (1 ≤ CCI ≤ 2)	36,311 (21.71)	2297 (6.33)	1709 (4.71)	9536 (13.40)	1007 (10.56)	763 (8.00)
Moderate (3 ≤ CCI ≤ 4)	40,608 (24.28)	3796 (9.35)	2826 (6.96)	14,773 (20.76)	1987 (13.45)	1546 (10.47)
Severe (CCI ≥ 5)	89,491 (53.51)	15,121 (16.90)	11,599 (12.96)	46,346 (65.11)	9117 (19.67)	7332 (15.82)
Total	2,696,986 (100.00)	196,404 (7.28)	141,625 (5.25)	1,058,703 (100.00)	110,834 (10.47)	83,760 (7.91)

^a DRG = diagnostic-related group.

Table 5 contains estimates of the effect of surgical category and specific comorbidities on the odds of developing an SSC or a non-infectious SSC from the logistic regression models used for propensity scoring. The odds of developing an SSC were higher for patients with comorbid conditions, with blood disorders in Medicare patients (OR = 2.05, 95 % CI: 2.03–2.08) and peripheral vascular disease in Premier patients (OR = 2.02, 95 % CI: 1.99–2.05) resulting in the largest increases in odds of SSC. The presence of a comorbidity was also associated with increased odds of developing a non-infectious SSC, with peripheral vascular disease associated with the largest increase in odds of non-infectious SSC in both populations.

The impact of overall SSCs and non-infectious SSCs in terms of additional LOS and costs for Medicare patients is described in Table 6 and Figs. 2–3. Of the 196,404 Medicare patients who experienced an SSC within 90 days following discharge, 44,922 (22.9 %) patients experienced SSCs during the index admission and had statistically significant ($p < .0001$) increases in index LOS and costs compared to patients without SSCs. The average increase in index LOS for these patients was 7.5 days (95 % CI: 7.5–7.5). SSC-related LOS generally increased with comorbidity level across surgical categories. Additional SSC-related costs of index admissions for patients who had an SSC during the index admission were \$10,959 (95 % CI: \$10,678–11,244). Of the 141,625 patients who experienced a non-infectious SSC within 90 days of discharge, 32,326 (22.8 %) experienced the SSC during the index admission resulting in an average

increased length of stay of 6.0 days (95 % CI: 6.0–6.0) and increased costs of \$8188 (95 % CI: \$7890–8488).

Over 54 % of patients who experienced an SSC in the 90 days following discharge had an SSC-related readmission. The mean LOS for these 106,985 patients was 11.2 days. SSC readmission rates and the associated LOS varied across procedures. The likelihood of the SSC resulting in a readmission and associated LOS generally increased with increasing comorbidity levels. The mean cost of an SSC-related readmission for Medicare patients was \$23,136. A total of 62,579 Medicare patients had outpatient visits related to SSCs. The average additional cost of an outpatient visit was \$709.

Over 48 % of patients who experienced a non-infectious SSC in the 90 days following discharge had an SSC-related readmission. The mean LOS for these 69,042 patients was 10.5 days. The mean cost of an SSC-related readmission for Medicare patients was \$21,478. A total of 47,480 Medicare patients had outpatient visits related to non-infectious SSCs. The average additional cost of an outpatient visit was \$691.

In total, the average incremental LOS for the 196,404 Medicare patients who experienced any SSC during the index admission or within 90 days of discharge was 7.8 days (95 % CI: 7.8–7.8), which included additional index LOS and LOS from SSC-related readmissions. The average cost per SSC for these 196,404 patients was \$15,339 (95 % CI: \$15,275–15,404), which included the additional costs incurred during the index admission due to SSC and SSC-related readmissions and outpatient visits. The average incremental LOS for the 141,625 Medicare patients

Table 3

Overall and non-infectious surgical site complication rates by surgical type and Charlson Comorbidity Index score for Premier patients.

Surgery category by procedure (DRG ^a) and comorbidity level, n (%)	Premier					
	All surgeries			Urgent/emergency surgeries		
	Discharges	Overall SSC	Non-infectious SSC	Discharges	Overall SSC	Non-infectious SSCs
Cardiac surgery	285,422 (15.46)	18,465 (6.47)	13,554 (4.75)	174,786 (23.58)	11,934 (6.83)	9132 (5.22)
001–002: Heart transplant	2910 (1.02)	503 (17.29)	363 (12.47)	2116 (1.21)	386 (18.24)	279 (13.19)
003: ECMO or tracheostomy MV >96HR with OR proc.	19,589 (6.86)	3049 (15.56)	2153 (10.99)	14,272 (8.17)	2088 (14.63)	1528 (10.71)
004: Tracheostomy MV >96HR without OR proc	10,770 (3.77)	530 (4.92)	498 (4.62)	9987 (5.71)	491 (4.92)	465 (4.66)
215: Other heart assist system implant	1871 (0.66)	225 (12.03)	176 (9.41)	1454 (0.83)	179 (12.31)	142 (9.77)
216–221: Cardiac valve and other cardiothoracic	46,406 (16.26)	2106 (4.54)	1457 (3.14)	13,727 (7.85)	860 (6.27)	606 (4.41)
222–227: Cardiac defibrillator implant	20,099 (7.04)	1038 (5.16)	961 (4.78)	16,391 (9.38)	847 (5.17)	784 (4.78)
228–229: Other cardiothoracic	9145 (3.20)	501 (5.48)	340 (3.72)	4155 (2.38)	270 (6.50)	192 (4.62)
231–236: Coronary bypass	82,019 (28.74)	4330 (5.28)	2691 (3.28)	42,207 (24.15)	2480 (5.88)	1568 (3.72)
242–244: Permanent cardiac pacemaker implant	53,024 (18.58)	1475 (2.78)	1360 (2.56)	47,130 (26.96)	1277 (2.71)	1184 (2.51)
245: AICD generator	1827 (0.64)	116 (6.35)	111 (6.08)	1481 (0.85)	97 (6.55)	94 (6.35)
246–251: Percutaneous cardiovascular	1493 (0.52)	248 (16.61)	192 (12.86)	1120 (0.64)	206 (18.39)	161 (14.38)
258–259: Cardiac pacemaker device replacement	1255 (0.44)	51 (4.06)	46 (3.67)	1088 (0.62)	42 (3.86)	37 (3.40)
260–262: Cardiac pacemaker revision	3988 (1.40)	238 (5.97)	200 (5.02)	3264 (1.87)	190 (5.82)	161 (4.93)
265: AICD lead	451 (0.16)	28 (6.21)	22 (4.88)	240 (0.14)	21 (8.75)	17 (7.08)
266–267: Endovascular cardiac valve replacement	3840 (1.35)	240 (6.25)	181 (4.71)	836 (0.48)	56 (6.70)	46 (5.50)
268–269: Aortic and heart assist	4213 (1.48)	428 (10.16)	272 (6.46)	1614 (0.92)	175 (10.84)	118 (7.31)
270–272: Other major cardiovascular	21,763 (7.62)	3303 (15.18)	2481 (11.40)	13,190 (7.55)	2233 (16.93)	1718 (13.03)
273–274: Percutaneous intracardiac	759 (0.27)	56 (7.38)	50 (6.59)	514 (0.29)	36 (7.00)	32 (6.23)
No comorbidities (CCI = 0)	30,501 (10.69)	894 (2.93)	675 (2.21)	15,625 (8.94)	461 (2.95)	351 (2.25)
Mild (1 ≤ CCI ≤ 2)	98,064 (34.36)	4096 (4.18)	3036 (3.10)	55,095 (31.52)	2360 (4.28)	1830 (3.32)
Moderate (3 ≤ CCI ≤ 4)	69,715 (24.43)	4385 (6.29)	3216 (4.61)	43,755 (25.03)	2808 (6.42)	2155 (4.93)
Severe (CCI ≥ 5)	87,142 (30.53)	9090 (10.43)	6627 (7.60)	60,311 (34.51)	6305 (10.45)	4796 (7.95)
Abdominal surgery	201,617 (10.92)	21,877 (10.85)	11,756 (5.83)	112,787 (15.21)	13,203 (11.71)	7293 (6.47)
326–328: Stomach, esophageal & duodenal	17,965 (8.91)	1962 (10.92)	994 (5.53)	10,178 (9.02)	1151 (11.31)	621 (6.10)
329–331: Major small & large bowel	119,210 (59.13)	13,986 (11.73)	6975 (5.85)	58,795 (52.13)	8312 (14.14)	4204 (7.15)
332–334: Rectal resection	1310 (0.65)	107 (8.17)	64 (4.89)	227 (0.20)	18 (7.93)	11 (4.85)
335–337: Peritoneal adhesiolysis	17,229 (8.55)	1787 (10.37)	1009 (5.86)	12,260 (10.87)	1112 (9.07)	648 (5.29)
338–343: Appendectomy	5007 (2.48)	464 (9.27)	209 (4.17)	4446 (3.94)	416 (9.36)	184 (4.14)
344–346: Minor small & large bowel	5273 (2.62)	439 (8.33)	319 (6.05)	3881 (3.44)	316 (8.14)	254 (6.54)
347–349: Anal & stomal	2966 (1.47)	153 (5.16)	140 (4.72)	2548 (2.26)	131 (5.14)	121 (4.75)
350–352: Inguinal & femoral hernia	7195 (3.57)	352 (4.89)	277 (3.85)	5918 (5.25)	272 (4.60)	208 (3.51)
353–355: Hernia except inguinal & femoral	17,850 (8.85)	1865 (10.45)	1183 (6.63)	9199 (8.16)	865 (9.40)	553 (6.01)
356–358: Other digestive system OR procedure	7612 (3.78)	762 (10.01)	586 (7.70)	5335 (4.73)	610 (11.43)	489 (9.17)
No comorbidities (CCI = 0)	61,394 (30.45)	4955 (8.07)	2556 (4.16)	34,527 (30.61)	2924 (8.47)	1522 (4.41)
Mild (1 ≤ CCI ≤ 2)	64,884 (32.18)	6825 (10.52)	3604 (5.55)	35,629 (31.59)	4024 (11.29)	2155 (6.05)
Moderate (3 ≤ CCI ≤ 4)	29,900 (14.83)	3724 (12.45)	2045 (6.84)	16,128 (14.30)	2233 (13.85)	1283 (7.96)
Severe (CCI ≥ 5)	45,439 (22.54)	6373 (14.03)	3551 (7.81)	26,503 (23.50)	4022 (15.18)	2333 (8.80)
OB-GYN surgery	166,555 (9.02)	6499 (3.90)	4804 (2.88)	39,750 (5.36)	1832 (4.61)	1479 (3.72)
734–735: Pelvic evisceration, hysterectomy, vulvectomy	1490 (0.89)	114 (7.65)	65 (4.36)	188 (0.47)	19 (10.11)	9 (4.79)
736–743: Uterine and adnexal procs	57,347 (34.43)	2637 (4.60)	1403 (2.45)	7013 (17.64)	419 (5.97)	213 (3.04)
744–745: D&C, conization, laparoscopy, tubal interruption	324 (0.19)	26 (8.02)	16 (4.94)	152 (0.38)	15 (9.87)	12 (7.89)
746–747: Vagina, cervix & vulva	2899 (1.74)	287 (9.90)	203 (7.00)	1042 (2.62)	123 (11.80)	116 (11.13)
748: Female reproductive reconstructive	1193 (0.72)	20 (1.68)	13 (1.09)	73 (0.18)	1 (1.37)	1 (1.37)
749–750: Other female reproductive system	1045 (0.63)	129 (12.34)	78 (7.46)	388 (0.98)	62 (15.98)	46 (11.86)
770: Abortion w/D&C, aspiration curettage or hysterectomy	69 (0.04)	7 (10.14)	3 (4.35)	43 (0.11)	5 (11.63)	2 (4.65)
783–788: Cesarean section	102,188 (61.35)	3279 (3.21)	3023 (2.96)	30,851 (77.61)	1188 (3.85)	1080 (3.50)
No comorbidities (CCI = 0)	123,702 (74.27)	3428 (2.77)	2800 (2.26)	30,094 (75.71)	986 (3.28)	842 (2.80)
Mild (1 ≤ CCI ≤ 2)	29,905 (17.96)	1737 (5.81)	1261 (4.22)	6992 (17.59)	481 (6.88)	395 (5.65)
Moderate (3 ≤ CCI ≤ 4)	4954 (2.97)	473 (9.55)	262 (5.29)	931 (2.34)	116 (12.46)	81 (8.70)
Severe (CCI ≥ 5)	7994 (4.80)	861 (10.77)	481 (6.02)	1733 (4.36)	249 (14.37)	161 (9.29)
Orthopedic surgery	1,025,378 (55.54)	53,221 (5.19)	41,271 (4.02)	324,421 (43.76)	30,246 (9.32)	24,726 (7.62)
239–241: Amputation except upper limb & toe	20,241 (1.97)	6155 (30.41)	5552 (27.43)	14,918 (4.60)	4657 (31.22)	4190 (28.09)
255–257: Upper limb & toe amputation	5072 (0.49)	1446 (28.51)	1300 (25.63)	4348 (1.34)	1245 (28.63)	1123 (25.83)
453–455: Anterior/posterior spinal fusion	60,690 (5.92)	2346 (3.87)	1301 (2.14)	4785 (1.47)	348 (7.27)	190 (3.97)
456–458: Spinal fusion with exclusions	9980 (0.97)	597 (5.98)	305 (3.06)	2448 (0.75)	218 (8.91)	122 (4.98)
459–460: Spinal fusion except cervical	58,547 (5.71)	2412 (4.12)	1342 (2.29)	6698 (2.06)	552 (8.24)	296 (4.42)
461–462: Multiple lower extremity major joint	8539 (0.83)	135 (1.58)	103 (1.21)	178 (0.05)	12 (6.74)	8 (4.49)
466–467: Revision of hip or knee replacement	27,716 (2.70)	2255 (8.14)	1654 (5.97)	9215 (2.84)	1033 (11.21)	721 (7.82)
468: Revision of hip/knee replacement w/o cc/mcc	18,928 (1.85)	711 (3.76)	547 (2.89)	1476 (0.45)	97 (6.57)	75 (5.08)
469–470: Major hip/knee joint replacement/reattachment	395,045 (38.53)	8274 (2.09)	6206 (1.57)	52,412 (16.16)	1777 (3.39)	1250 (2.38)
471–473: Cervical spinal fusion	47,505 (4.63)	1190 (2.50)	835 (1.76)	8866 (2.73)	314 (3.54)	226 (2.55)
474–476: Amputation, musculoskeletal system/connective tissue disorder	9240 (0.90)	2515 (27.22)	2273 (24.60)	6182 (1.91)	1750 (28.31)	1575 (25.48)
477–479: Biopsy of musculoskeletal system and connective tissue	5583 (0.54)	551 (9.87)	453 (8.11)	4091 (1.26)	429 (10.49)	361 (8.82)
480–482: Hip & femur except major joint	82,089 (8.01)	2658 (3.24)	1868 (2.28)	69,091 (21.30)	2140 (3.10)	1525 (2.21)
483: Major joint/limb reattachment of upper extremity	62,854 (6.13)	835 (1.33)	632 (1.01)	2870 (0.88)	73 (2.54)	54 (1.88)
485–489: Knee	12,346 (1.20)	1035 (8.38)	789 (6.39)	6102 (1.88)	618 (10.13)	483 (7.92)
492–494: Lower extremity/humerus except hip/foot/femur	60,845 (5.93)	3924 (6.45)	2629 (4.32)	42,318 (13.04)	2586 (6.11)	1779 (4.20)
495–499: Local excision/remove int fix dev except hip/femur	6214 (0.61)	768 (12.36)	544 (8.75)	2485 (0.77)	426 (17.14)	312 (12.56)
500–502: Soft tissue	18,345 (1.79)	2633 (14.35)	2236 (12.19)	12,867 (3.97)	2012 (15.64)	1750 (13.60)
503–505: Foot	7819 (0.76)	1172 (14.99)	1013 (12.96)	5629 (1.74)	935 (16.61)	826 (14.67)

Table 3 (continued)

Surgery category by procedure (DRG ^a) and comorbidity level, n (%)	Premier					
	All surgeries			Urgent/emergency surgeries		
	Discharges	Overall SSC	Non-infectious SSC	Discharges	Overall SSC	Non-infectious SSCs
506: Major thumb or joint	1066 (0.10)	115 (10.79)	105 (9.85)	905 (0.28)	98 (10.83)	93 (10.28)
507–508: Major shoulder or elbow joint	872 (0.09)	89 (10.21)	72 (8.26)	556 (0.17)	67 (12.05)	59 (10.61)
509: Arthroscopy	23 (0.00)	0 (0.00)	0 (0.00)	11 (0.00)	0 (0.00)	0 (0.00)
510–512: Shoulder, elbow, or forearm	10,568 (1.03)	302 (2.86)	213 (2.02)	8164 (2.52)	230 (2.82)	163 (2.00)
513–514: Hand/wrist	6797 (0.66)	673 (9.90)	600 (8.83)	5880 (1.81)	602 (10.24)	544 (9.25)
515–517: Musculoskeletal system/connective tissue OR	23,487 (2.29)	1139 (4.85)	675 (2.87)	8352 (2.57)	492 (5.89)	326 (3.90)
518–520: Back and neck except spinal fusion	23,732 (2.31)	982 (4.14)	564 (2.38)	9670 (2.98)	497 (5.14)	293 (3.03)
616–618: Low limb amputation for endocrine disorder	30,298 (2.95)	7608 (25.11)	6993 (23.08)	26,722 (8.24)	6657 (24.91)	6116 (22.89)
906: Hand procedures for injuries	2290 (0.22)	159 (6.94)	124 (5.41)	1784 (0.55)	114 (6.39)	89 (4.99)
956: Limb reattachment, hip/femur trauma	8647 (0.84)	542 (6.27)	343 (3.97)	5398 (1.66)	267 (4.95)	177 (3.28)
No comorbidities (CCI = 0)	425,656 (41.51)	9406 (2.21)	6634 (1.56)	92,457 (28.50)	3431 (3.71)	2506 (2.71)
Mild (1 ≤ CCI ≤ 2)	349,626 (34.10)	12,649 (3.62)	8983 (2.57)	96,647 (29.79)	5184 (5.36)	3845 (3.98)
Moderate (3 ≤ CCI ≤ 4)	123,681 (12.06)	10,561 (8.54)	8450 (6.83)	57,442 (17.71)	6689 (11.64)	5608 (9.76)
Severe (CCI ≥ 5)	126,415 (12.33)	20,605 (16.30)	17,204 (13.61)	77,875 (24.00)	14,942 (19.19)	12,767 (16.39)
Skin, subcutaneous tissue, breast surgery	74,318 (4.03)	13,691 (18.42)	12,419 (16.71)	49,729 (6.71)	10,092 (20.29)	9439 (18.98)
570–572: Skin debridement	17,527 (23.58)	4139 (23.61)	3835 (21.88)	14,797 (29.76)	3564 (24.09)	3340 (22.57)
573–578: Skin graft	5564 (7.49)	1185 (21.30)	1029 (18.49)	2682 (5.39)	615 (22.93)	554 (20.66)
579–581: Other skin, subcutaneous tissue & breast	43,284 (58.24)	7407 (17.11)	6770 (15.64)	30,100 (60.53)	5675 (18.85)	5335 (17.72)
582–583: Mastectomy for malignancy	2862 (3.85)	357 (12.47)	293 (10.24)	198 (0.40)	29 (14.65)	23 (11.62)
584–585: Breast biopsy, local excision, other breast	5081 (6.84)	603 (11.87)	492 (9.68)	1952 (3.93)	209 (10.71)	187 (9.58)
No comorbidities (CCI = 0)	24,476 (32.93)	3326 (13.59)	3073 (12.56)	17,912 (36.02)	2657 (14.83)	2505 (13.99)
Mild (1 ≤ CCI ≤ 2)	24,005 (32.30)	4094 (17.05)	3737 (15.57)	15,022 (30.21)	2870 (19.11)	2683 (17.86)
Moderate (3 ≤ CCI ≤ 4)	11,028 (14.84)	2528 (22.92)	2267 (20.56)	7169 (14.42)	1795 (25.04)	1686 (23.52)
Severe (CCI ≥ 5)	14,809 (19.93)	3743 (25.28)	3342 (22.57)	9626 (19.36)	2770 (28.78)	2565 (26.65)
Vascular surgery	92,964 (5.04)	10,550 (11.35)	8147 (8.76)	39,880 (5.38)	6164 (15.46)	5001 (12.54)
020–021: Intracranial vascular w/PDX hemorrhage	1808 (1.94)	72 (3.98)	45 (2.49)	1711 (4.29)	68 (3.97)	43 (2.51)
022: Intracranial vascular w/PDX hemorrhage w/occ/mcc	60 (0.06)	1 (1.67)	0 (0.00)	50 (0.13)	0 (0.00)	0 (0.00)
034–036: Carotid artery stent	563 (0.61)	39 (6.93)	31 (5.51)	141 (0.35)	18 (12.77)	16 (11.35)
037–039: Extracranial	34,809 (37.44)	1144 (3.29)	1007 (2.89)	6195 (15.53)	273 (4.41)	242 (3.91)
252–254: Other vascular	45,761 (49.22)	7587 (16.58)	5522 (12.07)	23,441 (58.78)	4347 (18.54)	3363 (14.35)
263: Vein ligation & stripping	244 (0.26)	32 (13.11)	27 (11.07)	152 (0.38)	25 (16.45)	21 (13.82)
264: Other circulatory system OR	9719 (10.45)	1675 (17.23)	1515 (15.59)	8190 (20.54)	1433 (17.50)	1316 (16.07)
No comorbidities (CCI = 0)	1491 (1.60)	138 (9.26)	99 (6.64)	935 (2.34)	104 (11.12)	76 (8.13)
Mild (1 ≤ CCI ≤ 2)	27,534 (29.62)	1752 (6.36)	1333 (4.84)	8118 (20.36)	845 (10.41)	656 (8.08)
Moderate (3 ≤ CCI ≤ 4)	25,094 (26.99)	2336 (9.31)	1769 (7.05)	9784 (24.53)	1282 (13.10)	1014 (10.36)
Severe (CCI ≥ 5)	38,845 (41.78)	6324 (16.28)	4946 (12.73)	21,043 (52.77)	3933 (18.69)	3255 (15.47)
Total	1,846,254 (100.00)	124,303 (6.73)	91,951 (4.98)	741,353 (100.00)	73,471 (9.91)	57,070 (7.70)

^a DRG = diagnostic-related group.

who experienced a non-infectious SSC during the index admission or within 90 days of discharge was 6.5 days (95 % CI: 6.5–6.5). The average cost per non-infectious SSC for these 141,625 patients, was \$12,703 (95 % CI: \$12,635–12,771).

The impact of overall SSCs and non-infectious SSC in terms of additional LOS and costs for Premier patients is described in Table 7 and Figs. 2–3. Of the 124,303 Premier patients with an SSC within 90 days following discharge, 26,768 (21.5 %) patients experienced SSCs during the index admission and had statistically significant ($p < .0001$) increases in index LOS compared to patients without SSCs. The average increase in mean index LOS for these patients was 9 days (95 % CI: 9.0–9.0). SSC-related LOS generally increased with comorbidity level across surgical categories. Premier patients with SSCs had statistically significantly ($p < .0001$) higher costs of index admissions than patients

without SSCs. Additional costs of index admissions attributed to SSCs were an average of \$25,089 higher for patients with SSCs. Of the 91,951 Premier patients with a non-infectious SSC within 90 days following discharge, 18,689 (20.3 %) patients experienced SSCs during the index admission and had statistically significant ($p < .0001$) increases in index LOS compared to patients without SSCs. The average increase in mean index LOS for these patients was 7.5 days (95 % CI: 7.5–7.5). Additional costs of index admissions attributed to non-infectious SSCs were an average of \$20,761 higher for patients with SSCs.

Of the 124,303 Premier patients with any SSC during the index admission or within 90 days following discharge, 58,610 (47.2 %) patients were readmitted for an SSC with a mean LOS of 9.0 days. SSC readmission rates and the associated LOS for patients with an SSC varied across procedures. The likelihood of the SSC resulting in a readmission and

Table 4

Number of surgical site complications by category for Medicare and Premier patients.

Surgical site complication category	Medicare				Premier			
	# of cases	% of cases (n = 2,696,986)	% of overall SSCs (n = 196,404)	% of non-infectious SSCs (n = 141,625)	# of cases	% of cases (n = 1,846,254)	% of overall SSCs (n = 124,303)	% of non-infectious SSCs (n = 91,951)
Surgical site infection	54,779	2.03	27.89	0.00	32,352	1.75	26.03	0.00
Non-infectious surgical site complications	141,625	5.25	72.11	100.00	91,951	4.98	73.97	100.00
Skin complication	87,244	3.23	44.42	61.6	57,505	3.11	46.26	62.54
Dehiscence	31,612	1.17	16.10	22.3	22,195	1.20	17.86	24.14
Non-healing wound	33,416	1.24	17.01	23.6	21,472	1.16	17.27	23.35
Post-operative seroma	2399	0.09	1.22	1.7	1173	0.06	0.94	1.28

Table 5

CI = confidence interval, Ref = reference category, COPD = chronic obstructive pulmonary disease, PVD = peripheral vascular disease, CCI = Charlson Comorbidity Index, CPD = chronic pulmonary disease.

^a Blood disorders: Coagulation defects, purpura, and other hemorrhagic conditions.

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Table 6
Additional Length of Stay (LOS) and Costs Attributable to Overall and Non-infectious Surgical Site Complications for Medicare Patients.

Surgery category by CCI ^a level		Additional LOS & costs due to SSC during the index admission ^b			SSC readmission LOS & costs			SSC outpatient visit cost		Cohort averaged SSC LOS ^c and costs ^d (includes index admission, readmissions, and outpatient visits)		
		n	Added LOS (95 % CI)	Added costs (\$)	(95 % CI)	n	Added LOS	Added costs (\$)	n	Added LOS per SSC (95 % CI)	Added costs (\$)	per SSC (95 % CI)
Overall SSC	Cardiac	11,379	10.5 (10.0, 11.0)	33,256 (31,620, 34,911)	14,332	13.1	26,375	7063	626	30,286	10.1 (9.9, 10.3)	25,122 (24,507, 25,744)
	0	324	8.0 (6.0, 10.5)	24,090 (14,992, 42,516)	148	8.7	18,224	185	586	646	6.0 (5.0, 7.3)	16,425 (11,862, 25,667)
	1–2	2014	9.0 (8.0, 9.5)	30,568 (26,614, 34,700)	1460	9.9	20,454	1198	581	4495	7.3 (6.8, 7.5)	20,495 (18,723, 22,346)
	3–4	2748	9.5 (9.0, 10.5)	31,490 (28,380, 34,734)	2566	11.3	22,722	1591	646	6416	8.6 (8.4, 9.0)	22,735 (21,403, 24,124)
	≥5	6293	11.5 (11.0, 12.0)	34,981 (32,778, 37,225)	10,158	14.0	28,245	4089	634	18,729	11.5 (11.3, 11.6)	27,211 (26,471, 27,965)
	Abdominal	12,173	9.5 (9.0, 9.5)	13,965 (13,511, 14,425)	13,899	11.1	20,965	8694	611	31,203	8.6 (8.4, 8.6)	14,957 (14,780, 15,136)
	0	1311	8.5 (8.0, 9.0)	11,176 (10,085, 12,301)	1148	8.5	17,192	1103	603	3307	6.3 (6.1, 6.5)	10,600 (10,167, 11,046)
	1–2	3365	9.0 (8.5, 9.0)	13,056 (12,286, 13,844)	3178	9.4	18,159	2508	584	8207	7.3 (7.1, 7.3)	12,563 (12,248, 12,887)
	3–4	2730	10.0 (9.5, 10.5)	14,878 (13,882, 15,905)	2897	11.1	21,207	1844	634	6605	9.0 (8.8, 9.2)	15,628 (15,216, 16,052)
	≥5	4767	9.5 (9.5, 10.0)	15,043 (14,244, 15,854)	6676	12.3	22,800	3239	623	13,084	9.7 (9.7, 9.9)	17,269 (16,978, 17,564)
	OB-GYN	657	9.0 (8.0, 10.0)	12,043 (10,109, 14,102)	1304	9.7	20,728	1053	612	2730	6.8 (6.5, 7.0)	13,035 (12,570, 13,531)
	0	74	2.0 (0.5, 3.5)	0 (–130, 3574)	93	7.0	14,661	136	490	295	2.7 (2.3, 3.1)	4848 (4816, 5745)
	1–2	129	6.5 (5.0, 9.0)	4569 (2399, 7848)	235	7.1	16,360	274	581	588	4.3 (3.9, 4.8)	7811 (7335, 8531)
3–4	106	10.5 (8.0, 13.0)	15,227 (9863, 22,519)	205	9.8	20,987	185	564	448	7.0 (6.4, 7.6)	13,439 (12,170, 15,165)	
≥5	348	10.5 (9.5, 12.0)	16,608 (13,978, 19,474)	771	10.8	22,636	458	686	1399	8.5 (8.3, 8.9)	16,831 (16,177, 17,543)	
Non-infectious	Orthopedic	12,376	5.5 (5.5, 6.0)	5605 (5268, 5947)	56,920	10.8	22,912	32,450	755	94,113	7.2 (7.2, 7.3)	14,855 (14,810, 14,900)
	0	1209	3.5 (3.0, 3.5)	3299 (2529, 4086)	4404	7.1	16,990	4243	738	9701	3.7 (3.6, 3.7)	8447 (8351, 8545)
	1–2	2500	4.5 (4.5, 5.0)	5154 (4480, 5870)	11,250	8.3	18,575	8078	717	20,928	5.0 (5.0, 5.1)	10,878 (10,797, 10,963)
	3–4	2358	5.5 (5.0, 6.0)	5496 (4730, 6298)	10,481	9.8	20,759	6497	732	17,953	6.4 (6.4, 6.5)	13,106 (13,005, 13,211)
	≥5	6309	6.5 (6.5, 7.0)	6332 (5823, 6854)	30,785	12.6	26,020	13,632	793	45,531	9.4 (9.4, 9.5)	18,708 (18,637, 18,780)
	Skin/tissue/breast	3742	2.5 (2.5, 3.0)	2416 (1978, 2866)	7683	10.9	20,338	7355	730	16,782	5.5 (5.5, 5.6)	10,170 (10,072, 10,270)
	0	351	1.0 (0.5, 2.0)	0 (–1032, 732)	366	7.3	14,437	837	721	1429	2.1 (2.0, 2.4)	4120 (3866, 4300)
	1–2	934	2.0 (1.5, 2.5)	1362 (625, 2141)	1272	9.5	18,051	1936	718	3789	3.7 (3.6, 3.8)	6762 (6581, 6955)
	3–4	818	3.0 (2.0, 3.5)	2670 (1815, 3563)	1629	10.0	18,836	1620	731	3632	5.2 (4.9, 5.3)	9376 (9183, 9577)
	≥5	1639	3.5 (3.0, 4.0)	3804 (3007, 4648)	4416	11.9	22,026	2962	741	7932	7.3 (7.2, 7.4)	13,325 (13,160, 13,499)
	Vascular	4665	5.5 (5.0, 5.5)	5322 (4910, 5743)	12,847	11.8	24,769	5964	695	21,290	8.3 (8.2, 8.3)	16,307 (16,217, 16,400)
	0	26	7.9 (3.5, 14.0)	9171 (4337, 13,975)	36	7.4	16,392	17	504	76	6.2 (4.7, 8.3)	11,015 (9361, 12,658)
	1–2	667	4.0 (3.5, 5.0)	5127 (4245, 6103)	995	8.9	18,823	819	805	2297	5.0 (4.9, 5.3)	9929 (9673, 10,213)
3–4	1023	4.5 (4.0, 5.0)	5112 (4335, 5914)	1921	10.0	21,160	1196	700	3796	6.3 (6.1, 6.4)	12,306 (12,097, 12,522)	
≥5	2949	6.0 (5.5, 6.0)	5432 (4871, 6008)	9895	12.4	26,092	3932	671	15,121	9.3 (9.2, 9.3)	18,308 (18,199, 18,420)	
Total	44,992	7.5 (7.5, 7.5)	10,959 (10,678, 11,244)	106,985	11.2	23,136	62,579	709	196,404	7.8 (7.8, 7.8)	15,339 (15,275, 15,404)	
Non-infectious SSC	Cardiac	8884	8.5 (8.0, 8.5)	24,805 (23,225, 26,433)	8991	11.4	23,119	5143	613	22,283	8.0 (7.8, 8.0)	19,359 (18,729, 20,008)
	0	283	6.5 (4.5, 8.5)	16,290 (10,197, 28,843)	80	8.2	18,170	136	633	507	4.9 (3.8, 6.0)	12,130 (8729, 19,137)
	1–2	1624	6.5 (5.5, 7.0)	20,415 (17,257, 23,960)	803	8.7	17,843	880	529	3313	5.3 (4.8, 5.5)	14,472 (12,924, 16,210)
	3–4	2142	7.5 (7.0, 8.5)	23,471 (20,527, 26,544)	1497	10.0	20,251	1144	629	4669	6.7 (6.4, 7.1)	17,415 (16,064, 18,825)
	≥5	4835	9.5 (9.0, 10.0)	27,123 (24,852, 29,454)	6611	12.1	24,457	2983	630	13,794	9.1 (8.9, 9.3)	21,365 (20,569, 22,182)
	Abdominal	5698	8.5 (8.0, 8.5)	11,542 (10,904, 12,192)	5676	9.9	18,622	5510	576	16,211	6.4 (6.3, 6.4)	10,773 (10,549, 11,001)
	0	606	7.0 (6.5, 8.0)	9039 (7379, 10,718)	368	8.1	15,012	696	562	1650	4.4 (4.2, 4.7)	6905 (6295, 7522)
	1–2	1577	8.0 (7.5, 8.5)	10,598 (9529, 11,679)	1166	8.3	15,828	1578	555	4197	5.3 (5.1, 5.5)	8588 (8186, 8994)
	3–4	1269	8.5 (8.0, 9.5)	12,012 (10,581, 13,517)	1093	9.1	17,613	1138	573	3340	6.2 (6.0, 6.6)	10,523 (9979, 11,095)
	≥5	2246	8.5 (8.0, 9.0)	12,792 (11,643, 13,963)	3049	11.0	20,447	2098	599	7024	7.5 (7.3, 7.6)	13,145 (12,777, 13,519)
	OB-GYN	354	6.5 (5.5, 8.0)	7524 (5430, 10,099)	505	8.4	17,393	691	554	1518	4.3 (4.1, 4.6)	7793 (7305, 8394)
	0	61	1.5 (0.5, 3.5)	0 (–150, 2891)	34	6.4	10,844	90	447	192	1.6 (1.3, 2.2)	2130 (2082, 3048)
	1–2	82	4.0 (2.5, 6.0)	1465 (–572, 4477)	97	5.7	14,837	200	496	371	2.4 (2.0, 2.8)	4470 (4020, 5136)
3–4	55	8.5 (5.0, 12.0)	11,773 (5106, 28,596)	69	7.5	16,674	114	446	236	4.2 (3.4, 5.0)	7834 (6281, 11,755)	
≥5	156	9.5 (8.0, 12.0)	14,914 (10,765, 19,410)	305	9.6	19,007	287	672	719	6.1 (5.8, 6.7)	11,567 (10,667, 12,542)	
Orthopedic	0	10,035	5.0 (5.0, 5.5)	4687 (4349, 5032)	38,828	10.2	21,826	24,913	730	70,466	6.4 (6.4, 6.4)	12,952 (12,904, 13,001)
	1–2	1021	3.0 (3.0, 3.5)	2851 (2077, 3671)	2442	6.3	15,944	3052	702	6803	2.7 (2.7, 2.8)	6466 (6350, 6589)
	1–2	1988	4.0 (4.0, 4.5)	3706 (3034, 4403)	6540	7.5	16,905	5846	653	14,501	3.9 (3.9, 4.0)	8395 (8303, 8491)
	3–4	1891	5.0 (5.0, 5.5)	4999 (4226, 5808)	6642	8.7	18,607	4884	714	12,998	5.2 (5.2, 5.3)	10,504 (10,391, 10,622)

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Table 6 (continued)

Surgery category by CCI ^a level	Additional LOS & costs due to SSC during the index admission ^b			SSC readmission LOS & costs			SSC outpatient visit cost			Cohort averaged SSC LOS ^c and costs ^d (includes index admission, readmissions, and outpatient visits)		
	n	Added LOS (95 % CI)	Added costs (\$)(95 % CI)	n	Added LOS	Added costs (\$)	n	Added costs (\$)	n	Added LOS per SSC (95 % CI)	Added costs (\$)	per SSC (95 % CI)
≥5	5135	6.0 (5.5, 6.5)	5366 (4842, 5900)	23,204	11.9	24,695	11,131	786	36,164	8.5 (8.4, 8.5)	16,849 (16,775, 16,925)	
Skin/tissue/breast	3436	2.5 (2.0, 2.5)	2058 (1623, 2508)	6362	10.6	19,642	6679	711	14,955	5.1 (5.0, 5.1)	9146 (9046, 9249)	
0	333	1.0 (0.0, 1.5)	0 (–540, 1173)	292	7.0	13,544	779	719	1303	1.8 (1.6, 1.9)	3465 (3327, 3765)	
1–2	875	1.5 (1.0, 2.0)	1039 (332, 1798)	1042	9.1	16,887	1793	723	3426	3.1 (3.0, 3.3)	5780 (5599, 5974)	
3–4	754	2.5 (2.0, 3.5)	2141 (1251, 3072)	1345	10.1	18,621	1469	712	3240	4.8 (4.7, 5.0)	8551 (8344, 8767)	
≥5	1474	3.0 (2.5, 4.0)	3302 (2507, 4120)	3683	11.5	21,267	2638	699	6986	6.7 (6.6, 6.9)	12,173 (12,005, 12,345)	
Vascular	3919	4.5 (4.5, 5.0)	4412 (4001, 4831)	8680	11.3	23,801	4544	691	16,192	7.2 (7.2, 7.3)	14,021 (13,921, 14,122)	
0	22	5.0 (2.0, 10.0)	6206 (1507, 11,072)	21	8.5	16,120	12	464	58	5.0 (3.8, 6.9)	8286 (6504, 10,132)	
1–2	587	3.5 (3.0, 4.5)	4900 (4098, 5760)	563	8.5	18,186	608	772	1709	4.0 (3.8, 4.4)	7949 (7673, 8244)	
3–4	870	4.0 (3.5, 5.0)	4200 (3415, 4991)	1150	9.2	20,202	907	742	2826	5.0 (4.8, 5.3)	9752 (9511, 9996)	
≥5	2440	5.0 (4.5, 5.5)	4373 (3791, 4965)	6946	11.9	24,870	3017	660	11,599	8.2 (8.1, 8.3)	15,985 (15,862, 16,109)	
Total	32,326	6.0 (6.0, 6.0)	8188 (7890, 8488)	69,042	10.5	21,748	47,480	691	141,625	6.5 (6.5, 6.5)	12,703 (12,635, 12,771)	

^a CCI: Charlson Comorbidity Index.

^b Additional LOS and costs due to SSC during the index admission were calculated using the Wilcoxon Signed Rank Test in the matched pairs of patients with and without SSCs.

^c Cohort averaged SSC LOS = incremental LOS due to SSC during index admission * (the percentage of SSCs occurring during the index admission) + readmission LOS * (the percentage of SSCs resulting in a readmission).

^d Cohort averaged SSC Costs = incremental cost of an SSC during index admission * (the percentage of SSCs occurring during the index admission) + cost of SSC-related readmission * (the percentage of SSCs resulting in a readmission) + cost of SSC-related outpatient visit * (the percentage of SSCs resulting in an outpatient visit).

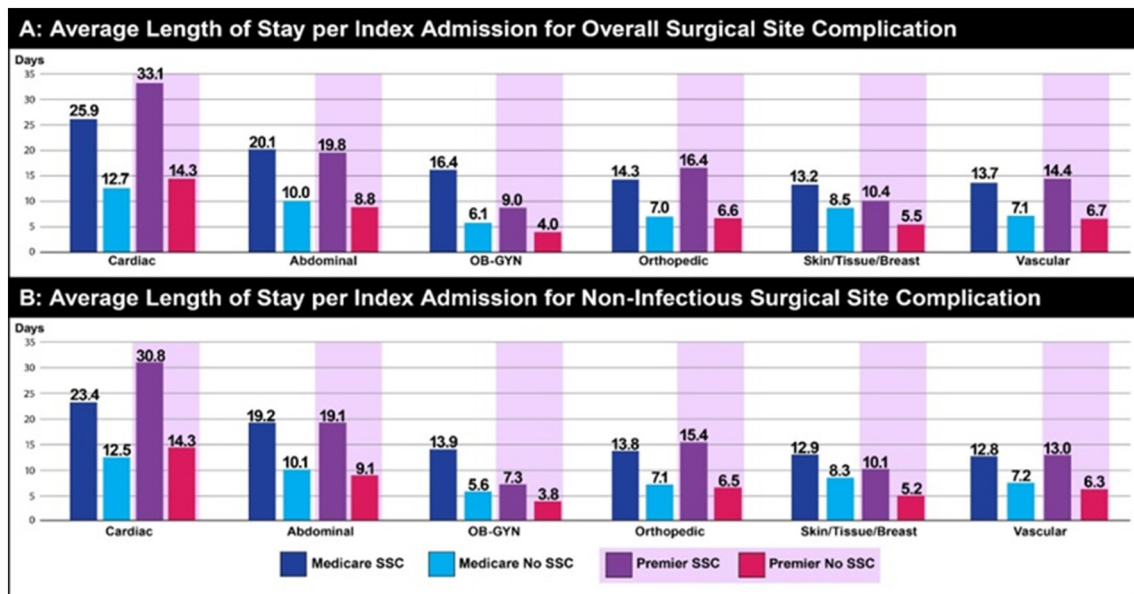


Fig. 2. Differences in length of stay for Medicare and Premier patients with and without surgical site complications.

readmission LOS generally increased with increasing comorbidity levels. The mean costs of an SSC-related readmission were \$23,058. A total of 54,355 Premier patients had outpatient visits related to SSCs. The average additional cost of an outpatient visit was \$2106. Of the 91,951 Premier patients with a non-infectious SSC during the index admission or within 90 days following discharge, 38,290 (41.6 %) patients were readmitted for a non-infectious SSC with a mean LOS of 8.7 days. The mean costs of an SSC-related readmission were \$22,272. A total of 43,782 Premier patients had outpatient visits related to non-infectious SSCs. The average additional cost of an outpatient visit was \$2065.

In total, the average incremental LOS for the 124,303 Premier patients who experienced any SSC during the index admission or within 90 days of discharge was 6.2 days (95 % CI: 6.2–6.2) which included additional LOS incurred during the index admission and LOS from SSC-related readmissions. The average cost per SSC for these 124,303 patients was \$17,196 (95 % CI: \$17,060–17,333), which included the

additional costs incurred during the index admission due to SSC and SSC-related readmissions and outpatient visits. In total, the average incremental LOS for the 91,951 Premier patients who experienced a non-infectious SSC during the index admission or within 90 days of discharge was 5.2 days (95 % CI: 5.2–5.2). The average cost per non-infectious SSC for these 91,951 patients was \$14,477 (95 % CI: \$14,332–14,625). Details regarding SSI rates by surgical type and CCI score and their impact on LOS and costs in these populations were reported in a previous publication [5].

Discussion

This retrospective analysis of patients undergoing open surgical procedures in the United States in 2019–2020 utilizing two large national databases provides strong and consistent evidence that SSCs, particularly non-infectious SSCs, are still common and result in significant

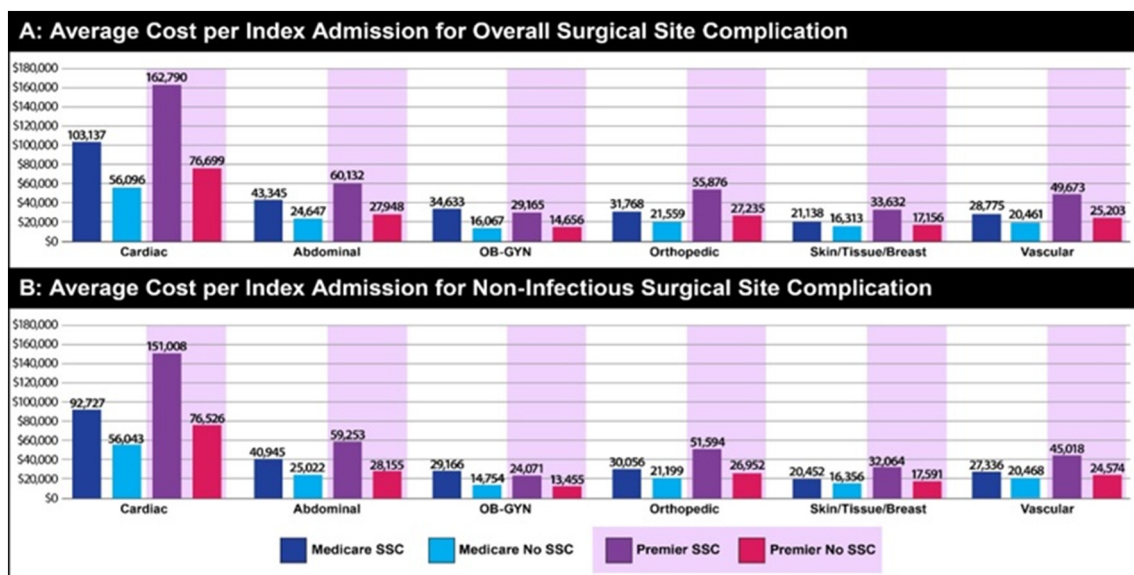


Fig. 3. Differences in index admission cost for Medicare and Premier patients with and without surgical site complications.

Table 7
Additional length of stay (LOS) and costs attributable to overall and non-infectious surgical site complications for Premier patients.

Surgery category by CCI ^a level		Additional LOS & costs due to SSC during the index admission ^b		SSC readmission LOS & costs		SSC outpatient visit cost		Cohort averaged SSC LOS ^c and costs ^d (includes index admission, readmissions, and outpatient visits)	
	n	Added LOS (95 % CI)	Added costs (\$)(95 % CI)	n	Added LOS	Added costs (\$)	n	Added LOS per SSC (95 % CI)	Added costs (\$ per SSC (95 % CI)
Overall SSC									
Cardiac	7995	13.5 (12.5, 14.0)	53,724 (51,052, 56,458)	7492	10.8	29,623	5244	18,465	35,826 (34,669, 37,010)
0	554	20.5 (17.5, 23.5)	79,919 (67,446, 92,785)	180	9.0	23,375	223	894	54,530 (46,800, 62,502)
1–2	1952	11.5 (10.5, 13.0)	45,655 (41,027, 50,552)	1255	8.9	24,544	1243	4096	29,776 (27,571, 32,110)
3–4	2007	12.5 (11.5, 14.0)	51,931 (46,940, 57,117)	1635	9.7	27,151	1257	4385	34,398 (32,113, 36,771)
≥5	3482	13.5 (13.0, 14.5)	55,893 (51,621, 60,323)	4422	11.7	32,233	2521	9090	37,701 (36,064, 39,398)
Abdominal									
0	8299	9.5 (9.5, 10.0)	24,778 (23,965, 25,607)	8348	8.1	18,675	8127	21,877	17,142 (16,834, 17,456)
1–2	1775	8.5 (8.0, 9.0)	18,935 (17,554, 20,380)	1588	6.3	14,237	2106	4955	11,924 (11,429, 12,442)
3–4	2573	9.5 (9.0, 9.5)	23,479 (22,131, 24,851)	2419	7.2	16,365	2743	6825	15,313 (14,805, 15,830)
≥5	1527	10.5 (10.0, 11.0)	29,316 (27,166, 31,552)	1446	8.7	20,377	1289	3724	20,561 (19,679, 21,477)
OB-GYN	2424	10.5 (10.0, 11.0)	28,200 (26,530, 29,922)	2895	9.4	22,189	1989	6373	21,397 (20,762, 22,052)
0	1533	3.5 (3.5, 4.0)	7317 (6424, 8295)	1856	6.2	14,608	3736	6499	6630 (6419, 6860)
1–2	893	2.0 (1.5, 2.0)	3481 (2946, 4065)	713	4.4	10,043	2053	3428	3596 (3456, 3748)
3–4	89	4.5 (3.5, 5.5)	8991 (7002, 11,253)	503	5.3	12,192	1071	1737	6123 (5724, 6576)
≥5	203	11.0 (9.5, 12.5)	30,025 (24,441, 36,592)	208	6.2	14,975	239	473	12,684 (11,402, 14,275)
Orthopedic									
0	5331	7.5 (7.5, 8.0)	27,360 (20,547, 35,811)	432	10.4	24,777	373	861	20,532 (19,215, 22,080)
1–2	971	6.0 (5.0, 6.5)	19,534 (18,511, 20,589)	4165	6.4	23,440	5036	53,221	16,173 (16,070, 16,278)
3–4	1379	7.0 (6.5, 7.5)	14,938 (12,861, 17,137)	6551	7.5	17,629	5949	9406	10,425 (10,211, 10,652)
≥5	1017	8.0 (7.5, 9.0)	18,415 (16,615, 20,309)	5749	8.4	21,198	5148	12,649	13,649 (13,452, 13,855)
Skin/tissue/breast									
0	1964	9.0 (8.5, 10.0)	22,152 (20,260, 24,107)	13,304	10.9	27,682	8588	20,605	14,723 (14,499, 14,958)
1–2	1439	3.5 (3.0, 4.0)	11,330 (10,159, 12,566)	5216	8.0	18,321	8642	13,691	21,104 (20,924, 21,291)
3–4	319	3.0 (2.5, 4.0)	7614 (5785, 9606)	893	5.5	12,570	2624	3326	9526 (9403, 9656)
≥5	462	2.5 (2.0, 3.5)	10,021 (8077, 12,154)	1306	7.0	15,947	2769	4094	5264 (5088, 5455)
Vascular									
0	274	3.5 (2.5, 5.0)	13,135 (10,222, 16,305)	1077	8.7	18,904	1527	2528	10,783 (10,468, 11,127)
1–2	384	5.0 (4.0, 6.5)	15,240 (12,661, 17,981)	1940	9.5	22,252	1974	3743	14,641 (14,376, 14,922)
3–4	2171	6.0 (5.5, 6.5)	14,483 (13,174, 15,849)	5929	9.8	25,818	3885	10,550	18,325 (18,056, 18,607)
≥5	26	12.5 (7.5, 23.0)	40,474 (16,278, 73,172)	53	7.2	17,328	74	138	15,242 (10,684, 21,403)
1–2	482	5.0 (4.0, 6.0)	10,800 (8581, 13,314)	763	8.0	21,125	686	1752	12,993 (12,382, 13,684)
3–4	543	5.0 (4.5, 6.0)	13,725 (11,359, 16,236)	1133	8.8	22,613	957	2336	15,136 (14,586, 15,720)
≥5	1120	6.5 (6.0, 7.5)	16,207 (14,183, 18,318)	3980	10.5	27,744	2168	6324	21,115 (20,756, 21,488)
Total	26,768	9.0 (9.0, 9.0)	25,089 (24,460, 25,728)	58,610	9.0	23,058	54,355	124,303	17,196 (17,060, 17,333)

Non-infectious SSC	Cardiac	6179 435 1566 1561 2617 3837 784 1181 738 1134 1267 831 282 54 100 4291 801 1070 810 1610 1304 290 431 248 335 1811 18 411 454 928 18,689	11.0 (10.5, 11.5) 16.0 (13.0, 19.5) 9.0 (8.0, 10.0) 10.5 (9.5, 11.5) 11.5 (11.0, 12.5) 8.5 (8.0, 9.0) 6.5 (6.0, 7.5) 8.0 (7.5, 8.5) 9.5 (8.5, 10.5) 9.5 (8.5, 10.0) 2.5 (2.0, 2.5) 1.5 (1.5, 2.0) 3.0 (2.5, 4.0) 10.0 (6.0, 15.5) 10.0 (7.5, 12.5) 7.0 (6.5, 7.5) 4.5 (4.0, 5.0) 6.0 (5.5, 6.5) 7.0 (6.5, 8.0) 9.0 (8.0, 9.5) 3.0 (2.5, 3.5) 2.0 (1.5, 3.0) 2.5 (2.0, 3.0) 4.0 (3.0, 6.0) 4.0 (2.5, 5.5) 5.5 (5.0, 6.0) 11.0 (5.5, 26.0) 4.0 (3.0, 5.0) 4.5 (4.0, 5.5) 6.5 (5.5, 7.0) 7.5 (7.5, 7.5)	43,661 (40,922, 46,474) 61,629 (49,377, 75,489) 34,091 (29,363, 39,228) 42,054 (37,211, 47,160) 48,052 (43,439, 52,903) 22,679 (21,441, 23,938) 15,327 (13,309, 17,467) 20,918 (18,918, 23,024) 27,933 (24,990, 31,059) 27,104 (24,358, 29,926) 4851 (4202, 5558) 3033 (2519, 3567) 5989 (4390, 7845) 30,741 (19,029, 47,400) 29,644 (21,866, 38,091) 16,524 (15,517, 17,561) 11,007 (9021, 13,154) 14,927 (13,229, 16,776) 16,690 (14,588, 18,897) 20,638 (18,698, 22,665) 9785 (8664, 10,977) 6387 (4545, 8347) 9235 (7488, 11,039) 13,416 (10,315, 16,994) 11,609 (8993, 14,486) 13,064 (11,741, 14,434) 33,864 (7702, 87,679) 8722 (6740, 11,062) 12,016 (9892, 14,303) 15,370 (13,263, 17,561) 20,761 (20,046, 21,489)	4529 95 668 963 2803 3516 514 943 648 1411 892 412 224 75 181 20,913 2273 3888 4155 10,597 4384 754 1090 900 1640 4056 30 459 724 2843 38,290	9.6 7.5 8.1 8.7 10.4 7.8 5.9 6.9 7.2 9.2 5.4 4.1 4.7 5.8 9.2 8.8 5.6 6.9 8.0 10.5 8.0 5.6 6.9 9.0 9.4 9.6 7.1 7.7 8.7 10.2 8.7	26,089 21,221 22,367 23,424 28,058 18,384 13,556 15,437 18,526 22,043 13,203 9565 11,829 15,650 22,171 22,698 15,868 18,619 19,742 26,816 18,250 12,483 15,683 19,394 21,990 25,522 15,564 19,914 22,038 27,420 22,272	3956 175 953 953 1875 5379 1395 1778 868 1338 2973 1706 851 164 252 20,320 3871 4386 7409 8021 2242 2569 1401 1809 3133 59 550 757 1767 43,782	1822 1072 1476 1715 2122 1486 1165 1428 1580 1837 1160 898 1192 1615 2542 2352 1899 2128 2429 2685 2109 1591 1993 2171 2867 2248 1766 2098 2384 2253 2065	13,554 675 3036 3216 6627 11,756 2556 3604 2045 3551 4804 2800 1261 262 481 41,271 6634 17,204 12,419 3073 2267 3342 8147 99 1333 1769 4946 91,951	8.2 (8.0, 8.5) 11.4 (9.4, 13.6) 6.4 (5.9, 6.9) 7.7 (7.2, 8.2) 8.9 (8.7, 9.3) 5.1 (5.0, 5.3) 3.2 (3.0, 3.5) 4.4 (4.3, 4.6) 5.9 (5.6, 6.3) 6.7 (6.4, 6.8) 1.7 (1.5, 1.7) 1.0 (1.0, 1.2) 1.5 (1.4, 1.7) 3.7 (2.9, 4.9) 5.5 (5.0, 6.1) 5.2 (5.1, 5.2) 2.5 (2.4, 2.5) 3.7 (3.6, 3.8) 4.6 (4.5, 4.7) 7.3 (7.2, 7.4) 3.1 (3.1, 3.2) 1.6 (1.5, 1.7) 2.3 (2.3, 2.4) 4.0 (3.9, 4.2) 5.0 (4.8, 5.1) 6.0 (5.9, 6.1) 4.2 (3.2, 6.9) 3.9 (3.6, 4.2) 4.7 (4.6, 5.0) 7.1 (6.9, 7.2) 5.2 (5.2, 5.2)	29,153 (27,905, 30,436) 42,981 (35,086, 51,913) 22,969 (20,530, 25,619) 27,935 (25,584, 30,413) 31,444 (29,622, 33,359) 13,580 (13,176, 13,991) 8063 (7444, 8720) 11,598 (10,943, 12,288) 16,621 (15,559, 17,750) 18,107 (17,230, 19,008) 4449 (4278, 4635) 2855 (2702, 3013) 4245 (3887, 4660) 11,827 (9413, 15,261) 15,838 (14,221, 17,594) 14,378 (14,273, 14,485) 7874 (7634, 8133) 10,939 (10,737, 11,159) 12,568 (12,367, 12,780) 19,606 (19,424, 19,795) 8832 (8714, 8957) 4827 (4653, 5012) 7010 (6808, 7218) 10,509 (10,169, 10,900) 13,507 (13,244, 13,795) 16,475 (16,181, 16,779) 11,926 (7169, 21,710) 10,412 (9801, 11,133) 13,123 (12,578, 13,710) 19,450 (19,055, 19,861) 14,477 (14,332, 14,625)
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^a CCI: Charlson Comorbidity Index.

^b Additional LOS and costs due to SSC during the index admission were calculated using the Wilcoxon Signed Rank Test in the matched pairs of patients with and without SSCs.

^c Cohort averaged SSC LOS = incremental LOS due to SSC during index admission * (the percentage of SSCs occurring during the index admission) + readmission LOS * (the percentage of SSCs resulting in a readmission).

^d Cohort averaged SSC Costs = incremental cost of an SSC during index admission * (the percentage of SSCs occurring during the index admission) + cost of SSC-related readmission * (the percentage of SSCs resulting in a readmission) + cost of SSC-related outpatient visit * (the percentage of SSCs resulting in an outpatient visit).

increases in LOS and health care costs. Although many studies have provided evidence of the deleterious effects of SSIs, this study is one of the first to examine the incidence of overall SSCs and non-infectious SSCs at a national level and the impact of these complications on health care utilization across surgical procedures. Overall SSC rates were approximately 7 % in both the Medicare (7.3 %) and Premier (6.7 %) populations. In both the Medicare and Premier populations, approximately 5 % of patients had non-infectious SSCs while about 2 % experienced SSIs. The most common non-infectious SSCs were skin complications ($\approx 62\%$), followed by dehiscence (22–24 %) and non-healing wounds ($\approx 23\%$) in both populations. Non-infectious SSC rates varied by surgical category, ranging from 2.9 % - 20.6 % across all surgical categories but were highest for skin, subcutaneous tissue, and breast surgeries for both Medicare (20.6 %) and Premier (17.0 %) patients. Across surgical categories, rates of overall SSCs and non-infectious SSCs and SSC-associated LOS and costs tended to increase with increasing levels of CCI scores. Overall, Medicare and Premier patients with SSCs experienced a 7.8 and 6.2 day increase in average LOS and increased costs of \$15,339 and \$17,196 respectively compared to patients who did not experience an SSC. Medicare and Premier patients with non-infectious SSCs experienced a 6.5 and 5.2 day increase in average LOS and increased costs of \$12,703 and \$14,477 respectively compared to patients who did not experience any SSC.

Extrapolating the average impact of SSCs across the 196,404 Medicare and 124,303 Premier patients who experienced a SSC results in more than additional 1.5 million and 770,678 in hospital days and more than \$3 billion and \$2.1 billion in potentially avoidable costs to the respective health systems over two years (including one year impacted by COVID-19). Approximately 920,562 and 478,145 of these visits and \$1.3 billion and \$1.8 billion of these potentially avoidable costs can be attributed to non-infectious SSCs in the Medicare and Premier populations respectively. Given that PHD represents approximately 25 % of annual inpatient admissions in the United States, the annual impact of SSCs nationally can be estimated as >1.5 million additional hospital days and almost \$4.3 billion in additional healthcare costs, with 956,290 additional hospital days and over \$ 2.6 billion in additional costs attributed to non-infectious SSCs.

Although this study is one of the first to examine overall and non-infectious SSC rates at a national level and to stratify risk of SSCs by both surgery type and level of comorbidities, our findings that SSCs are not uncommon and result in increased LOS and health care costs were consistent across two patient populations and were similar to studies that examined the impact of SSIs as well as the smaller studies that investigated the impact of SSCs. In a large study utilizing 2005 hospital stay data from the Healthcare Cost and Utilization Project's Nationwide Inpatient Sample, de Lissoy et al. found that 1 % of patients experienced an SSI and that SSIs extended LOS by 9.7 days while increasing costs by \$20,842 per admission and resulted in 91,613 SSI-related readmissions that accounted for an additional 521,933 days of care at a cost of nearly \$700 million [1]. A recent retrospective comparative cohort study examining SSCs, including both non-infectious complications and superficial SSIs, in Medicare patients undergoing elective total joint arthroplasty at a large, urban medical center found that 7.1 % of patients developed SSCs, and these patients had a statistically significant increase in post-discharge costs of \$5349 compared to patients who did not experience SSCs [6].

In our study examining the impact of SSIs on LOS and costs in the same population of Medicare and Premier patients, we found that SSI rates were approximately 2 % and were associated with a 9.3 and 7.8 day increase in average LOS and increased costs of \$18,626 and \$20,979, respectively [5]. Although SSIs were relatively uncommon, they had a detrimental effect on both patient recovery and costs to patients and payors. By expanding this work to include non-infectious SSCs, we demonstrate that these potentially avoidable complications are more common, effecting approximately 5 % of all open surgeries and 8 % of emergency and urgent surgeries. Although SSIs were

associated with longer LOS and higher costs than non-infectious SSCs in general, non-infectious SSCs, which were much more prevalent, had a profound impact on LOS and costs. Given the transition to bundled payment models, such as the Comprehensive Care for Joint Replacement model, where hospitals are financially responsible for the 90-day post-operative period and share financial risk based upon the difference between episode-of-care costs and predetermined targets, high rates of preventable SSCs could negatively impact hospital reimbursement [6].

SSCs also negatively impact patients beyond increased time spent in hospitals and increased health care costs. SSCs can result in increased pain and morbidity and can have damaging economic consequences for patients in terms of lost work and wages. For instance, O'Hara et al. found that postoperative infections were associated with a \$6080 annual decrease in household income in the 6 years after injury and a 6.6 % increase in the risk of catastrophic wage loss within 2 years [23].

The observed incidence of SSCs, particularly non-infectious SSCs, and their detrimental impact on patient health, health care utilization, and health care costs in this study establishes the need for adoption of evidence-based interventions that have been shown to be effective in reducing SSIs and non-infectious SSCs and related complications. These interventions include smoking cessation, preoperative medical nutrition and diabetes management, preoperative chlorhexidine wipes, appropriate antibiotic use, meticulous surgical technique, attentive postoperative monitoring, modern wound closure dressings, and closed-incision negative pressure therapy [6,7,24–29]. While there is growing evidence for the use of these interventions to improve patient care, including guidelines from the World Union Wound Healing Society (WUWHS) suggesting that improving patient outcomes through the reduction of SSCs could significantly impact patient lives and societal and healthcare costs, there has not been widespread implementation and uptake [30]. This study enumerates overall and non-infectious SSC rates by surgery type and patient comorbidity level and pinpoints possible surgical categories where implementation of these interventions may have the greatest impact on improving patient care and outcomes. Some SSCs may be unavoidable, particularly in emergency and urgent procedures, which represent 40 % of the surgeries in this analysis, but improvement in SSC rates, particularly for elective surgeries may be achieved with targeted quality improvement efforts. Although some of the interventions for reducing SSCs are costly, they may be cost-effective or even generate cost savings given the negative consequences of infectious and non-infectious SSCs quantified by this study.

Limitations. Given that this study was a retrospective study, it has many inherent limitations, including the inability to adjust for unobserved covariates. The study was limited to selected open procedures. Claims for services provided by noninstitutional providers were only available for 5 % of the Medicare population. In addition, outpatient SSC-related visits were limited to outpatient hospital visits for Premier patients. Thus, this study may underestimate the impact of SSCs on costs of outpatient visits. The study only captured SSCs documented in ICD-10s and select DRGs, so rates of SSCs may be underreported. We were unable to determine which SSCs were potentially avoidable. Despite these limitations, this study provides a comprehensive overview of current SSC rates and a benchmark for evaluating the effectiveness and cost-effectiveness of interventions to reduce these complications.

Conclusions

The results of this study indicate that SSCs, particularly non-infectious SSCs, are not uncommon for patients undergoing open surgeries and result in additional care and substantial costs. These findings demonstrate the need for implementation and increased adoption of interventions and strategies for reducing SSCs and mitigating their impact on patient recovery after surgery.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.sopen.2023.05.004>.

Funding

No external funding was received for this work.

Ethical approval statement

This study involved de-identified data and was therefore exempt from IRB approval.

CRediT authorship contribution statement

Yuefeng Hou: Investigation, Conceptualization, Methodology, Formal analysis, Validation, Data curation, Writing – review & editing, Visualization. **Ashley Collinsworth:** Conceptualization, Writing – original draft, Writing – review & editing, Visualization. **Flutura Hasa:** Conceptualization, Writing – review & editing. **Leah Griffin:** Conceptualization, Writing – review & editing, Supervision.

Declaration of competing interest

Yuefeng Hou, Ashley Collinsworth, Flutura Hasa, and Leah Griffin are employees of 3M.

Acknowledgements

The authors would like to thank Julie M. Robertson, PhD (3M) for editorial support.

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