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Open surgical incisions after colorectal surgery improve quality metrics, but do patients benefit?

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Abstract

Background—Surgical site infection is a frequent cause of morbidity after colorectal resection, and is a quality measure for hospitals and surgeons. In an effort to reduce the risk of postoperative infections, many wounds are left open at the time of surgery for secondary or delayed primary wound closure.

Objective—Evaluate the impact of delayed wound closure on the rate of surgical infections and resource utilization.

Design—This retrospective propensity matched study compared colorectal surgery patients with wounds left open with a cohort of patients with primary skin closure.

Settings—The American College of Surgeons National Quality Improvement Program Participant Use file for 2014 was queried.

Patients—50,212 patients who underwent elective or emergent colectomy, proctectomy, and stoma creation were included.

Main Outcome Measures—Rates of postoperative infections and discharge to medical facilities.

Results—Surgical wounds were left open in 2.9% of colorectal cases (n=1,466). Patients with skin left open were broadly higher-risk, as evident by a significantly higher median estimated probability of 30-day mortality (3.4% vs 0.45%, $p<0.0001$). After propensity matching (n=1,382 per group), there were no significant differences between baseline characteristics. Within the matched cohort, there were no differences in the rates of 30-day mortality, deep or organ space infection, or sepsis (all $p>0.05$). Resource utilization was higher for patients with incisions left open including longer length of stay (11 vs 10 days, $p=0.006$) and higher rates of discharge to a facility (34% vs 27%, $p<0.001$).

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Category: Socioeconomic issues.

Limitations—This study was limited by its retrospective design, and a large dataset with a bias toward academic institutions

Conclusions—In a well-matched colorectal cohort, secondary or delayed wound closure eliminates superficial surgical infections, but there was no decrease in deep or organ space infections. Additionally, attention should be given to the possibility for increased resource utilization associated with open surgical incisions. See **Video Abstract** at <http://links.lww.com/DCR/Axxx>.

Keywords

Colorectal surgery; Delayed primary closure; Delayed wound closure; Quality metrics; Surgical site infections

Surgical site infection (SSI) is among the most common nosocomial infections and is a frequent and costly complication following colorectal surgery.¹ SSI is categorized by the American College of Surgeons National Quality Improvement Program (ACS NSQIP) by the depth of the infection. For colorectal patients, incisional SSI is divided into either superficial or deep, while organ space SSI are infections below the fascia. SSI has been linked to significant increases in postoperative morbidity.² Rates of SSI following colorectal surgery range from 5% to 30% and are widely implicated as a hospital quality metric.^{3, 4}

Many patient and operative factors affect the rate of SSI in colorectal surgery, and incision closure following resection has been implicated as an important factor. Delayed wound closure is a method of leaving a contaminated surgical wound open at the end of an operation to be closed at a later date (delayed primary closure) or left to close by secondary intention. Both methods are employed to minimize the risk of SSI, and have proven to be efficacious.⁵⁻⁷ Delayed wound closure techniques were initially developed by trauma surgeons performing exploratory laparotomy in contaminated surgical fields, but are now utilized by other surgical disciplines including colorectal surgery, cardiothoracic surgery, gynecology, and emergency general surgery when the surgical field appears contaminated. While leaving wounds open may be effective in reducing SSI risk, these techniques hold other disadvantages for patients including pain with dressing changes and potential need for wound closure at a later date.

Prior studies have compared SSI rates in primary vs. delayed wound closure.⁸ However, no prior study has examined the impact of wound closure on surgical outcomes in a large, national dataset. The objective of this study was to determine the impact of leaving a surgical wound open at the time of an index operation on postoperative outcomes. We hypothesized that although delayed wound closure may decrease rates of superficial SSI, thus improving a carefully tracked quality metric, these techniques may actually increase resource utilization associated with care for these wounds. Therefore, there are likely to be unintended consequences of leaving wounds open that are not so easily quantified and tracked in comparison to simply measuring the rate of superficial SSI.

Methods

Dataset

Patient records for colorectal cases including laparoscopic and open colectomy, proctectomy and stoma creation were obtained using the 2014 ACS NSQIP Participant Use File (ACS NSQIP PUF). This included 50,212 patients from 517 participating hospitals. The ACS NSQIP PUF is a robust nationwide dataset designed for surgical quality improvement and the methodology and risk stratification are described elsewhere.⁹

Patients

A total of 50,212 patients were identified by CPT codes including 45,239 colon and 4,973 rectal resections. Of these 1,734 patients also underwent stoma creation. Patients with fascia left open were excluded due to small sample size and extent of baseline differences from the remaining patients. Both elective and emergent cases were included. Patients were stratified by wound closure classification, either skin closed or skin open with fascia closed. Preoperative variables included patient demographics, preexisting medical comorbidities, laboratory results and operative characteristics. The estimated probabilities of morbidity and mortality are calculated and provided within the dataset. Postoperative variables included standard complications as well as resource utilization measures. Information on superficial SSI is not collected for open wounds and therefore comparisons to closed wounds are made based on the principle that an open wound cannot have a superficial SSI.

Statistical Analyses

Unadjusted comparisons by wound closure classification were performed using Pearson chi-square test for categorical variables and the Mann-Whitney test for continuous data. Propensity score matching utilized a logistic regression model with demographic, comorbidities, and operative covariates selected *a priori* (supplemental Table 1). Patients were then matched in a 1 to 1 fashion without replacement using a nearest neighbor algorithm from the *psmatch2* package. Within the matched cohort, comparisons as a function of wound closure classification were again performed using Pearson chi-square or Mann-Whitney tests, as appropriate. Statistical calculations were performed using STATA (StataCorp, College Station, TX). Statistical significance was set at an $\alpha = 0.05$.

Results

Prior to propensity matching, the unadjusted superficial SSI rate was 5.7% ($n = 2,777$) for those with their skin closed. The unadjusted rates of deep SSI were 1.6% ($n = 768$) compared to 2.46% ($n = 36$) for patients with skin closed versus left open. Similarly organ space SSI rate was 5.2% ($n = 2,519$) versus 11.3% ($n = 166$) for patients with skin closed versus open. The unadjusted preoperative and operative characteristics are described in Table 1. The results are notable for the widespread significant differences between the two groups where patients with their skin left open are sicker with higher ASA and estimated probabilities of morbidity and mortality, all $p < 0.001$. The only variables not statistically different between unmatched groups are age and sex.

Following propensity matching, within the matched cohort, the superficial SSI rate was 8.7% (n = 120) for those with their skin closed. The rates of deep SSI after matching based on preoperative patient demographics were equivalent at 3.3% (n = 45) and 2.4% (n = 33) for patients with skin closed versus left open, p = 0.168. The organ space SSI rates were also equivalent at 11.1% (n = 154) and 11.6% (n = 160) with skin closed versus open, p = 0.719. The preoperative and operative characteristics for the matched cohort are listed in Table 2. The two groups of skin closed versus left open were well matched with no significantly different baseline variables. Ostomy creation was equivalent between the matched groups. The median estimated risk of mortality among the matched cohorts was 3.4% (IQR 0.9%-14.2%) versus 3.5% (IQR 0.9%-13.7%) for patients with skin closed and left open, p = 0.533. Similarly the median estimated risk of morbidity was 30.1% (IQR 20.5%-43.9%) versus 30.9% (IQR 20.9%-44.3%) for patients with skin closed and left open, p = 0.579.

Within the entire dataset, comparisons demonstrate that the patients with their skin left open were not only sicker but also suffered more frequent complications. This included statistically higher rates of 30-day mortality, deep and organ space SSI, dehiscence, sepsis, reintubation, pulmonary embolism, acute renal failure requiring dialysis, stroke, unplanned reoperation, cardiac arrest, myocardial infarction, transfusion, DVT, hospital length of stay and discharge location to a facility prior to propensity matching (all p<0.05, Table 3). Within the matched cohort, postoperative events were similar between groups except for reintubation, hospital length of stay and discharge to a facility. The reintubation rate of 5.1% (n = 70) in patient's whose skin was closed versus 8.1% (n = 112) in those left open. The median hospital length of stay for patients with their skin closed was 10 days (IQR 6-17) compared to 11 (IQR 7-17) in those with their skin left open. Finally, the rate of discharge to a facility was 26.6% (n = 367) versus 34.2% (n = 471) for skin closed versus open.

Discussion

The purpose of this study was to assess the impact of delayed wound closure on outcomes following colorectal surgery. We found that patients who undergo delayed or secondary wound closure had greater preoperative medical comorbidity, substantially higher rates of wound contamination, much poorer health at baseline compared with those who undergo primary closure of their surgical wounds. Although all factors which lead to delayed wound closure by each surgeon could not be accounted for, to best account for baseline differences in patient demographics and preoperative comorbidities, we performed propensity matched risk adjustment to evaluate the impact of wound closure on postoperative outcomes and healthcare utilization.

Within the matched cohort, we found that patients whose wounds are left open after surgery have a longer postoperative length of stay and are more likely to be discharged to a medical facility following their index hospitalization (34.1% vs 26.6%). They also demonstrated a statistically higher rate of reintubation (8% vs 5%). The reason for this is likely multifactorial and related to worse pain in those with open wounds, more medical comorbidities, as well as higher levels of surgical complexity persuading the surgeon to leave the skin open.

Several disciplines within general surgery are evaluating the impact of delayed wound closure on infection. This includes clinical trials evaluating the efficacy of delayed wound closure for complicated appendicitis cases are currently ongoing (NCT01659983).¹⁰ Delayed wound closure for traumatic injuries remains controversial. The Cochrane group has examined this issue, feels more research is necessary, and has made no consensus statements regarding traumatic wounds, which present within 24 hours of injury.¹¹

In addition to delayed closure, other factors impact SSI within colorectal surgery. Watanabe et al performed a retrospective analysis to evaluate risk factors for SSI in emergency colorectal operations.¹² They found wound class III/IV and obesity to be independent predictors of SSI and concluded that delayed primary or secondary wound closure should be considered in cases of generalized wound contamination.¹² In the present study, nearly 15% of wounds classified as clean and clean-contaminated were left open. This is most likely the result of incorrect documentation by operating room staff, and miscoding by the NSQIP reporter, as has been previously shown.¹³ This can be improved with better communication regarding wound classification between surgeons and operating room nurses. Pendlimari et al found that diagnosis and reason for colorectal resection heavily impacts the rates of SSI, with rectal cancer resection patients having the highest rates of superficial, deep and organ space SSI. The authors concluded that disease processes must be considered when institutional SSI rates are utilized as a quality metric.¹⁴ Several recent investigators have confirmed that laparoscopy has substantially reduced rates of SSI when compared with open colorectal resection.¹⁵⁻¹⁷

While the possibility of superficial SSI is eliminated when wounds are left open at the time of surgery, there were no differences within the matched cohort for rates of deep incisional or organ space SSI. Organ space infections occur due to anastomotic leak and dehiscence, which should not be related to postoperative skin closure. One advantage of leaving a wound open is to prevent a deep incisional infection involving the fascia and subcutaneous tissues, which can contribute to further wound break down and either wound dehiscence or the creation of an incisional hernia.¹⁸ However, our data suggests that leaving the wounds open did not, in fact, impact the overall rate of deep incisional infections, negating the most significant advantage of leaving a wound open. If this is true then leaving a wound open may, in fact, increase wound care costs without impacting long-term outcomes such as ventral hernia.

The identification of increased resource utilization is limited by the NSQIP dataset. The impact on healthcare cost extends beyond increased length of stay and discharge to medical facilities. Patient with open surgical wounds typically require daily packing and dressing changes, oftentimes requiring either home health nursing or discharge to a nursing facility for wound care. These patients were found to have more medical comorbidities at baseline, which increases the likelihood they will require discharge to a transitional medical facility prior to returning home. Additionally, negative pressure wound vacuum devices are frequently used in patients with large open wounds. These devices increase the cost of care to patients and hospital systems and almost invariably require additional home healthcare nursing. Cost analyses were not able to be performed in this study, but include an important area for future research. Prolonged wound care needs are also likely to impact the next phase

of care, including patients returning to normal activities or for ongoing medical needs, such as chemotherapy, all of which are likely delayed by open wounds.¹⁹ Finally, ongoing wound care is also likely to have significant impact on the patient experience, including the emotional impact on both the patient and family members who are often asked need to provide local wound care. Measuring the emotional impact of these long care issues are difficult to completely quantify but should not be trivialized.²⁰

This study is inherently limited by the ACS NSQIP dataset, limited procedures abstracted, limited participation across many diverse medical centers nationally, and limitations in variable capture. NSQIP has designated personnel at each center specifically trained to review the medical record and document specific patient related characteristics and outcomes, however diversity across hospital systems may limit the generalizability of our findings. The definition of superficial, deep, and organ space wound infection is clearly defined in the NSQIP protocol, and is used by all participating NSQIP centers. Although the definition is standardized across the dataset, there clearly exists heterogeneity in what is considered and documented as a wound infection in the medical chart, which is at the discretion of each patient's healthcare providers, as has been previously shown.²¹ Negative pressure wound therapy (eg wound vac) techniques are commonly used in cases where delayed/secondary wound closure is employed, but this information was not available in the dataset. Delayed wound closure was much more commonly performed in patients with worse underlying medical conditions including the presence of preoperative sepsis, and those with contaminated/dirty wounds, therefore interpretations of direct comparison are limited to the matched cohort and care should be taken when extrapolating these findings. Additionally, since patients who underwent delayed wound closure had more comorbidities at baseline, these factors contribute to patient discharge to medical facilities. Important areas for further investigation include prospective, randomized studies examining the true impact of delayed wound closure on hospital length of stay and discharge to medical facilities. A comparison of delayed primary closure versus wound closure by secondary intention with negative pressure wound therapy for contaminated and frankly dirty wounds is also warranted.

This study represents the first to evaluate the direct impact of primary vs. delayed/secondary wound closure on outcomes following colorectal surgery in a nationally representative dataset. In summary, while leaving a wound open may improve the overall rate of SSI by eliminating superficial SSIs, it may come at an increased cost to both the medical system and to the patient. In a well-matched cohort, delayed wound closure was not associated with decreased risk of deep incisional SSI, organ space SSI, or short-term morbidity and mortality. Delayed wound closure was associated with increased postoperative length of stay and need for discharge to a medical facility. Most importantly, improved understanding of the burden of delayed wound closure on patients and how open surgical wounds affect the patient experience has been under-assessed in the literature and must be explored. Beyond longer postoperative stays, open wounds likely lengthen patient time away from work and normal life activities due to the need for wound dressing changes, negative pressure vacuum therapy, and prolonged use of pain medication. The use of Patient Reported Outcome Measures (PROMs) would be an excellent method to further study this important issue. As currently constructed, surgeons may be incentivized to leave wounds open as quality metrics

focus solely on the rates of SSI. Since open wounds incur costs, whether opened due to an SSI or deliberately left open at the time of surgery, perhaps quality metrics should focus on the number of open wounds and not simply on SSI. This is particularly true if leaving the wound open does not seem to prevent a deep wound infection, as our data suggests.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Unadjusted demographics of patients undergoing colorectal surgery

Patient Characteristics	Skin Closed n = 48,746		Skin Open n = 1,466		p value
	n	(%)	n	%	
Age (median, IQR)	62	52.73	62	52.72	0.6837
Sex (female)	25,535	52.38	756	51.57	0.538
Weight in lbs (median, IQR)	170	142, 202	176	145, 214	<0.0001
Recent weight loss (>10%)	2,362	4.85	89	6.07	0.032
BMI (kg/m ² , median, IQR)	27.32	23.63, 31.76	28.34	24.01, 33.98	<0.0001
Smoker	8,471	17.38	327	22.31	<0.001
Congestive heart failure	590	1.21	32	2.18	0.001
Hypertension requiring medication	23,264	47.72	774	52.80	<0.001
COPD	2,701	5.54	142	9.69	<0.001
Dyspnea					<0.001
At rest	275	0.56	22	1.50	
With moderate exertion	2,866	5.88	95	6.48	
Diabetes					<0.001
Insulin dependent	2,467	5.06	126	8.59	
Non-insulin dependent	4,779	9.80	123	8.39	
Renal failure requiring dialysis	249	0.51	44	3.00	<0.001
Steroid	4,396	9.02	210	14.32	<0.001
Bleeding disorder	2,064	4.23	186	12.69	<0.001
Transfusion of >4 units within 72 hrs of surgery	1,550	3.18	87	5.93	<0.001
Preoperative Sepsis					<0.001
SIRS	1,504	3.09	82	5.59	
Sepsis	2,377	4.88	534	36.43	
Septic shock	710	1.46	182	12.41	
Existing wound infection or open wound	1,049	2.15	107	7.30	<0.001
Wound Class					<0.001
Clean	513	1.05	8	0.55	

Patient Characteristics		Skin Closed n = 48,746		Skin Open n = 1,466		p value
		n	(%)	n	%	
Clean contaminated		36,557	74.99	211	14.39	
Contaminated		5,991	12.29	236	16.10	
Dirty infected		5,685	11.66	1,011	68.96	
Functional Status						<0.001
Independent		46,737	95.88	1,322	90.18	
Partially dependent		1,393	2.86	100	6.82	
Totally dependent		362	0.74	30	2.05	
ASA Classification						<0.001
Class 1		1,264	2.59	21	1.43	
Class 2		20,164	41.37	301	20.53	
Class 3		23,438	48.08	719	49.05	
Class 4		3,654	7.50	378	25.78	
Class 5		174	0.36	47	3.21	
Estimated probability of morbidity (median, IQR)		14.00	9.25, 21.63	30.63	20.62, 44.28	<0.0001
Estimated probability of mortality (median, IQR)		0.45	0.16, 1.47	3.42	0.86, 13.65	<0.0001
Preoperative laboratory values						
Creatinine		0.86	0.70, 1.03	0.90	0.70, 1.30	<0.0001
Bilirubin		0.5	0.3, 0.7	0.6	0.4, 1.0	<0.0001
White blood cell count		7.3	5.8, 9.5	10.7	7.2, 15.7	<0.0001
Operative urgency						<0.001
Elective		35,074	71.95	309	21.08	
Urgent		7,719	15.84	318	21.69	
Emergent		5,953	12.21	839	57.23	
Total operative time (min; median, IQR)		157	110, 224	141	102, 200	<0.0001
Operation						<0.001
Colon		43,841	89.94	1,398	95.36	
Rectal		4,905	10.06	68	4.64	
Ostomy created		1,700	3.49	34	2.32	0.016

IQR= interquartile range; BMI= body mass index; COPD = Chronic obstructive pulmonary disease; SIRS= systemic inflammatory response syndrome; ASA= American Society of Anesthesiologists.

Table 2

Propensity matched demographics of patients undergoing colorectal surgery

Patient Characteristics	Skin Closed n = 1,382		Skin Open n = 1,382		p value
	n	(%)	n	%	
Age (median, IQR)	62	51.73	62	52.72	0.880
Sex (female)	705	51.01	713	51.59	0.761
Weight in lbs (median, IQR)	175	145, 212	176	145, 213	0.689
Recent weight loss (>10%)	82	5.93	85	6.15	0.811
BMI (kg/m ² , median, IQR)	28.26	24.12, 33.97	28.34	24.00, 33.95	0.982
Smoker	309	22.36	313	22.65	0.855
Congestive heart failure	23	1.66	32	2.32	0.220
Hypertension requiring medication	745	53.91	737	53.33	0.760
COPD	122	8.83	135	9.77	0.395
Dyspnea					0.857
At rest	24	1.74	21	1.52	
With moderate exertion	92	6.66	88	6.37	
Diabetes					0.115
Insulin dependent	102	7.38	120	8.68	
Non-insulin dependent	142	10.27	115	8.32	
Renal failure requiring dialysis	53	3.84	59	4.27	0.563
Steroid	199	14.40	201	14.54	0.914
Bleeding disorder	175	12.66	179	12.95	0.820
Transfusion of >4 units within 72 hrs of surgery	85	6.15	84	6.08	0.937
Preoperative Sepsis					0.872
SIRS	71	5.14	77	5.57	
Sepsis	495	35.82	509	36.83	
Septic shock	167	12.08	165	11.94	
Existing wound infection or open wound	110	7.96	99	7.16	0.429
Wound Class					0.491
Clean	3	0.22	7	0.51	

Patient Characteristics	Skin Closed n = 1,382		Skin Open n = 1,382		p value
	n	(%)	n	%	
Clean contaminated	192	13.89	197	14.25	
Contaminated	238	17.22	220	15.92	
Dirty infected	949	68.67	958	69.32	
Functional Status					0.283
Independent	1,255	90.81	1,247	90.23	
Partially dependent	99	7.16	96	6.95	
Totally dependent	23	1.66	26	1.88	
ASA Classification					0.983
Class 1	19	1.37	18	1.30	
Class 2	278	10.12	270	19.54	
Class 3	676	48.91	691	50.00	
Class 4	368	26.63	361	26.12	
Class 5	41	2.97	42	3.04	
Estimated probability of morbidity (median, IQR)	0.3012	0.2048, 0.4386	0.3089	0.2094, 0.4433	0.579
Estimated probability of mortality (median, IQR)	0.0336	0.0087, 0.1419	0.0353	0.0093, 0.1365	0.533
Preoperative laboratory values					
Creatinine	0.90	0.70, 1.26	0.90	0.70, 1.29	0.988
Bilirubin	0.6	0.4, 0.9	0.6	0.4, 1.0	0.089
White blood cell count	10.6	6.8, 15.6	10.5	7.1, 15.6	0.811
Operative urgency					0.018
Elective	334	24.17	284	20.55	
Urgent	334	24.17	313	22.65	
Emergent	714	51.66	785	56.8	
Total operative time (min; median, IQR)	145	103, 203	141	103, 200	0.783
Operation					0.525
Colon	1,315	95.15	1,322	95.66	
Rectal	67	4.85	60	4.34	
Ostomy created	28	2.03	31	2.24	0.693

IQR= interquartile range; BMI= body mass index; COPD = Chronic obstructive pulmonary disease; SIRS= systemic inflammatory response syndrome; ASA= American Society of Anesthesiologists.

Table 3

Outcomes of patients undergoing colorectal surgery

Outcome	Unadjusted outcomes			Propensity matched outcomes						
	Skin Closed	Skin Open	p value	Skin Closed	Skin Open	p value				
	n = 48,746	n = 1,466		n = 1,382	n = 1,382					
	n (%)	n (%)		n (%)	n (%)					
30-day mortality	1,199	2.46	174	11.87	<0.001	152	11.00	166	12.01	0.404
Superficial incisional SSI	2,777	5.70	7	7	7	120	8.68	7	7	7
Deep incision SSI	768	1.58	36	2.46	0.008	45	3.26	33	2.39	0.168
Organ space SSI	2,519	5.17	166	11.32	<0.001	154	11.14	160	11.58	0.719
Dehiscence	612	1.26	47	3.21	<0.001	34	2.46	44	3.18	0.251
Sepsis	2,663	5.46	276	18.83	<0.001	277	20.04	266	19.25	0.598
Pneumonia										
Reintubation	1,000	2.05	115	7.84	<0.001	70	5.07	112	8.10	0.001
Pulmonary embolism	342	0.70	29	1.98	<0.001	16	1.16	28	2.03	0.068
Renal insufficiency (Increase in creatinine by 2mg/dl)	411	0.84	17	1.16	0.194	21	1.52	16	1.16	0.408
Acute renal failure requiring dialysis	318	0.65	42	2.86	<0.001	40	2.89	40	2.89	1.000
CVA/Stroke	140	0.29	10	0.68	0.006	12	0.87	10	0.72	0.669
Unplanned reoperation	2,580	5.29	138	9.41	<0.001	119	8.61	133	9.62	0.355
Unplanned readmission	5,116	10.5	175	11.94	0.183	189	13.68	165	11.94	0.393
Cardiac Arrest	334	0.69	40	2.73	<0.001	33	2.39	37	2.68	0.628
Myocardial infarction	328	0.67	21	1.43	0.001	18	1.30	19	1.37	0.869
Transfusion within 72 hrs	5,382	11.04	391	26.67	<0.001	347	25.11	372	26.92	0.278
DVT requiring therapy	694	1.42	61	4.16	<0.001	46	3.33	58	4.20	0.230
Total hospital length of stay (days; median, IQR)	5	4.9	11	7.17	<0.0001	10	6.17	11	7.17	0.006
Discharge destination					<0.001					<0.001
Expired	902	1.85	136	9.28		125	9.06	130	9.43	
Facility	5,535	11.37	497	34.02		367	26.59	471	34.18	
Home	42,238	86.78	828	56.67		888	64.35	777	56.39	

[†]Invalid entry for wounds left open. SSI=surgical site infection; CVA=cerebrovascular accident; DVT = deep venous thrombosis; IQR = interquartile range.