Risk Factors for Hospital-Based Surgical Site Infections

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Abstract

Background: Surgical site infections (SSIs) contribute to morbidity and are costly to the healthcare system.

Objective: To identify factors associated with SSIs.

Methods: Case-control study analyzing the Nationwide Readmission Database (NRD).

Results: We identified 45,445 SSIs. Infection rates were higher in those who were obese (BMI ≥ 30) (OR: 1.39, 95% CI: 1.28-1.51); tobacco users (OR: 1.08, 95% CI: 1.02-1.15); diagnosed with diabetes (OR: 1.16, 95% CI: 1.10-1.22); with Elixhauser Comorbidity Index ≥2 (OR: 1.14, 95% CI: 1.09-1.20), admitted to hospital for 4-6 days (OR: 1.35, 95% CI: 1.29-1.42); in medium size hospital (OR: 1.15, 95% CI: 1.05-1.26); or large-size hospital (OR: 1.43, 95% CI: 1.31-1.56). In contrast, patients who were 60-79 years old (OR: 0.78, 95% CI: 0.73-0.84); 80 years or older (OR: 0.66, 95% CI: 0.59-0.73); female (OR: 0.95, 95% CI: 0.91-0.99); underweight (BMI < 18.5) (OR: 0.14, 95% CI: 0.03-0.59); in a non-metropolitan hospital (OR: 0.83, 95% CI: 0.75-0.91); self-pay (OR: 0.82, 95% CI: 0.74-0.91); or covered by Medicare (OR: 0.86, 95% CI: 0.80-0.91) had lower odds.

Limitations: Initial data entry to NRD is susceptible to human error.

Conclusions: Patients who are obese, use tobacco, have multiple comorbidities, and have long hospital stays in medium-to-large size hospitals are at risk of SSIs. Conversely, odds of SSIs are

lower in females, age ≥ 60, BMI < 18.5, self-pay or Medicare (versus private insurance), or at smaller hospitals. Understanding factors associated with SSIs may help surgeons anticipate complications.

Introduction

The Center for Disease Control and Prevention (CDC) classifies surgical site infections as those occurring within 30 days of surgery, and involving only the skin and subcutaneous tissue of the incision.[1] Surgical site infections (SSI) have a significant impact on patient morbidity, potentially elongating hospital stays by nearly 10 days and incurring an estimated annual expense of around $3.3 billion for healthcare institutions.[2]

Recognition of the potential factors associated with surgical site infections may facilitate comprehensive patient counseling, thereby leading to improved patient outcomes.[3] Previous studies have demonstrated that SSIs may be associated with: age ≥ 50 years; extended duration of surgery; emergency surgery; obesity; comorbidities such as diabetes and anemia; and pre-operative hospital stay extending beyond 24 hours.[4,5]

Notably, several studies evaluating risk factors for SSIs are limited in that they only focus on infections following one type of procedure or risk factor.[3–7] Given the burden of SSIs, we sought to better characterize the patient- and facility-associated factors that may be associated with surgical site infections following various types of surgical procedures, not just those performed by dermatologists or other specific subspecialties. Although the risk of SSIs in dermatologic surgery is typically less than 5%, the risk can be as high as 28% depending on the procedure and anatomical location[8,9]. SSIs continue to create unfavorable outcomes that affect patients in several aspects[10]. For this reason, we believe the findings obtained in this study will be of great relevance to dermatologists.

Methods

Case-control study approved by Northwestern University IRB (STU00208901). The 2010–2014 Nationwide Readmission Database (NRD), which was developed for the Healthcare Cost and Utilization Project (HCUP), was used to identify cases of SSI. The NRD contains a weighted cross-sectional sample of all U.S. readmissions.

For inclusion, cases were required to meet three criteria. First, a primary diagnosis of post-operative infection must have been documented according to the International Classification of Diseases, Ninth Revision (ICD-9) (DX1 = 99851, 99859). Second, the procedure code for the most recent hospital admission preceding the readmission must have met the definition of surgical operation which was “the incision of the skin and underlying structure for diagnostic or therapeutic purposes.” Lastly, the maximum duration between admissions could not exceed one month. Post-operative infections occurring in January were excluded, as admissions from the prior month could not be identified. Patients undergoing a similar procedure, who were not subsequently readmitted for post-operative infection, were identified as controls. Four controls were matched to each case.

Predefined study variables were related to patient characteristics, admission characteristics and hospital characteristics. Patient characteristic variables included age, gender, insurance status, household income, and the Elixhauser Comorbidity Index (ECI), a weighted index to measure patient comorbidity based on ICD-9 codes. ICD-9 codes were also used to identify tobacco use, alcohol use, drug use, human immunodeficiency virus (HIV) status, history of transplant, malignancy, and diabetes. Drug use encompassed the abuse of cannabis, sedatives, amphetamines, cocaine, hallucinogens, opioids, antidepressants, and mixed drug use. Admission characteristics included whether the procedure or surgery was elective, and whether the patient was initially admitted on a weekday or weekend. Finally, hospital characteristics included hospital size as determined by number of beds (i.e., small, medium, and large, Table 1).

Table 1
Bedsize categories based on location, region, and teaching status of hospitals.*

Location and Teaching Status	Hospital Bedsize		
	Small	Medium	Large
Northeast Region			
Rural	1–49	50–99	100+
Urban, nonteaching	1-124	125–199	200+
Urban, teaching	1-249	250–424	425+
Midwest Region			
Rural	1–29	30–49	50+
Urban, nonteaching	1–74	75–174	175+
Urban, teaching	1-249	250–374	375+
Southern Region			
Rural	1–39	40–74	75+
Urban, nonteaching	1–99	100–199	200+
Urban, teaching	1-249	250–449	450+
Western Region			
Rural	1–24	25–44	45+
Urban, nonteaching	1–99	100–174	175+
Urban, teaching	1-199	200–324	325+
*From Healthcare Cost and Utilization Project			

The specific number of beds in each hospital category was adjusted to account for regional differences, urban or rural location of the hospital, and the hospital's teaching status.

Descriptive statistics were performed to identify the frequency distribution of all variables extracted. The NRD website instructs that the complex samples function be used to incorporate the stratum, cluster, and discharge weights to produce national estimates that are valid. Bivariate logistic regression was performed, with statistical significance defined as $p < 0.05$ and corrected for multiple comparisons. Variables with statistical significance in bivariate analysis were included in a multivariable logistic regression, with statistical significance defined as $p < 0.05$. All statistical analyses were performed using SPSS (v25, IBM, Armonk, NY).

Results

There were 45,445 post-operative SSIs identified in the NRD, with an additional 173,130 patients in the control cohort. Descriptive statistics regarding the distribution of patient demographic factors, comorbidities, and social history in the case and control groups are shown in Tables 2, 3, and 4.

Table 2
Descriptive Statistics and Results of Bivariate and Multivariate Analysis of Patient Characteristics Associated with Post-Operative Surgical Site Infection

	Post-Op Infection (N = 45,445)	**No Post-Op Infection (N = 173,130)**	**Bivariate Odds Ratio (95% CI)**	**p-Value**	**Multivariate Odds Ratio (95% CI)**	**p-Value**
Age				< 0.001		< 0.001
18–39	9,072 (20.0%)	34,642 (20.0%)	[reference]		[reference]	
40–59	17,210 (37.9%)	57,493 (33.2%)	1.14 (1.08–1.21)		1.05 (0.99–1.11)	
60–79	15,449 (34.0%)	63,424 (36.6%)	0.93 (0.88–0.99)		0.78 (0.73–0.84)	
80+	3,713 (8.2%)	17,572 (10.1%)	0.81 (0.74–0.88)		0.66 (0.59–0.73)	
Gender				0.006		0.012
Male	20,245 (44.5%)	74,817 (43.2%)	[reference]		[reference]	
Female	25,200 (55.5%)	98,313 (56.8%)	0.95 (0.91–0.99)		0.95 (0.91–0.99)	
BMI				< 0.001		< 0.001
Underweight (BMI < 18.5)	< 11 (0.0%)	95 (0.1%)	0.15 (0.04–0.65)		0.14 (0.03–0.59)	
Normal weight (BMI 18.5–24.9)	41,023 (90.3%)	161,584 (93.3%)	[reference]		[reference]	
Overweight (BMI 25-29.9)	164 (0.4%)	680 (0.4%)	0.95 (0.66–1.37)		0.85 (0.58–1.24)	
Obese (BMI ≥ 30)	4,253 (9.4%)	10,771 (6.2%)	1.56 (1.43–1.69)		1.39 (1.28–1.51)	

Table 3
Descriptive Statistics and Results of Bivariate and Multivariate Analysis of Patient Medical History Associated with Post-Operative Surgical Site Infection

	Post-Op Infection (N = 45,445)	No Post-Op Infection (N = 173,130)	Bivariate Odds Ratio (95% CI)	p-Value	Multivariate Odds Ratio (95% CI)	p-Value
Elixhauser Comorbidity Index				< 0.001		< 0.001
0–1	20,379 (44.8%)	86,655 (50.1%)	[reference]		[reference]	
2+	25,066 (55.2%)	86,475 (49.9%)	1.23 (1.18–1.28)		1.14 (1.09–1.20)	
Malignant Tumor				0.458		
Yes	4,535 (10.0%)	17,699 (10.2%)	0.97 (0.91–1.05)			
No	40,910 (90.0%)	155,431 (89.8%)	[reference]			
Diabetes				< 0.001		< 0.001
Yes	10,621 (23.4%)	33,352 (19.3%)	1.28 (1.22–1.34)		1.16 (1.10–1.22)	
No	34,824 (76.6%)	139,778 (80.7%)	[reference]		[reference]	
HIV Status				0.558		
Yes	64 (0.1%)	211 (0.1%)	1.15 (0.72–1.85)			
No	45,269 (99.9%)	172,432 (99.9%)	[reference]			
History of Transplant Complications				0.63		
Yes	82 (0.2%)	279 (0.2%)	1.12 (0.70–1.79)			

	Post-Op Infection (N = 45,445)	No Post-Op Infection (N = 173,130)	Bivariate Odds Ratio (95% CI)	p-Value	Multivariate Odds Ratio (95% CI)	p-Value
Elixhauser Comorbidity Index				< 0.001		< 0.001
0–1	20,379 (44.8%)	86,655 (50.1%)	[reference]		[reference]	
No	45,363 (99.8%)	172,851 (99.8%)	[reference]			

Table 4
Descriptive Statistics and Results of Bivariate and Multivariate Analysis of Patient Social History Associated with Post-Operative Surgical Site Infection

	Post-Op Infection (N = 45,445)	**No Post-Op Infection (N = 173,130)**	**Bivariate Odds Ratio (95% CI)**	**p-Value**	**Multivariate Odds Ratio (95% CI)**	**p-Value**
Insurance				< 0.001		< 0.001
Private Insurance	17,605 (38.9%)	68,733 (39.8%)	[reference]		[reference]	
Medicaid	6,170 (13.6%)	19,141 (11.1%)	1.26 (1.17–1.35)		1.03 (0.96–1.12)	
Medicare	16,335 (36.1%)	66,361 (38.4%)	0.96 (0.92–1.01)		0.86 (0.80–0.91)	
Self-Pay	2,381 (5.3%)	9,515 (5.5%)	0.98 (0.88–1.08)		0.82 (0.74–0.91)	
No charge	434 (1.0%)	1,424 (0.8%)	1.19 (0.93–1.53)		0.991 (0.77–1.28)	
Other	2,369 (5.2%)	7,565 (4.4%)	1.22 (1.11–1.35)		1.07 (0.96–1.19)	
Income				0.012		0.521
< 50th percentile	24,643 (55.1%)	90,831 (53.3%)	[reference]		[reference]	
> 50th percentile	20,047 (44.9%)	79,532 (46.7%)	0.93 (0.88–0.98)		0.98 (0.93–1.04)	
Tobacco Use				< 0.001		0.007
Yes	37,805 (16.8%)	25,458 (14.7%)	1.17 (1.11–1.24)		1.08 (1.02–1.15)	
No	7,639 (83.2%)	147,672 (85.3%)	[reference]		[reference]	
Alcohol Use				0.546		

	Post-Op Infection (N = 45,445)	No Post-Op Infection (N = 173,130)	Bivariate Odds Ratio (95% CI)	p-Value	Multivariate Odds Ratio (95% CI)	p-Value
Yes	997 (2.2%)	3,654 (2.1%)	1.04 (0.92–1.18)			
No	44,448 (97.8%)	169,476 (97.9%)	[reference]			
Drug Use				0.952		
Yes	814 (1.8%)	3,087 (1.8%)	1.00 (0.88–1.15)			
No	44,631 (98.2%)	170,043 (98.2%)	[reference]			

The hospital and admission characteristics in the case and control groups are in Table 5.

Table 5
Descriptive Statistics and Results of Bivariate and Multivariate Analysis of Admission and Hospital Characteristics Associated with Post-Operative Surgical Site Infection

	Post-Op Infection (N = 45,445)	**No Post-Op Infection (N = 173,130)**	**Bivariate Odds Ratio (95% CI)**	**p-Value**	**Multivariate Odds Ratio (95% CI)**	**p-Value**
Length of Stay				< 0.001		< 0.001
0–3 days	26,588 (58.5%)	112,902 (65.2%)	[reference]		[reference]	
4–6 days	13,520 (29.8%)	41,984 (24.3%)	1.37 (1.31–1.43)		1.35 (1.29–1.42)	
7 + days	5,336 (11.7%)	18,238 (10.5%)	1.24 (1.16–1.33)		1.19 (1.11–1.27)	
Day of Admission				0.716		
Weekday	39,963 (87.9%)	152,052 (87.8%)	[reference]			
Weekend	5,482 (12.1%)	21,078 (12.2%)	0.99 (0.94–1.05)			
Elective Status				0.174		
Elective	22,001 (48.6%)	85,549 (49.6%)	1.04 (0.98–1.10)			
Non-Elective	23,270 (51.4%)	86,964 (50.4%)	[reference]			
Hospital Size				< 0.001		< 0.001
Small	5,071 (11.2%)	25,078 (14.5%)	[reference]		[reference]	
Medium	10,136 (22.3%)	43,514 (25.1%)	1.15 (1.05–1.26)		1.13 (1.03–1.24)	

	Post-Op Infection (N = 45,445)	No Post-Op Infection (N = 173,130)	Bivariate Odds Ratio (95% CI)	p-Value	Multivariate Odds Ratio (95% CI)	p-Value
Large	30,238 (66.5%)	104,538 (60.4%)	1.43 (1.31–1.56)		1.39 (1.27–1.52)	
Hospital Location				< 0.001		< 0.001
Metropolitan	41,667 (91.7%)	155,821 (90.0%)	[reference]		1	
Non-Metropolitan	3778 (8.3%)	17,309 (10.0%)	0.82 (0.75–0.89)		0.83 (0.75–0.91)	
Teaching Status				0.001		0.083
Non-Teaching	19,643 (43.2%)	79,234 (45.8%)	[reference]		[reference]	
Teaching	25,802 (56.8%)	93,896 (54.2%)	1.11 (1.04–1.18)		1.06 (0.99–1.14)	

Based on multivariable analysis, the rate of SSI was higher in patients who were obese (OR: 1.39, 95% CI: 1.28–1.51); tobacco users (OR: 1.08, 95% CI: 1.02–1.15); diagnosed with diabetes (OR: 1.16, 95% CI: 1.10–1.22); had an Elixhauser Comorbidity Index of two or greater (OR: 1.14, 95% CI: 1.09–1.20), admitted for 4–6 days (OR: 1.35, 95% CI: 1.29–1.42); or admitted to a medium size (OR: 1.15, 95% CI: 1.05–1.26) or large hospital (OR: 1.43, 95% CI: 1.31–1.56). Odds were decreased in patients who were 60–79 years of age (OR: 0.78, 95% CI: 0.73–0.84); 80 years or older (OR: 0.66, 95% CI: 0.59–0.73); female (OR: 0.95, 95% CI: 0.91–0.99); underweight (OR: 0.14, 95% CI: 0.03–0.59); admitted to a non-metropolitan hospital (OR: 0.83, 95% CI: 0.75–0.91); self-pay (OR: 0.82, 95% CI: 0.74–0.91); or covered by Medicare (OR: 0.86, 95% CI: 0.80–0.91).

Discussion

This case-control study evaluated the extent to which patient and hospital characteristics are associated with the odds of subsequent surgical site infections. The study is notable and novel in that it: (1) included a very large cohort of SSI patients; and (2) the patients assessed were not all treated by a single specialty and did not receive a particular procedure, but rather underwent a broad, diverse range of surgical procedures provided by different specialists.

We found that patients who are obese, suffer from two or more comorbidities, and use tobacco are more likely to have their hospital course complicated by SSI. In addition, a longer hospital stay is also associated with higher odds of SSIs. Female gender, age over 60 years, BMI less than 18.5, Medicare insurance, self-pay, and non-metropolitan hospitals are associated with a decreased likelihood of developing SSIs.

We believe there remains a lack of certainty regarding the association between age and the odds of developing post-operative infections. While several studies have shown that patients over the age of 50 are more susceptible,[4,5] we found a decreased odd of SSIs in those above age 60. Our findings are consistent with those of Kaye et. al, who found that in patients younger than 65, there is an increased risk of SSIs, and that in patients over the age of 65, there is a 1.2% decrease in risk for each additional year.[11] The decreased odds observed in elderly patients may attributable to heightened skin laxity in this cohort, which may result in decreased wound tension and increased perfusion at the wound margins. Additionally, elderly patients may exhibit lower levels of physical activity, and hence decrease their likelihood of exposing their post-operative wounds to potential infectious agents, or to induce an exercise-associated dehiscence, which may predispose younger patients to SSIs. To some extent, the lower rate of SSI in older patients may indicate underrepresentation of such cases, as since infections have unusual presentations in older patients[9], inadequate diagnosis and reporting of SSIs in this group may contribute to the observed association between age and likelihood of SSIs.

The findings that obesity, presence of two or more comorbidities, and tobacco use increase the likelihood of SSI aligns with the existing literature.[4,5] These factors contribute to the overall health of the patient prior to surgery, as assessed by the American Society of Anesthesiologist (ASA) Physical Classification System, and inform the risks associated with not only the procedure but the recovery.[10] Patients with higher ASA Physical Classification scores are at increased risk of developing SSIs.[4,5] In addition, obesity, comorbid conditions, such as diabetes, and tobacco use may all independently influence immunity and healing, thus contributing to an increased chance of SSIs.

Our study found lower association of SSI with underweight BMI, which is in contrast to findings reported by Cho et al, who reported that underweight BMI is a risk for SSIs following laparoscopic appendectomy.[11] The role of confounding variables, like malnutrition and underlying disease, may alter host defense mechanisms against infections; however, their contribution to these findings remain unclear .[12] Conversely, the Cho study has a limited sample size comprised of only 9 underweight patients, and is further constrained to focusing on one specific type of procedure.

It is intuitive that prolonged hospital stays, along with the resulting extended exposure to nosocomial infections, would be associated with increased odds of SSI. Indeed, we found that longer length of hospital stay was associated with higher odds of developing SSIs. Prior research has found the same.[13] Additionally, our investigation revealed that larger hospitals had higher odds of SSIs, whereas non-metropolitan hospitals demonstrated reduced odds. This may stem from the likelihood that larger hospitals, catering to a larger patient volume and often sicker patients, could face increased risks of nosocomial infections. Furthermore, the severity of surgical procedures conducted at larger hospitals may be greater compared to those at smaller hospitals, with likely riskier and more complicated procedures. As for non-metropolitan hospitals, in the NRD classification, even “large” non-metropolitan hospitals are much smaller than large urban hospitals based on number of hospital beds, and so non-metropolitan is also a general marker for small hospital size in terms of hospital beds.[14] Interestingly, patients in teaching hospitals did not have lower odds of SSIs. This outcome may be attributed to the fact that teaching hospitals often admit the most critically ill patients based on risk stratification.

We detected an association between insurance status and SSIs. Those on Medicare and self-pay patients were less likely to develop SSIs, as compared to those with private insurance. Possibly, although this is highly speculative, individuals with self-pay and with the ability to pay out of pocket for procedures may have higher-incomes that facilitate improved and prompt healthcare access. This, coupled with potentially more favorable post-operative nutrition and social support, could collectively contribute to reducing their likelihood of developing SSIs. Medicare patients tend to be older, and as discussed earlier, older age may be associated with factors (e.g., skin laxity, reduced intense physical activity) associated with lower odds of SSIs. When combined with other social risk factors such as low neighborhood income, however, receiving Medicare may be associated with higher risk of SSIs, as noted by Qi et al.[15]

One limitation of this study was the odds of SSI were not linked to specific surgical maneuvers. Factors such as surgical approach, procedure indication, invasiveness, incision size, and location were not used to separate the cohort into sub-cohorts for analysis. However, this could also be considered a strength, as our goal was to find factors associated with SSIs that were consistent across procedures, and not specific to a particular type of surgery or surgeon. Finally, the quality of the data we extracted from the NRD is limited by the accuracy of the initial data entry into the database.

In conclusion, this was one of the largest studies of surgical site infections and was unique in that it evaluated the likelihood of SSIs across surgical procedures, regardless of specialty or type of procedure. Our findings suggest increased odds of developing SSIs in patients who are obese, suffer from comorbidities, and use tobacco. In addition, patients in larger hospitals and with longer hospital stays are at increased odds of SSIs. In contrast, females, age $\geq$ 60 years, underweight BMI, Medicare insurance, self-pay, and admission to non-metropolitan hospitals are associated with lower odds of SSIs. Given these results, physicians may be better equipped to

screen and identify patients at risk of SSIs regardless of surgical procedure.

Declarations

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Conflicts of Interest: None declared.

IRB Status: The study was approved by the Northwestern University Institutional Review Board (STU00208901)

References

1. Centers for Disease Control and Prevention. Surgical Site Infection Event (SSI). https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf. Published January 2022. Accessed May 28, 2022.
2. Zimlichman, E., et al., "Health Care-Associated Infections. A Meta-analysis of Costs and Financial Impact on the US Health Care System". JAMA Intern Med, 173(22): (2013): 2039–46.
3. Bykowski MR, Sivak WN, Cray J, Buterbaugh G, Imbriglia JE, Lee WPA. Assessing the Impact of Antibiotic Prophylaxis in Outpatient Elective Hand Surgery: A Single-Center, Retrospective Review of 8,850 Cases. The Journal of Hand Surgery. 2011;36A:1741–1747.
4. Ansari S, Hassan M, Barry HD, Bhatti TA, Hussain SZM, Jabeen S, Fareed S. Risk Factors Associated with Surgical Site Infections: A Retrospective Report from a Developing Country. Cureus. 2019;11(6):e4801. doi: 10.7759/cureus.4801. PMID: 31396469; PMCID: PMC6679712.
5. Carvalho RLR, Campos CC, Franco LMC, Rocha AM, Ercole FF. Incidence and risk factors for surgical site infection in general surgeries. Rev Lat Am Enfermagem. 2017;25:e2848. doi: 10.1590/1518-8345.1502.2848.
6. Cunningham C, Slattery W, Luxford W. Postoperative infection in cochlear implant patients. Otolaryngology - Head and Neck Surgery. 2003;129(2):193.
7. Riordan M, Simpson V, Hall W. Analysis of Factors Contributing to Infections After Cranioplasty: A Single-Institution Retrospective Chart Review. World Neurosurg. 2016;87:207–213
8. Dixon AJ, Dixon MP, Askew DA, Wilkinson D. Prospective study of wound infections in dermatologic surgery in the absence of prophylactic antibiotics. Dermatol Surg 2006;32:819–26; discussion 26–7.
9. Futoryan T, Grande D. Postoperative wound infection rates in dermatologic surgery. Dermatol Surg 1995;21:509–14.
10. Saleh, Karim MD[*]; Schmidtchen, Artur MD, PhD[*,†]. Surgical Site Infections in Dermatologic Surgery: Etiology, Pathogenesis, and Current Preventative Measures. Dermatologic Surgery 41(5):p 537–549, May 2015. | DOI: 10.1097/DSS.0000000000000364
11. Kaye KS, Schmit K, Pieper C, et al. The effect of increasing age on the risk of surgical site infection. J Infect Dis. 2005;191(7):1056–1062.
12. Yoshikawa, TT. Epidemiology and unique aspects of aging and infectious diseases; *Clin Infect Dis*, 2000 vol. 30 (pg. 931-3)
13. American Society of Anesthesiologists. ASA Physical Status Classification System. https://www.asahq.org/standards-and-guidelines/asa-physical-status-classification-system. Published December 13, 2020. Accessed May 28, 2022.

14. Cho M, Kang J, Kim IK, Lee KY, Sohn SK. Underweight body mass index as a predictive factor for surgical site infections after laparoscopic appendectomy. Yonsei Med J. 2014;55(6):1611–6. doi: 10.3349/ymj.2014.55.6.1611. PMID: 25323899; PMCID: PMC4205702.
15. Brown RF, Bartrop R, Beumont P, Birmingham CL. Bacterial infections in anorexia nervosa: delayed recognition increases complications. Int J Eat Disord. 2005;37(3):261–5. doi: 10.1002/eat.20135.
16. Olaechea PM, Ulibarrena MA, Alvarez-Lerma F, Insausti J, Palomar M, De la Cal MA; ENVIN-UCI Study Group. Factors related to hospital stay among patients with nosocomial infection acquired in the intensive care unit. Infect Control Hosp Epidemiol. 2003;24(3):207–13. doi: 10.1086/502191.
17. Healthcare Cost and Utilization Project (HCUP) NIS notes. https://www.hcup-us.ahrq.gov/db/vars/hosp_bedsize/nisnote.jsp. Published September 17, 2008. Accessed May 28, 2022.
18. Qi AC, Peacock K, Luke AA, Barker A, Olsen MA, Joynt Maddox KE. Associations Between Social Risk Factors and Surgical Site Infections After Colectomy and Abdominal Hysterectomy. JAMA Netw Open. 2019;2(10):e1912339. doi: 10.1001/jamanetworkopen.2019.12339.