Diseases of the Colon & Rectum

Assessment of the Risk and Economic Burden of Surgical Site Infection Following Colorectal Surgery Using a US Longitudinal Database: Is There a Role for Innovative Antimicrobial Wound Closure Technology To Reduce the Risk of Infection?

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Abstract:	BACKGROUND: Colorectal surgical procedures place substantial burden on healthcare systems because of the high complication risk, especially surgical site

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	infections. Risk of infection post-procedure is one of the highest of any surgical specialty. OBJECTIVE: The purpose of this study was to determine the incidence and cost of infections after colorectal surgery and potential economic impact of using antimicrobial wound closure to improve patient outcomes. DESIGN: Retrospective observational cohort analysis and probabilistic cost analysis. SETTINGS: The analysis utilized IBM MarketScan® database for colorectal surgery patients in the United States between 2014-2018. PATIENTS: 107,665 patients undergoing colorectal surgery. MAIN OUTCOME MEASURES: Rate of infection was identified between 3-180 days postoperatively, infection risk factors, infection costs over 24-months postoperatively by payer type (Commercial payers and Medicare), and potential costs avoided per patient using an evidence-based innovative wound closure technology. RESULTS: Post-operative infections were diagnosed in 23.9% of patients (4.0% superficial and 19.9% deep/organ-space). Risk factors significantly increased risk of deep/organ-space infection and included selective patient comorbidities, age, payer type, and admission type. After 12-months, increased costs associated with superficial and deep/organ-space infections were $36,196 and $77,043 for Commercial payers and $17,323 and $55,089 for Medicare, respectively. Incremental costs continued to increase over a 24-month study period for both payers. Use of antimicrobial wound closure for colorectal surgery is projected to significantly reduce median payer costs by $1,512-$2,414 per patient compared with traditional wound closure. LIMITATIONS: Inherent biases associated with retrospective databases limited this study. CONCLUSIONS: Infection cost burden was found to be higher than previously reported, with payer costs escalating over a 24 months postoperative period. Cost analysis results for adopting antimicrobial wound closure aligns with previous evidence-based studies, suggesting a fiscal benefit for it use as a component of a comprehensive evidence-based surgical care bundle for reducing the risk of infection
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DISEASES OF THE COLON & RECTUM

Susan Galandiuk, M.D.
Editor-in-Chief
Diseases of the Colon & Rectum

January 30, 2020

Re: Manuscript Submission

Dear Dr. Galandiuk,

Please find the following original contribution manuscript entitled *"**Assessment of the risk and economic burden of surgical site infection following colorectal surgery using a US longitudinal database: is there a role for innovative antimicrobial wound closure technology to reduce the risk of infection?**"* for peer review and publication in *Diseases of the Colon & Rectum*.

Authors David J. Leaper, Chantal E. Holy, Maureen Spencer, Abhishek Chitnis, Andrew Hogan, George WJ Wright, Brian Po-Han Chen, and Charles E. Edmiston have all read and complied with author guidelines.

We trust this manuscript is well suited to *DC&R* given its focus on identifying the true incidence and cost of surgical site infections after colorectal surgical procedures in the US. Additionally, this manuscript explores the potential economic impact associated with the adoption of antimicrobial wound closure technology as a component of surgical site infection prevention bundles. The findings of this manuscript highlight the infection cost burden in colorectal procedures is higher than previously reported, highlighting potential fiscal benefits for the adoption of a comprehensive evidence-based surgical care bundle for reducing the risk of infection.

Preliminary findings have previously been presented at conferences for the International Society of Pharmacoeconomics and Outcomes Research (noted below), however, this work contains updated findings from the database analysis, more comprehensive results, and a probabilistic cost analysis exploring antimicrobial wound closure technology. Please note we have also included 4 supplemental data tables for editorial review.

Preliminary Manuscript Information Presented at:

1. International Society of Pharmacoeconomics and Outcomes Research Europe 2018 Congress, Nov. 10-14, Barcelona, Spain
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Sincerely,

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Assessment of the Risk and Economic Burden of Surgical Site Infection Following Colorectal Surgery Using a US Longitudinal Database: Is There a Role for Innovative Antimicrobial Wound Closure Technology To Reduce the Risk of Infection?

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Running Head: Incidence, Cost of Colorectal Infections

Key words: colorectal surgery; surgical site infection; antimicrobial sutures; surgical care bundles; IBM MarketScan; superficial incisional; deep incisional; organ-space

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ABSTRACT

BACKGROUND: Colorectal surgical procedures place substantial burden on healthcare systems because of the high complication risk, especially surgical site infections. Risk of infection post-procedure is one of the highest of any surgical specialty.

OBJECTIVE: The purpose of this study was to determine the incidence and cost of infections after colorectal surgery and potential economic impact of using antimicrobial wound closure to improve patient outcomes.

DESIGN: Retrospective observational cohort analysis and probabilistic cost analysis.

SETTINGS: The analysis utilized IBM MarketScan® database for colorectal surgery patients in the United States between 2014-2018.

PATIENTS: 107,665 patients undergoing colorectal surgery.

MAIN OUTCOME MEASURES: Rate of infection was identified between 3-180 days postoperatively, infection risk factors, infection costs over 24-months postoperatively by payer type (Commercial payers and Medicare), and potential costs avoided per patient using an evidence-based innovative wound closure technology.

RESULTS: Post-operative infections were diagnosed in 23.9% of patients (4.0% superficial and 19.9% deep/organ-space). Risk factors significantly increased risk of deep/organ-space infection and included selective patient comorbidities, age, payer type, and admission type. After 12-months, increased costs associated with superficial and deep/organ-space infections were $36,196 and $77,043 for Commercial payers and $17,323 and $55,089 for Medicare, respectively. Incremental costs continued to increase over a 24-month study period for both payers. Use of antimicrobial wound closure for colorectal surgery is projected to significantly reduce median payer costs by $1,512-$2,414 per patient compared with traditional wound closure.

LIMITATIONS: Inherent biases associated with retrospective databases limited this study.

CONCLUSIONS: Infection cost burden was found to be higher than previously reported, with payer costs escalating over a 24 months postoperative period. Cost analysis results for adopting antimicrobial wound closure aligns with previous evidence-based studies, suggesting a fiscal benefit for it use as a component of a comprehensive evidence-based surgical care bundle for reducing the risk of infection.

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INTRODUCTION

In the United States (US), elective colorectal surgery ranks in the top 10 of operating room procedures, with over 300,000 procedures reported in 2012.[1] This presents a high cost to healthcare systems, in-part relating to increased length of hospital stay and the high risk of managing post-operative complication, including surgical site infection (SSI).[2] The rate of SSI after colorectal surgery is one of the highest of any surgical specialty, with a reported incidence ranging from 9%-41%.[2-4] Patient comorbidities, related to this group of patients, increase the risk of SSI.[5; 6] In addition, SSIs are associated with prolonged hospital and intensive care unit stays, increased readmission to hospital, and additional community care.[3; 7-9] In the US, SSIs have been reported to account for $3.2 billion in attributable cost per year to acute care hospital budgets.[10; 11] More accurate understanding of the epidemiology of infection, and the associated patient co-morbid risk factors, are important considerations in the effort to mitigate their occurrence and provide patients with appropriate interventional care.

Evidence-based surgical care bundles have been devised to reduce the incidence of SSI after selective surgical procedures and improve patient outcomes. Components of these care bundles have included interventions such as weight-based, antibiotic prophylaxis, antiseptic skin preparation, appropriate hair removal, maintenance of normothermia, and glycemic control.[3; 12] A meta-analysis of 13 studies involving 8,515 patients documented that use of an evidence-based care bundles can significantly lower SSI rates after open, elective, colorectal surgery compared with standard methods: 7.0% compared with 15.1%, respectively (RR = 0.55 95% CI 0.39–0.77).[3] A subsequent analysis of 35 randomized controlled trials (RCTs) published in 2017 involving 17,557 patients documented a 40% reduction ($p<0.001$) in infection following colorectal surgery when a care bundle strategy was implemented.[12] In this meta-analysis only one study included the analysis used antimicrobial (triclosan) wound closure in its care bundle. Although, antimicrobial wound closure is not documented in many of the systematic reviews and meta-analysis of surgical care bundles, the use of antimicrobial wound closure, using triclosan-coated or impregnated sutures, is supported by 1A clinical evidence for reducing the risk of SSIs following selective (clean, clean-contaminated, and contaminated) surgical procedures.[13-19]

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The objective of the current study using a Nationwide longitudinal database, was to accurately assess the true incidence and actual costs associated with SSIs, following colorectal procedures in the US. The findings of this analysis suggest a potential economic and clinical outcome benefit for the inclusion of antimicrobial wound closure technology as a sentinel component of an evidence-based colorectal surgical care bundle.

MATERIALS AND METHODS

Database analysis

A retrospective observational cohort analysis using the IBM® MarketScan® Commercial, Multi-State Medicaid and Medicare Supplemental databases was conducted to evaluate adult patients (≥18 years) undergoing colorectal surgery in the U.S. between 2014 and 2018. Colorectal surgery was defined as the index procedure using the International Classification of Diseases, 9th and 10th Revision, Clinical Modification (ICD-9-CM and ICD-10-CM) procedure codes and Current Procedural Terminology (CPT) codes (**Supplementary Table 1**). All patients were required to have continuous enrollment for ≥12 months before and 6 months after each colorectal surgical procedure. Patients were categorized by demographic and clinical comorbidities using the 31 domains of the Elixhauser Comorbidity Index.

The following outcomes were evaluated: the rate of SSI (using diagnostic codes for superficial or deep incisional infections) identified from day 3 to 180th postoperative day, risk factors associated with deep/organ-space SSI, and costs of infection over a 24-month follow-up period by payer type (Commercial payers and Medicare). Infections identified within the first two days after surgery were not included as they may have been present on admission. The time from index operative procedure to any identified SSI was recorded. The full list of diagnostic codes used to inform superficial and deep incisional/organ-space infections are available in **Supplemental Table 2** and **Supplemental Table 3**.

Statistical analyses were performed fitting the data with logistic regression models to evaluate which variables were associated with a deep/organ-space SSI. Generalized linear regression models with log-link and gamma distribution were used to

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evaluate the adjusted total payments for patients with and without SSI. The adjusted incremental cost of infection was calculated using least-squares means over 24 months post-index procedure. All payments were adjusted to a 2018 consumer price-index. All regressions analyses were conducted using SAS 9.0.

Cost analysis

An exploratory cost analysis utilizing data extracted from the retrospective observational cohort, in combination with publicly available literature, was created to evaluate the potential economic impact of introducing antimicrobial suture wound closure after colorectal surgery to Commercial payers and Medicare. A decision tree was designed and run as a Monte Carlo simulation to compare colorectal procedures in a current treatment practice to where antimicrobial suture wound closure was utilized in future practice (**Figure 1**).

Key variables for each of the model branches included: the differential cost of antimicrobial wound closure compared with traditional suture technology, the probability of developing an SSI with antimicrobial sutures compared to traditional sutures, and the inpatient cost of SSI. The probability of SSI with traditional sutures was assumed to be equal to the rate calculated from the retrospective observational database cohort. The SSI risk reduction with antimicrobial wound closure was taken from available publications on contaminated and dirty (Class 3 or Class 4) wound types.[20] Costs of SSI were taken from the 12-month adjusted cost for superficial and deep/organ-space SSIs from the retrospective observational database cohort. The unit costs of traditional sutures and antimicrobial sutures were obtained from the vendor. With the probabilistic analysis, the increased incremental cost with antimicrobial sutures was assumed to be approximately $0.48 (USD) per suture strand, with a log-logistic distribution.

Results of the model consisted of a primary analysis which examined the incremental costs per patient over the first postoperative 12 months for superficial and deep/organ-space SSI. A secondary analysis, removing superficial infection rates and costs, was performed to examine the impact of deep/organ-space SSI only. To address uncertainty in input parameters, results of the primary and secondary analyses were conducted probabilistically.

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RESULTS

Database analysis

A total of 107,665 patients undergoing colorectal surgery between 2014 and 2018 were included in the analysis (**Figure 2**). Demographics and clinical presentation of patients at time of their index surgery are shown in **Table 1**. Within 6 months of the post-index procedure, 23.9% of patients had a diagnosis of SSI after colorectal surgery. The majority of infections were classified as deep/organ-space infection, accounting for 19.9% of infections; while the remaining 4.0% were superficial incisional infections (**Figure 3**). Most infections, diagnosed post-procedure, occurred within 3-25 days (50%) and by 2 months 75% had been identified. A summary of patient baseline comorbidities relative to infection status at 6 months is summarized in **Supplementary Table 4**. When analyzing the risk factors associated with deep/organ-space SSIs, regression analysis found certain patient comorbidities, age, payer type, and admission type to be associated with adverse outcome (**Figure 4**).

For the Commercial payer population, after adjusting for patient demographic and clinical characteristics, the incremental costs of superficial incisional SSIs were $28,698 at 6-months, $36,196 at 12-months, and $44,093 at 24-months post-index surgery. The adjusted incremental costs for deep/organ-space SSIs were $65,509 at 6-months, $77,043 at 12-months, and $89,450 at 24-months post-index surgery. For the Medicare population, the incremental costs for superficial SSIs were $15,797 at 6-months, $17,323 at 12-months, and $20,452 at 24-months post-index surgery. The adjusted incremental costs for deep/organ-space SSIs were $46,654 at 6-months, $55,089 at 12-months, and $69,041 at 24-months post-index surgery. Across the study time horizon, superficial incisional SSIs were associated with the lowest cost to payers and deep/organ-space infections were associated with the highest cost (**Table 2**). The longitudinal analysis found that the cost associated with a both superficial and deep/organ-space SSI can be substantial.

Cost analysis

Results of the primary cost analysis suggest that use of antimicrobial wound (fascial and incisional) closure would result in a statistically significant cost avoidance for superficial and deep/organ-space infection at 12 months compared to current

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practice for both Medicare and Commercial payers. Median costs avoided per patient for Commercial payers and Medicare were $2,414 (95% confidence interval [CI] $240-$11,786) and $1,674 (95% CI $140-$8,344) (**Figure 5**). In the secondary analysis of deep/organ-space SSI only, incremental costs avoided per patient were similarly reduced, with Commercial payers and Medicare predicting avoidance of $2,032 (95% CI $73-$10,876) and $1,512 (95% CI $44-$8,138), respectively, per patient for antimicrobial suture wound closure (**Figure 6**).

DISCUSSION

The IBM® MarketScan® Commercial, Multi-State Medicaid and Medicare Supplemental database is a unique, observational, cohort database study which highlights the true cost and accurate economic burden of SSIs following colorectal surgery. With over 1 in 5 patients at risk to experience an SSI within 6-months after colorectal surgery, and the cost burden of each episode ranging from $15,797 to $77,043 over 6-12 months, the cost of SSIs to the US healthcare system is substantial. These results demonstrate the importance of minimizing SSI-related costs by using evidence-based, care bundles.

All surgical wounds are contaminated to some degree at closure – the primary determinant of whether the contamination is implicated in establishing a surgical infection is dependent on patient comorbid risk factors, degree of wound contamination and immune-host tissue competency at the time of closure.[21] At first incision, sebaceous glands and hair follicles are transected, allowing skin-colonizing bacteria to contaminate the surgical wound. The intrinsic virulence of the skin flora combined with the level of contaminating bioburden can be the nidus for infection in a susceptible host. Furthermore, the rate of SSI for colorectal procedures is significantly influenced by the "layering-effect" of multiple, comorbid risk factors such as obesity, diabetes, low-serum albumin, alcohol consumption, cigarette smoking, extended operative times and anesthetic time.[22]

Several recent studies, meta-analysis and systematic reviews have documented the beneficial role of an evidence-based surgical care bundle.[12; 13; 23-25] While in most published care bundles the inclusion of antimicrobial sutures is absent from consideration, the intrinsic benefit of antimicrobial suture wound closure for fascia and

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subcuticular closure relates to documented antimicrobial activity against both Gram-positive and Gram-negative surgical wound pathogens.[26, 27]

When considering the benefits of an antimicrobial suture wound closure, two questions are warranted. First, are sutures a potential nidus for infection? A study published in 2013 documented that traditional (non-antimicrobial) braided or monofilament sutures excised from infected surgical patients, demonstrated an established microbial biofilm in 100% of cases, clearly suggesting that an implanted suture, like other biomedical devices, is at high risk for microbial biofilm formation when implanted within a contaminated field.[28] Secondly, does the level of evidence for antimicrobial sutures justify their inclusion in current, evidence-based colorectal surgical care bundles? Numerous RCTs, including multiple systematic reviews and meta-analyses, have been conducted to compare antimicrobial sutures with traditional, non-antimicrobial sutures (braided or monofilament absorbable sutures) for closure of fascia and muscle, subcutaneous tissues and skin. Use of antimicrobial sutures was found to be effective at significantly reducing the risk of SSI across different a myriad of surgical procedures including colorectal.[19, 29-34] A recent robust analysis evaluated 25 RCTs, representing 11,957 surgical patients, demonstrated that the use of antimicrobial sutures significantly reduced the risk of SSI at 30 days (relative risk 0.73, 95% CI 0.65 to 0.82). Sensitivity analysis also documented a significant SSI reduction benefit for clean and contaminated surgical procedures.[35]

The findings of this current study are important as they not only confirm the financial burden of SSIs after colorectal procedures, which have been reported in published, indirect estimates of cost, but also emphasize that the true economic burden is under-recognized. With the longitudinal nature of the database, a large cohort (n=107,665) of “real-world” patient information was used to determine that the incidence of SSIs within 6 months of colorectal surgery was 23.9%; a finding similar to previously reported SSI rates. It is also clear that the incidence of SSI has not been under-reported in the databases used in the study; a reflection of accurate post-discharge surveillance, the accuracy of which has often marred earlier reports. A key finding that highlights the limitations of currently available literature in establishing the actual cost of SSIs after colorectal procedures over time; with the adjusted incremental cost to payers at 6-

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months ranging up to $65,509. Additionally, the cost of SSIs to payers is not limited to the first 6-months post-procedure. Between 6-12 months and 12-24 months costs continued to escalate for all SSI types and payers. These findings indicate that there is often a need for prolonged care for patients who experience an SSI following colorectal surgery, especially in the case of an anastomotic leak (organ-space).

In this study, the costs of an SSI were found to be higher than those previously reported which have ranged from $11,778 to $42,177.[10; 36] Recent NICE guidelines on SSI prevention and treatment reported an average cost of managing a single patient with an SSI of £3,122.86.[16] CDC guidelines cited estimated mean attributable cost of SSI treatment ranging from $10,443 (2005 USD) to $25,546 (2002 USD) per SSI.[14] One reason for the disparity between these reported costs and those from this analysis, other than the extended level of post-discharge surveillance, is the increase in infection treatment costs to payers over time. Earlier reported costs were presented as 2002-2012 USD while the costs in this study are reported in 2018 USD, although this is not likely to be the primary cause for the differences observed. In earlier publications, the most common definition for the cost of an SSI was the incremental costs to the hospital for the added inpatient stay attributable for the infection, or flowing readmission.[36] In this analysis, costs of SSI after colorectal surgery reflect the overall cost to payers over time. These overall costs for patients provide a more accurate representation of the true cost of an SSI which has previously been underestimated by surrogate data rather than the “real world” data presented here.

Two studies involving the economic benefits associated with using an antimicrobial suture for wound closure have been recently published,[19; 37] In the first study, published by Singh and colleagues, the increased cost of antimicrobial sutures was minimal compared with the potential avoided costs of SSIs to third-party payers. Despite similar conclusions to the current study, there are several key differences between our analysis and that of Singh et al.[37] These differences included the population of interest (abdominal procedures), published sources for the risk and cost of infection, and the cost perspectives which were evaluated (hospital, third-party, and societal). The current analysis focuses solely on colorectal procedures using data from a large national database to inform baseline infection risk, the reduced risk of infection

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following the use of antimicrobial sutures which was taken from a recent meta-analysis by Leaper and colleagues, and all the relevant costs of SSIs to different payers were captured during a 12-month period.[19] Singh et al., used an overall SSI rate of 15% derived from the study of Alexander, et al. 2009, which evaluated morbidly obese patients.[38] The superficial and deep/organ-space SSI rates were calculated based on previously published estimates multiplied by 15%.[37] Whereas this study utilized real-world data from over 100,000 patients to document the rates of 19.9% and 4.0% for deep/organ-space and superficial incisional SSI, respectively. Here costs avoided are presented per patient, whereas those from Singh et al., costs were presented per SSI averted.[37] Compared to the recent meta-analysis and probabilistic cost analysis by Leaper et al., 2017, the results presented here demonstrate that similar costs can be avoided when using antimicrobial sutures, although the magnitude of the results differ.[19] In the United Kingdom (UK), the costs of SSI derived from UK NHS sources are much lower, ranging from £3,000 to £5,000,[19] whereas the 12-month mean costs of an SSI used in the current study ranged from $36,196 to $77,043 for Commercial payers and from $17,323 to $55,089 for Medicare, for superficial and deep/organ-space SSIs, respectively.

The results of this study have some important limitations; as with all retrospective database observational studies, results are limited to the captured information. All information within the IBM® MarketScan® Commercial, Multi-State Medicaid and Medicare Supplemental databases are provided by individual healthcare settings and are subject to errors in incomplete hospital reporting, coding errors, or misclassification of patients; causality cannot be inferred. We were unable to control for potentially important factors including physical function, socioeconomic status, and nutritional status. The exclusion of these and other potential predictive factors could impair the accuracy of our model estimates. The occurrence of SSIs was identified based on ICD-9-CM and ICD-10-CM diagnosis codes, without the availability of laboratory confirmation, although the diagnosis of an SSI is primarily a clinical decision. Future prospective studies might be useful to supplement the results of the current analysis.

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CONCLUSION

The results of this study highlight the substantial burden associated with surgical site infection following colorectal surgery, and the potential economic benefit of including an antimicrobial suture for wound closure in evidence-based, surgical care bundles for colorectal surgery. Despite a minimal increase in operative costs, use of antimicrobial sutures for fascia and subcuticular wound closure should be viewed as effective based on an evidence-based (level 1A) perspective. The potential impact on SSI costs avoided, by using antimicrobial sutures alone, was considered in this analysis. However, these sutures should not be considered as a “silver bullet,” but rather as a sentinel component of an evidence-based, SSI prevention care bundle.

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FIGURES LEGENDS

Figure 1. Basic structure of decision-tree cost model. The model was run for each type of payer and infection evaluated.

Figure 2. Flow diagram for included colorectal surgery patients.

Figure 3. SSI rate at 6 months post-index colorectal surgery, by infection type.

Figure 4. Risk factors significantly associated with deep/organ-space SSI (p-value <0.001).

Figure 5. Primary cost analysis median, 95% confidence interval, and distribution of savings per patient with antimicrobial sutures in the future practice over 12 months for deep/organ-space and superficial SSI: a) commercial payers, b) Medicare

Figure 6. Secondary cost analysis median, 95% confidence interval, and distribution of savings per patient with antimicrobial sutures in the future practice over 12 months for deep/organ-space SSI only: a) commercial payers, b) Medicare.

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Table

Table 1. Demographics and clinical presentation of study patients at time of index surgery.

	Overall (n=107,665)		Deep/Organ-Space SSI (n=21,441)		Superficial SSI (n=4,292)		No Infection (n=81,932)	
	N	%	N	%	N	%	N	%
Male Gender	50,246	46.7%	9,919	46.3%	1,997	46.5%	38,330	46.8%
Years								
2014	27,970	26.0%	5,754	26.8%	1,268	29.5%	20,948	25.6%
2015	23,110	21.5%	4,832	22.5%	921	21.5%	17,357	21.2%
2016	21,725	20.2%	4,499	21.0%	801	18.7%	16,425	20.1%
2017	18,714	17.4%	3,584	16.7%	691	16.1%	14,439	17.6%
2018	16,146	15.0%	2,772	12.9%	611	14.2%	12,763	15.6%
Age Category								
18-24	3,290	3.1%	845	3.9%	102	2.4%	2,343	2.9%
25-34	6,196	5.8%	1,541	7.2%	268	6.2%	4,387	5.4%
35-44	12,763	11.9%	2,733	12.8%	500	11.7%	9,530	11.6%
45-54	26,966	25.1%	5,064	23.6%	1,054	24.6%	20,848	25.5%
55-64	36,257	33.7%	6,840	31.9%	1,415	33.0%	28,002	34.2%
65-74	10,507	9.8%	2,048	9.6%	420	9.8%	8,039	9.8%
75+	11,686	10.9%	2,370	11.1%	533	12.4%	8,783	10.7%
Site of Care								
Outpatient	5,076	4.7%	658	3.1%	153	3.6%	4,265	5.2%
Inpatient	102,589	95.3%	20,783	96.9%	4,139	96.4%	77,667	94.8%
Admission Type								
Non-emergency	84,805	78.8%	14,784	69.0%	3,109	72.4%	66,912	81.7%
Emergency	22,860	21.2%	6,657	31.1%	1,183	27.6%	15,020	18.3%
Database Indicator								
Commercial	70,243	65.2%	12,605	58.8%	2,530	59.0%	55,108	67.3%
Medicaid	15,690	14.6%	4,542	21.2%	827	19.3%	10,321	12.6%

Medicare	21,732	20.2%	4,294	20.0%	935	21.8%	16,503	20.1%
Charlson Comorbidity Index								
0	39,743	36.9%	7,255	33.8%	1,348	31.4%	31,140	38.0%
1-2	36,333	33.8%	6,909	32.2%	1,463	34.1%	27,961	34.1%
3-4	16,971	15.8%	3,530	16.5%	753	17.5%	12,688	15.5%
+5	14,618	13.6%	3,747	17.5%	728	17.0%	10,143	12.4%
Functional Comorbidity Index								
0	20,225	18.8%	3,627	16.9%	649	15.1%	15,949	19.5%
1-2	40,003	37.2%	6,864	32.0%	1,336	31.1%	31,803	38.8%
3-4	28,270	26.3%	5,693	26.6%	1,181	27.5%	21,396	26.1%
+5	19,167	17.8%	5,257	24.5%	1,126	26.2%	12,784	15.6%
Elixhauser Comorbidity Index								
0	17,730	16.5%	3,180	14.8%	556	13.0%	13,994	17.1%
1-2	38,363	35.6%	6,365	29.7%	1,293	30.1%	30,705	37.5%
3-4	27,666	25.7%	5,294	24.7%	1,139	26.5%	21,233	25.9%
+5	23,906	22.2%	6,602	30.8%	1,304	30.4%	16,000	19.5%

Table

Table 2. Summary of SSI costs from the database analysis by infection type, payer and timepoint.

Mean Cost (95% CI)		Deep/Organ Space SSI	Superficial SSI
Commercial Payers	6-months	$65,509 ($64,235-$66,804)	$28,698 ($26,511-$30,960)
	12-months	$77,043 ($75,179-$78,941)	$36,196 ($32,840-$39,691)
	24-months	$89,450 (86,333-$92,649)	$44,093 ($38,334-$50,180)
Medicare	6-months	$46,654 ($44,734-$48,634)	$15,797 ($12,652-$19,153)
	12-months	$55,089 ($52,340-$57,940)	$17,323 ($12,805-$22,191)
	24-months	$69,041 ($63,979-$74,365)	$20,452 ($12,234-$29,528)

Abbreviations: CI = confidence interval; SSI = surgical site infection.

Table

Supplementary Table 1. Procedure codes used to identify colorectal surgeries.

Code Type	Code	Description	Laparoscopy
CPT4	44139	Mobilization (take-down) of splenic flexure performed in conjunction with partial colectomy (List separately in addition to primary procedure)	Open
CPT4	44140	Colectomy, partial; with anastomosis	Open
CPT4	44141	Colectomy, partial; with skin level cecostomy or colostomy	Open
CPT4	44143	Colectomy, partial; with end colostomy and closure of distal segment (Hartmann type procedure)	Open
CPT4	44144	Colectomy, partial; with resection, with colostomy or ileostomy and creation of mucofistula	Open
CPT4	44145	Colectomy, partial; with coloproctostomy (low pelvic anastomosis)	Open
CPT4	44146	Colectomy, partial; with coloproctostomy (low pelvic anastomosis), with colostomy	Open
CPT4	44147	Colectomy, partial; abdominal and transanal approach	Open
CPT4	44150	Colectomy, total, abdominal, without proctectomy; with ileostomy or ileoproctostomy	Open
CPT4	44151	Colectomy, total, abdominal, without proctectomy; with continent ileostomy	Open
CPT4	44152	Colectomy, total, abdominal, without proctectomy; with rectal mucosectomy, ileoanal anastomosis, with or without loop ileostomy	Open
CPT4	44153	Colectomy, total, abdominal, without proctectomy; with rectal mucosectomy, ileoanal anastomosis, creation of ileal reservoir (S or J), with or without loop ileostomy	Open
CPT4	44155	Colectomy, total, abdominal, with proctectomy; with ileostomy	Open
CPT4	44156	Colectomy, total, abdominal, with proctectomy; with continent ileostomy	Laparoscopy
CPT4	44157	Colectomy, total, abdominal, with proctectomy; with ileoanal anastomosis, includes loop ileostomy, and rectal mucosectomy, when performed	Laparoscopy
CPT4	44158	Colectomy, total, abdominal, with proctectomy; with ileoanal anastomosis, creation of ileal reservoir (S or J), includes loop ileostomy, and rectal mucosectomy, when performed	Laparoscopy
CPT4	44160	Colectomy, partial, with removal of terminal ileum with ileocolostomy	Laparoscopy
CPT4	44188	Laparoscopy, surgical, colostomy or skin level cecostomy	Laparoscopy
CPT4	44204	Laparoscopy, surgical; colectomy, partial, with anastomosis	Laparoscopy
CPT4	44205	Laparoscopy, surgical; colectomy, partial, with removal of terminal ileum with ileocolostomy	Laparoscopy
CPT4	44206	Laparoscopy, surgical; colectomy, partial, with end colostomy and closure of distal segment (Hartmann type procedure)	Laparoscopy
CPT4	44207	Laparoscopy, surgical; colectomy, partial, with anastomosis, with coloproctostomy (low pelvic anastomosis)	Laparoscopy
CPT4	44208	Laparoscopy, surgical; colectomy, partial, with anastomosis, with coloproctostomy (low pelvic anastomosis) with colostomy	Laparoscopy
CPT4	44209	Unlisted laparoscopy procedure, intestine (except rectum)	Laparoscopy
CPT4	44210	Laparoscopy, surgical; colectomy, total, abdominal, without proctectomy, with ileostomy or ileoproctostomy	Laparoscopy
CPT4	44211	Laparoscopy, surgical; colectomy, total, abdominal, with proctectomy, with ileoanal anastomosis, creation of ileal reservoir (S or J), with loop ileostomy, with or without rectal mucosectomy	Open

Code Type	Code	Description	Laparoscopy
CPT4	44212	Laparoscopy, surgical; colectomy, total, abdominal, with proctectomy, with ileostomy	Open
CPT4	44213	Laparoscopy, surgical, mobilization (take-down) of splenic flexure performed in conjunction with partial colectomy (List separately in addition to primary procedure)	Open
CPT4	44227	Laparoscopy, surgical, closure of enterostomy, large or small intestine, with resection and anastomosis	Open
CPT4	44300	Enterostomy or cecostomy, tube (eg, for decompression or feeding) (separate procedure)	Open
CPT4	44320	Colostomy or skin level cecostomy; (separate procedure)	Open
CPT4	44322	Colostomy or skin level cecostomy; with multiple biopsies (eg, for congenital megacolon) (separate procedure)	Open
CPT4	44340	Revision of colostomy; simple (release of superficial scar) (separate procedure)	Open
CPT4	45111	Proctectomy; partial resection of rectum, transabdominal approach	Open
CPT4	45112	Proctectomy, combined abdominoperineal, pull-through procedure (eg, colo-anal anastomosis)	Open
CPT4	45113	Proctectomy, partial, with rectal mucosectomy, ileoanal anastomosis, creation of ileal reservoir (S or J), with or without loop ileostomy	Open
CPT4	45114	Proctectomy, partial, with anastomosis; abdominal and transsacral approach	Open
CPT4	45116	Proctectomy, partial, with anastomosis; transsacral approach only (Kraske type)	Open
CPT4	45119	Proctectomy, combined abdominoperineal pull-through procedure (eg, colo-anal anastomosis), with creation of colonic reservoir (eg, J-pouch), with or without proximal diverting ostomy	Open
CPT4	45120	Proctectomy, complete (for congenital megacolon), abdominal and perineal approach; with pull-through procedure and anastomosis (eg, Swenson, Duhamel, or Soave type operation)	Open
CPT4	45121	Proctectomy, complete (for congenital megacolon), abdominal and perineal approach; with subtotal or total colectomy, with multiple biopsies	Open
CPT4	45123	Proctectomy, partial, without anastomosis, perineal approach	Laparoscopy
CPT4	45126	Pelvic exenteration for colorectal malignancy, with proctectomy (with or without colostomy), with removal of bladder and ureteral transplantations, and/or hysterectomy, or cervicectomy, with or without removal of tube(s), with or without removal of ovary(s	Laparoscopy
CPT4	45135	Excision of rectal procidentia, with anastomosis; abdominal and perineal approach	Laparoscopy
CPT4	45190	Destruction of rectal tumor (eg, electrodessication, electrosurgery, laser ablation, laser resection, cryosurgery) transanal approach	Laparoscopy
CPT4	45395	Laparoscopy, surgical; proctectomy, complete, combined abdominoperineal, with colostomy	Laparoscopy
CPT4	45397	Laparoscopy, surgical; proctectomy, combined abdominoperineal pull-through procedure (eg, colo-anal anastomosis), with creation of colonic reservoir (eg, J-pouch), with diverting enterostomy, when performed	Laparoscopy
ICD9	17.3	Laparoscopic partial excision of large intestine	Laparoscopy
ICD9	17.31	Laparoscopic multiple segmental resection of large intestine	Laparoscopy
ICD9	17.32	Laparoscopic cecectomy	Laparoscopy
ICD9	17.33	Laparoscopic right hemicolectomy	Laparoscopy
ICD9	17.34	Laparoscopic resection of transverse colon	Open

Code Type	Code	Description	Laparoscopy
ICD9	17.35	Laparoscopic left hemicolectomy	Open
ICD9	17.36	Laparoscopic sigmoidectomy	Open
ICD9	17.39	Other laparoscopic partial excision of large intestine	Open
ICD9	45.7	Open and other partial excision of large intestine	Open
ICD9	45.71	Open and other multiple segmental resection of large intestine	Open
ICD9	45.72	Open and other cecectomy	Open
ICD9	45.73	Open and other right hemicolectomy	Open
ICD9	45.74	Open and other resection of transverse colon	Open
ICD9	45.75	Open and other left hemicolectomy	Laparoscopy
ICD9	45.76	Open and other sigmoidectomy	Open
ICD9	45.79	Other and unspecified partial excision of large intestine	Open
ICD9	45.8	Total intra-abdominal colectomy	Open
ICD9	45.81	Laparoscopic total intra-abdominal colectomy	Open
ICD9	45.82	Open total intra-abdominal colectomy	Laparoscopy
ICD9	45.83	Other and unspecified total intra-abdominal colectomy	Open
ICD9	48.5	Abdominoperineal resection of rectum	Open
ICD9	48.5	Abdominoperineal resection of the rectum, not otherwise specified	Open
ICD9	48.51	Laparoscopic abdominoperineal resection of the rectum	Open
ICD9	48.52	Open abdominoperineal resection of the rectum	Open
ICD9	48.59	Other abdominoperineal resection of the rectum	Open
ICD9	48.6	Other resection of rectum	Open
ICD9	48.62	Anterior resection of rectum with synchronous colostomy	Open
ICD9	48.63	Other anterior resection of rectum	Open
ICD10	0DBE0ZZ	Excision of Large Intestine, Open Approach	Open
ICD10	0DBE3ZZ	Excision of Large Intestine, Percutaneous Approach	Open
ICD10	0DBE4ZZ	Excision of Large Intestine, Percutaneous Endoscopic Approach	Other
ICD10	0DBE7ZZ	Excision of Large Intestine, Via Natural or Artificial Opening	Other
ICD10	0DBE8ZZ	Excision of Large Intestine, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DBF0ZZ	Excision of Right Large Intestine, Open Approach	Open
ICD10	0DBF3ZZ	Excision of Right Large Intestine, Percutaneous Approach	Open
ICD10	0DBF4ZZ	Excision of Right Large Intestine, Percutaneous Endoscopic Approach	Other
ICD10	0DBF7ZZ	Excision of Right Large Intestine, Via Natural or Artificial Opening	Other
ICD10	0DBF8ZZ	Excision of Right Large Intestine, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DBG0ZZ	Excision of Left Large Intestine, Open Approach	Open
ICD10	0DBG3ZZ	Excision of Left Large Intestine, Percutaneous Approach	Open
ICD10	0DBG4ZZ	Excision of Left Large Intestine, Percutaneous Endoscopic Approach	Other
ICD10	0DBG7ZZ	Excision of Left Large Intestine, Via Natural or Artificial Opening	Other

Code Type	Code	Description	Laparoscopy
ICD10	0DBG8ZZ	Excision of Left Large Intestine, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DBH0ZZ	Excision of Cecum, Open Approach	Open
ICD10	0DBH3ZZ	Excision of Cecum, Percutaneous Approach	Open
ICD10	0DBH4ZZ	Excision of Cecum, Percutaneous Endoscopic Approach	Other
ICD10	0DBH7ZZ	Excision of Cecum, Via Natural or Artificial Opening	Other
ICD10	0DBH8ZZ	Excision of Cecum, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DBK0ZZ	Excision of Ascending Colon, Open Approach	Open
ICD10	0DBK3ZZ	Excision of Ascending Colon, Percutaneous Approach	Open
ICD10	0DBK4ZZ	Excision of Ascending Colon, Percutaneous Endoscopic Approach	Other
ICD10	0DBK7ZZ	Excision of Ascending Colon, Via Natural or Artificial Opening	Other
ICD10	0DBK8ZZ	Excision of Ascending Colon, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DBL0ZZ	Excision of Transverse Colon, Open Approach	Open
ICD10	0DBL3ZZ	Excision of Transverse Colon, Percutaneous Approach	Open
ICD10	0DBL4ZZ	Excision of Transverse Colon, Percutaneous Endoscopic Approach	Other
ICD10	0DBL7ZZ	Excision of Transverse Colon, Via Natural or Artificial Opening	Other
ICD10	0DBL8ZZ	Excision of Transverse Colon, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DBM0ZZ	Excision of Descending Colon, Open Approach	Open
ICD10	0DBM3ZZ	Excision of Descending Colon, Percutaneous Approach	Open
ICD10	0DBM4ZZ	Excision of Descending Colon, Percutaneous Endoscopic Approach	Other
ICD10	0DBM7ZZ	Excision of Descending Colon, Via Natural or Artificial Opening	Other
ICD10	0DBM8ZZ	Excision of Descending Colon, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DBN0ZZ	Excision of Sigmoid Colon, Open Approach	Open
ICD10	0DBN3ZZ	Excision of Sigmoid Colon, Percutaneous Approach	Open
ICD10	0DBN4ZZ	Excision of Sigmoid Colon, Percutaneous Endoscopic Approach	Other
ICD10	0DBN7ZZ	Excision of Sigmoid Colon, Via Natural or Artificial Opening	Open
ICD10	0DBN8ZZ	Excision of Sigmoid Colon, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DTE0ZZ	Resection of Large Intestine, Open Approach	Open
ICD10	0DTE4ZZ	Resection of Large Intestine, Percutaneous Endoscopic Approach	Other
ICD10	0DTE7ZZ	Resection of Large Intestine, Via Natural or Artificial Opening	Open
ICD10	0DTE8ZZ	Resection of Large Intestine, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DTF0ZZ	Resection of Right Large Intestine, Open Approach	Open
ICD10	0DTF4ZZ	Resection of Right Large Intestine, Percutaneous Endoscopic Approach	Other
ICD10	0DTF7ZZ	Resection of Right Large Intestine, Via Natural or Artificial Opening	Open
ICD10	0DTF8ZZ	Resection of Right Large Intestine, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DTG0ZZ	Resection of Left Large Intestine, Open Approach	Open
ICD10	0DTG4ZZ	Resection of Left Large Intestine, Percutaneous Endoscopic Approach	Other

Code Type	Code	Description	Laparoscopy
ICD10	0DTG7ZZ	Resection of Left Large Intestine, Via Natural or Artificial Opening	Open
ICD10	0DTG8ZZ	Resection of Left Large Intestine, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DTH0ZZ	Resection of Cecum, Open Approach	Open
ICD10	0DTH4ZZ	Resection of Cecum, Percutaneous Endoscopic Approach	Open
ICD10	0DTH7ZZ	Resection of Cecum, Via Natural or Artificial Opening	Other
ICD10	0DTH8ZZ	Resection of Cecum, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DTK0ZZ	Resection of Ascending Colon, Open Approach	Open
ICD10	0DTK0ZZ	Resection of Ascending Colon, Open Approach	Open
ICD10	0DTK4ZZ	Resection of Ascending Colon, Percutaneous Endoscopic Approach	Other
ICD10	0DTK7ZZ	Resection of Ascending Colon, Via Natural or Artificial Opening	Open
ICD10	0DTK8ZZ	Resection of Ascending Colon, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DTL0ZZ	Resection of Transverse Colon, Open Approach	Open
ICD10	0DTL4ZZ	Resection of Transverse Colon, Percutaneous Endoscopic Approach	Other
ICD10	0DTL7ZZ	Resection of Transverse Colon, Via Natural or Artificial Opening	Open
ICD10	0DTL8ZZ	Resection of Transverse Colon, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DTM0ZZ	Resection of Descending Colon, Open Approach	Open
ICD10	0DTM4ZZ	Resection of Descending Colon, Percutaneous Endoscopic Approach	Other
ICD10	0DTM7ZZ	Resection of Descending Colon, Via Natural or Artificial Opening	Open
ICD10	0DTM8ZZ	Resection of Descending Colon, Via Natural or Artificial Opening Endoscopic	Open
ICD10	0DTN0ZZ	Resection of Sigmoid Colon, Open Approach	Other
ICD10	0DTN4ZZ	Resection of Sigmoid Colon, Percutaneous Endoscopic Approach	Other
ICD10	0DTN7ZZ	Resection of Sigmoid Colon, Via Natural or Artificial Opening	Other
ICD10	0DTN8ZZ	Resection of Sigmoid Colon, Via Natural or Artificial Opening Endoscopic	Other
DRG	329	Major small and large bowel procedrues w MCC	
DRG	330	Major small and large bowel procedrues w CC	
DRG	331	Major small and large bowel procedrues w/o CC/MCC	
DRG	332	Rectal resection W MCC	
DRG	333	Rectal resection W CC	
DRG	334	Rectal resection W/0 CC/MCC	

Table

Supplementary Table 2. Procedure codes used to identify deep/organ-space SSI in colorectal surgeries.

Code Type	Code	Description
ICD9	004.8	other specified shigella infections
ICD9	006.8	amebic infection of other sites
ICD9	008.00	intestinal infection due to e coli unspecified
ICD9	008.01	intestinal infection due to enteropathogenic e coli
ICD9	008.02	intestinal infection due to enterotoxigenic e coli
ICD9	008.03	intestinal infection due to enteroinvasive e coli
ICD9	008.04	intestinal infection due to enterohemorrhagic e coli
ICD9	008.09	intestinal infection due to other intestinal e coli infections
ICD9	008.1	intestinal infection due to arizona group of paracolon bacilli
ICD9	008.2	intestinal infection due to aerobacter aerogenes
ICD9	008.3	intestinal infection due to proteus - mirabilis- - morganii-
ICD9	008.41	intestinal infection due to staphylococcus
ICD9	008.42	intestinal infection due to pseudomonas
ICD9	008.43	intestinal infection due to campylobacter
ICD9	008.44	intestinal infection due to yersinia enterocolitica
ICD9	008.45	intestinal infection due to clostridium difficile
ICD9	008.46	intestinal infection due to other anaerobes
ICD9	008.47	intestinal infection due to other gram-negative bacteria
ICD9	008.49	intestinal infection due to other organisms
ICD9	008.8	intestinal infection due to other organism not elsewhere classified
ICD9	038.0	streptococcal septicemia
ICD9	038.10	staphylococcal septicemia unspecified
ICD9	038.11	methicillin susceptible staphylococcus aureus septicemia
ICD9	038.12	Methicillin resistant Staphylococcus aureus septicemia
ICD9	038.19	other staphylococcal septicemia
ICD9	038.3	septicemia due to anaerobes
ICD9	038.40	septicemia due to gram-negative organism unspecified
ICD9	038.42	septicemia due to escherichia coli - e coli-
ICD9	038.43	septicemia due to pseudomonas
ICD9	038.44	septicemia due to serratia
ICD9	038.49	other septicemia due to gram-negative organisms
ICD9	038.8	other specified septicemias
ICD9	038.9	unspecified septicemia
ICD9	040.0	gas gangrene

Code Type	Code	Description
ICD9	040.42	Wound botulism
ICD9	040.82	toxic shock syndrome
ICD9	040.89	other specified bacterial diseases
ICD9	041.00	streptococcus infection in conditions classified elsewhere and of unspecified site streptococcus u
ICD9	041.01	streptococcus infection in conditions classified elsewhere and of unspecified site streptococcus g
ICD9	041.02	streptococcus infection in conditions classified elsewhere and of unspecified site streptococcus g
ICD9	041.03	streptococcus infection in conditions classified elsewhere and of unspecified site streptococcus g
ICD9	041.04	streptococcus infection in conditions classified elsewhere and of unspecified site streptococcus g
ICD9	041.05	streptococcus infection in conditions classified elsewhere and of unspecified site streptococcus g
ICD9	041.09	streptococcus infection in conditions classified elsewhere and of unspecified site other streptococ
ICD9	041.10	staphylococcus infection in conditions classified elsewhere and of unspecified site staphylococcus
ICD9	041.11	methicillin susceptible staphylococcus aureus in conditions classified elsewhere and of unspecified
ICD9	041.19	staphylococcus infection in conditions classified elsewhere and of unspecified site other staphyloc
ICD9	041.3	friedl?nder s bacillus infection in conditions classified elsewhere and of unspecified site
ICD9	041.6	proteus - mirabilis- - morganii- infection in conditions classified elsewhere and of unspecified s
ICD9	041.7	pseudomonas infection in conditions classified elsewhere and of unspecified site
ICD9	041.81	other specified bacterial infections in conditions classified elsewhere and of unspecified site myc
ICD9	041.82	bacteroides fragilis
ICD9	041.83	other specified bacterial infections in conditions classified elsewhere and of unspecified site clo
ICD9	041.84	other specified bacterial infections in conditions classified elsewhere and of unspecified site oth
ICD9	041.85	other specified bacterial infections in conditions classified elsewhere and of unspecified site oth
ICD9	041.89	other specified bacterial infections in conditions classified elsewhere and of unspecified site oth
ICD9	041.9	bacterial infection unspecified in conditions classified elsewhere and of unspecified site
ICD9	135	sarcoidosis
ICD9	288.04	neutropenia due to infection
ICD9	379.60	inflammation - infection- of postprocedural bleb unspecified
ICD9	379.61	inflammation - infection- of postprocedural bleb stage 1
ICD9	379.62	inflammation - infection- of postprocedural bleb stage 2
ICD9	379.63	inflammation - infection- of postprocedural bleb stage 3
ICD9	560.81	peritoneal adhesions - postoperative- - postinfection-
ICD9	567.39	other retroperitoneal infections
ICD9	569.61	infection of colostomy or enterostomy
ICD9	590.9	infection of kidney unspecified

Code Type	Code	Description
ICD9	596.81	infection of cystostomy
ICD9	598.00	urethral structure due to unspecified infection
ICD9	614.6	pelvic peritoneal adhesions female - postoperative- - postinfection-
ICD9	713.1	arthropathy associated with gastrointestinal conditions other than infections
ICD9	958.3	posttraumatic wound infection not elsewhere classified
ICD9	995.90	systemic inflammatory response syndrome, unspecified
ICD9	995.91	sepsis
ICD9	995.92	severe sepsis
ICD9	996.60	infection and inflammatory reaction due to unspecified device implant and graft
ICD9	996.62	infection and inflammatory reaction due to other vascular device implant and graft
ICD9	996.64	infection and inflammatory reaction due to indwelling urinary catheter
ICD9	996.65	infection and inflammatory reaction due to other genitourinary device implant and graft
ICD9	998.59	other postoperative infection
ICD9	999.31	other and unspecified infection due to central venous catheter
ICD9	999.32	bloodstream infection due to central venous catheter
ICD9	999.33	local infection due to central venous catheter
ICD9	999.34	acute infection following transfusion infusion or injection of blood and blood products
ICD9	999.39	infection following other infusion injection transfusion or vaccination
ICD10	A02.1	salmonella sepsis
ICD10	A02.20	localized salmonella infection unspecified
ICD10	A02.29	salmonella with other localized infection
ICD10	A02.8	other specified salmonella infections
ICD10	A02.9	salmonella infection unspecified
ICD10	A04.0	enteropathogenic escherichia coli infection
ICD10	A04.1	enterotoxigenic escherichia coli infection
ICD10	A04.2	enteroinvasive escherichia coli infection
ICD10	A04.3	enterohemorrhagic escherichia coli infection
ICD10	A04.4	other intestinal escherichia coli infections
ICD10	A04.8	other specified bacterial intestinal infections
ICD10	A04.9	bacterial intestinal infection unspecified
ICD10	A08.8	other specified intestinal infections
ICD10	A26.7	erysipelothrix sepsis
ICD10	A31.0	pulmonary mycobacterial infection
ICD10	A31.8	other mycobacterial infections
ICD10	A31.9	mycobacterial infection unspecified
ICD10	A32.7	listerial sepsis
ICD10	A40.0	sepsis due to streptococcus group a
ICD10	A40.1	sepsis due to streptococcus group b

Code Type	Code	Description
ICD10	A40.8	other streptococcal sepsis
ICD10	A40.9	streptococcal sepsis unspecified
ICD10	A41.01	sepsis due to methicillin susceptible staphylococcus aureus
ICD10	A41.02	sepsis due to methicillin resistant staphylococcus aureus
ICD10	A41.1	sepsis due to other specified staphylococcus
ICD10	A41.2	sepsis due to unspecified staphylococcus
ICD10	A41.4	sepsis due to anaerobes
ICD10	A41.50	gram-negative sepsis unspecified
ICD10	A41.51	sepsis due to escherichia coli [e. coli]
ICD10	A41.52	sepsis due to pseudomonas
ICD10	A41.53	sepsis due to serratia
ICD10	A41.59	other gram-negative sepsis
ICD10	A41.81	sepsis due to enterococcus
ICD10	A41.89	other specified sepsis
ICD10	A41.9	sepsis unspecified organism
ICD10	A48.52	Wound botulism
ICD10	A49.01	methicillin susceptible staphylococcus aureus infection unspecified site
ICD10	A49.02	methicillin resistant staphylococcus aureus infection unspecified site
ICD10	A49.1	streptococcal infection unspecified site
ICD10	A49.3	mycoplasma infection unspecified site
ICD10	A49.8	other bacterial infections of unspecified site
ICD10	A49.9	bacterial infection unspecified
ICD10	A69.1	other vincent's infections
ICD10	A69.8	other specified spirochetal infections
ICD10	A69.9	spirochetal infection unspecified
ICD10	B17.0	acute delta-(super) infection of hepatitis b carrier
ICD10	B37.7	candidal sepsis
ICD10	B66.8	other specified fluke infections
ICD10	B66.9	fluke infection unspecified
ICD10	B67.2	echinococcus granulosus infection of bone
ICD10	B67.32	echinococcus granulosus infection multiple sites
ICD10	B67.39	echinococcus granulosus infection other sites
ICD10	B67.4	echinococcus granulosus infection unspecified
ICD10	B67.61	echinococcus multilocularis infection multiple sites
ICD10	B67.69	echinococcus multilocularis infection other sites
ICD10	B67.7	echinococcus multilocularis infection unspecified
ICD10	B71.8	other specified cestode infections
ICD10	B71.9	cestode infection unspecified
ICD10	B95.61	methicillin susceptible staphylococcus aureus infection as the cause of diseases classified elsewhere

Code Type	Code	Description
ICD10	B9562	methicillin resistant staphylococcus aureus infection as the cause of diseases classified
ICD10	D70.3	neutropenia due to infection
ICD10	D76.2	hemophagocytic syndrome infection-associated
ICD10	H59.40	inflammation (infection) of postprocedural bleb unspecified
ICD10	H59.41	inflammation (infection) of postprocedural bleb stage 1
ICD10	H59.42	inflammation (infection) of postprocedural bleb stage 2
ICD10	H59.43	inflammation (infection) of postprocedural bleb stage 3
ICD10	K56.5	intestinal adhesions [bands] with obstruction (postprocedural) (postinfection)
ICD10	K66.0	peritoneal adhesions (postprocedural) (postinfection)
ICD10	K94.02	colostomy infection
ICD10	K94.12	enterostomy infection
ICD10	N99.511	cystostomy infection
ICD10	R65.20	severe sepsis without septic shock
ICD10	R65.21	severe sepsis with septic shock
ICD10	T80.211A	bloodstream infection due to central venous catheter initial encounter
ICD10	T80.211D	bloodstream infection due to central venous catheter subsequent encounter
ICD10	T80.211S	bloodstream infection due to central venous catheter sequela
ICD10	T80.218A	other infection due to central venous catheter initial encounter
ICD10	T80.218D	other infection due to central venous catheter subsequent encounter
ICD10	T80.218S	other infection due to central venous catheter sequela
ICD10	T80.219A	unspecified infection due to central venous catheter initial encounter
ICD10	T80.219D	unspecified infection due to central venous catheter subsequent encounter
ICD10	T80.219S	unspecified infection due to central venous catheter sequela
ICD10	T80.22XA	acute infection following transfusion infusion or injection of blood and blood products initial encounter
ICD10	T80.22XD	acute infection following transfusion infusion or injection of blood and blood products subsequent encounter
ICD10	T80.22XS	acute infection following transfusion infusion or injection of blood and blood products sequela
ICD10	T80.29XA	infection following other infusion transfusion and therapeutic injection initial encounter
ICD10	T80.29XD	infection following other infusion transfusion and therapeutic injection subsequent encounter
ICD10	T80.29XS	infection following other infusion transfusion and therapeutic injection sequela
ICD10	T81.4XXA	infection following a procedure initial encounter
ICD10	T81.4XXD	infection following a procedure subsequent encounter
ICD10	T81.4XXS	infection following a procedure sequela
ICD10	T83.51XA	infection and inflammatory reaction due to indwelling urinary catheter initial encounter
ICD10	T83.51XD	infection and inflammatory reaction due to indwelling urinary catheter subsequent encounter
ICD10	T83.51XS	infection and inflammatory reaction due to indwelling urinary catheter sequela
ICD10	V09.0	infection with microorganisms resistant to penicillins
ICD10	V09.1	infection with microorganisms resistant to cephalosporins and other b-lactam antibiotics
ICD10	V09.2	infection with microorganisms resistant to macrolides

Code Type	Code	Description
ICD10	V09.3	infection with microorganisms resistant to tetracyclines
ICD10	V09.4	infection with microorganisms resistant to aminoglycosides
ICD10	V09.50	infection with microorganisms without mention of resistance to multiple quinolones and fluroquinolon
ICD10	V09.51	infection with microrganisms with resistance to multiple quinolones and fluroquinolones
ICD10	V09.6	infection with microorganisms resistant to sulfonamides
ICD10	V09.70	infection with microorganisms without mention of resistance to multiple antimycobacterial agents
ICD10	V09.71	infection with microorganisms with resistance to multiple antimycobacterial agents
ICD10	V09.80	infection with microorganisms without mention of resistance to multiple drugs
ICD10	V09.81	infection with microorganisms with resistance to multiple drugs
ICD10	V09.90	infection with drug-resistant microorganisms unspecified without mention of multiple drug resistance
ICD10	V09.91	infection with drug-resistant microorganisms unspecified with multiple drug resistance
ICD10	K61.0	ANAL ABSCESS
ICD10	K61.1	RECTAL ABSCESS
ICD10	K61.2	ANORECTAL ABSCESS
ICD10	K61.3	ISCHIORECTAL ABSCESS
ICD10	K61.4	INTRASPHINCTERIC ABSCESS
ICD10	K63.0	ABSCESS OF INTESTINE
ICD10	K65.1	PERITONEAL ABSCESS
ICD10	K68.11	POSTPROCEDURAL RETROPERITONEAL ABSCESS
ICD10	K68.12	PSOAS MUSCLE ABSCESS
ICD9	566	ABSCESS OF ANAL AND RECTAL REGIONS
ICD9	567.22	PERITONEAL ABSCESS
ICD9	567.31	PSOAS MUSCLE ABSCESS
ICD9	567.38	OTHER RETROPERITONEAL ABSCESS
ICD9	569.5	ABSCESS OF INTESTINE
ICD9	590.2	RENAL AND PERINEPHRIC ABSCESS
ICD9	614.3	ACUTE PARAMETRITIS AND PELVIC CELLULITIS
ICD10	N73.0	ACUTE PARAMETRITIS AND PELVIC CELLULITIS
ICD10	N73.1	CHRONIC PARAMETRITIS AND PELVIC CELLULITIS
ICD10	N73.2	UNSPECIFIED PARAMETRITIS AND PELVIC CELLULITIS

Table

Supplementary Table 3. Procedure codes used to identify superficial SSI in colorectal surgeries.

Code Type	Code	Description
ICD9-Diagnosis	682.6	Other cellulitis and abscess, Leg, except foot
ICD9-Diagnosis	998.32	Disruption of external operation (surgical) wound
ICD9-Diagnosis	998.5	Postoperative infection
ICD9-Diagnosis	998.51	Infected postoperative seroma
ICD9-Diagnosis	998.59	Other postoperative infection
CPT	10030	Image-guided fluid collection drainage by catheter (eg, abscess, hematoma, seroma, lymphocele, cyst), soft tissue (eg, extremity, abdominal wall, neck), percutaneous
CPT	10160	Puncture aspiration of abscess, hematoma, bulla, or cyst
CPT	10180	Incision and drainage, complex, postoperative wound infection
ICD10-CM	T81.30	Disruption of wound, unspecified
ICD10-CM	T81.30XA	Disruption of wound, unspecified, initial encounter
ICD10-CM	T81.30XD	Disruption of wound, unspecified, subsequent encounter
ICD10-CM	T81.30XS	Disruption of wound, unspecified, sequela
ICD10-CM	T81.31	Disruption of external operation (surgical) wound, not elsewhere classified
ICD10-CM	T81.31XA	Disruption of external operation (surgical) wound, not elsewhere classified, initial encounter
ICD10-CM	T81.31XD	Disruption of external operation (surgical) wound, not elsewhere classified, subsequent encounter
ICD10-CM	T81.31XS	Disruption of external operation (surgical) wound, not elsewhere classified, sequela
ICD10-CM	T81.4	Infection following a procedure, unspecified
ICD10-CM	T81.4XXA	Infection following a procedure, initial encounter
ICD10-CM	T81.4XXD	Infection following a procedure, subsequent encounter
ICD10-CM	T81.4XXS	Infection following a procedure, sequela
ICD10-CM	T80.212A	Local infection due to central venous catheter, initial encounter
ICD10-CM	T81.82XA	Emphysema (subcutaneous) resulting from a procedure, initial encounter
ICD10-CM	T80.212D	Local infection due to central venous catheter, subsequent encounter
ICD10-CM	T80.212S	Local infection due to central venous catheter, sequela
ICD10-CM	T81.82XD	Emphysema (subcutaneous) resulting from a procedure, subsequent encounter
ICD9-Diagnosis	682.2	CELLULITIS AND ABSCESS OF TRUNK
ICD9-Diagnosis	682.5	CELLULITIS AND ABSCESS OF BUTTOCK
ICD9-Diagnosis	682.6	CELLULITIS AND ABSCESS OF LEG EXCEPT FOOT
ICD9-Diagnosis	682.7	CELLULITIS AND ABSCESS OF FOOT EXCEPT TOES
ICD9-Diagnosis	682.8	CELLULITIS AND ABSCESS OF OTHER SPECIFIED SITES
ICD9-Diagnosis	682.9	CELLULITIS AND ABSCESS OF UNSPECIFIED SITES
ICD10-CM	L03.115	CELLULITIS OF RIGHT LOWER LIMB

Code Type	Code	Description
ICD10-CM	L03.116	CELLULITIS OF LEFT LOWER LIMB
ICD10-CM	L03.119	CELLULITIS OF UNSPECIFIED PART OF LIMB
ICD10-CM	L03.311	CELLULITIS OF ABDOMINAL WALL
ICD10-CM	L03.312	CELLULITIS OF BACK [ANY PART EXCEPT BUTTOCK]
ICD10-CM	L03.313	CELLULITIS OF CHEST WALL
ICD10-CM	L03.314	CELLULITIS OF GROIN
ICD10-CM	L03.315	CELLULITIS OF PERINEUM
ICD10-CM	L03.316	CELLULITIS OF UMBILICUS
ICD10-CM	L03.317	CELLULITIS OF BUTTOCK
ICD10-CM	L03.319	CELLULITIS OF TRUNK UNSPECIFIED
ICD10-CM	L03.818	CELLULITIS OF OTHER SITES
ICD10-CM	L03.90	CELLULITIS UNSPECIFIED
ICD10-CM	O90.0	DISRUPTION OF CESAREAN DELIVERY WOUND
ICD10-CM	O90.1	DISRUPTION OF PERINEAL OBSTETRIC WOUND

Table

Supplementary Table 4. Key comorbidities of patients included in the study, at study start and based on infection status at 6 months post-index.

Elixhauser Comorbidity	Overall (n=107,665)		Infection (n=25,733)		No Infection (n=81,932)	
	N	%	N	%	N	%
Hypertension, uncomplicated	50,553	47.0%	12,981	50.4%	37,572	45.9%
Solid tumor without metastasis	32,289	30.0%	6,934	26.9%	25,355	30.9%
Chronic pulmonary disease	19,544	18.2%	5,813	22.6%	13,731	16.8%
Fluid and electrolyte disorders	18,722	17.4%	6,456	25.1%	12,266	15.0%
Cardiac arrhythmias	18,710	17.4%	5,559	21.6%	13,151	16.1%
Diabetes, uncomplicated	18,253	17.0%	5,234	20.3%	13,019	15.9%
Depression	17,380	16.1%	5,334	20.7%	12,046	14.7%
Obesity	16,865	15.7%	4,773	18.5%	12,092	14.8%
Liver disease	15,363	14.3%	3,867	15.0%	11,496	14.0%
Hypothyroidism	13,678	12.7%	3,482	13.5%	10,196	12.4%
Deficiency anemia	13,520	12.6%	3,743	14.5%	9,777	11.9%
Weight loss	9,990	9.3%	3,437	13.4%	6,553	8.0%
Peripheral vascular disorders	9,446	8.8%	2,846	11.1%	6,600	8.1%
Diabetes, complicated	8,360	7.8%	2,692	10.5%	5,668	6.9%
Valvular disease	8,186	7.6%	2,328	9.0%	5,858	7.1%
Metastatic cancer	7,327	6.8%	2,024	7.9%	5,303	6.5%
Renal failure	6,811	6.3%	2,213	8.6%	4,598	5.6%
Congestive heart failure	6,608	6.1%	2,268	8.8%	4,340	5.3%
Hypertension, complicated	6,335	5.9%	1,977	7.7%	4,358	5.3%
Rheumatoid arthritis/ collagen vascular diseases	5,343	5.0%	1,660	6.5%	3,683	4.5%
Other neurological disorders	5,052	4.7%	1,865	7.2%	3,187	3.9%
Blood loss anemia	4,820	4.5%	1,311	5.1%	3,509	4.3%
Coagulopathy	3,979	3.7%	1,308	5.1%	2,671	3.3%
Drug abuse	3,559	3.3%	1,362	5.3%	2,197	2.7%

Elixhauser Comorbidity	Overall (n=107,665)		Infection (n=25,733)		No Infection (n=81,932)	
	N	%	N	%	N	%
Alcohol abuse	3,248	3.0%	1,042	4.0%	2,206	2.7%
Pulmonary circulation disorders	2,895	2.7%	1,041	4.0%	1,854	2.3%
Peptic ulcer disease	2,447	2.3%	715	2.8%	1,732	2.1%
Psychoses	1,665	1.5%	640	2.5%	1,025	1.3%
Paralysis	1,625	1.5%	847	3.3%	778	0.9%
Lymphoma	1,103	1.0%	311	1.2%	792	1.0%
AIDS/HIV	524	0.5%	127	0.5%	397	0.5%

Figure
Figure 1:

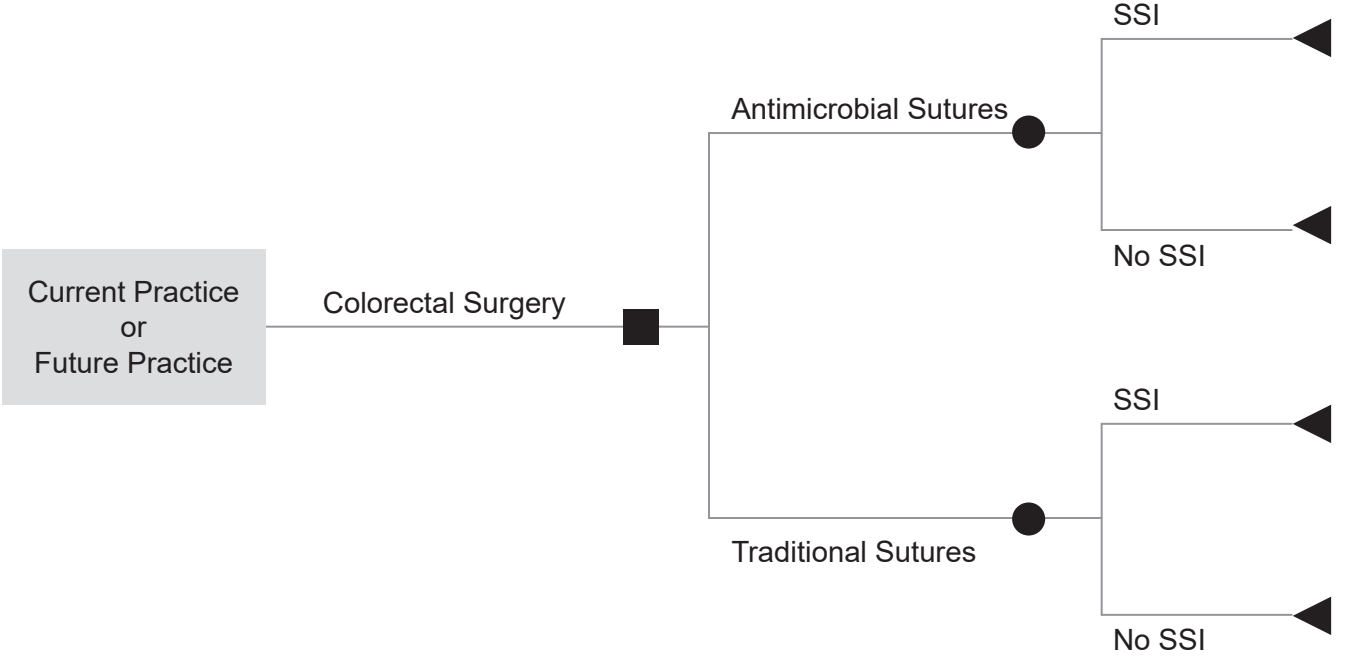
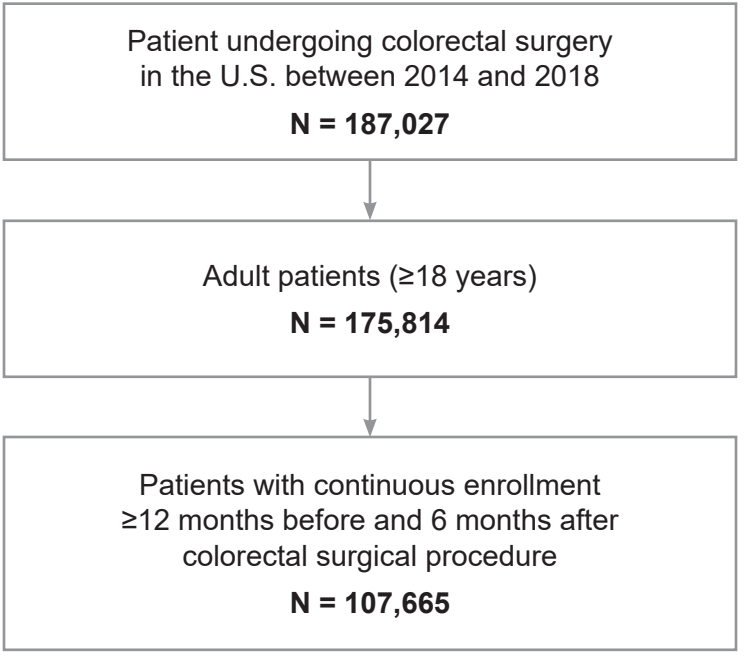


Figure
Figure 2:



Figure

Figure 3:

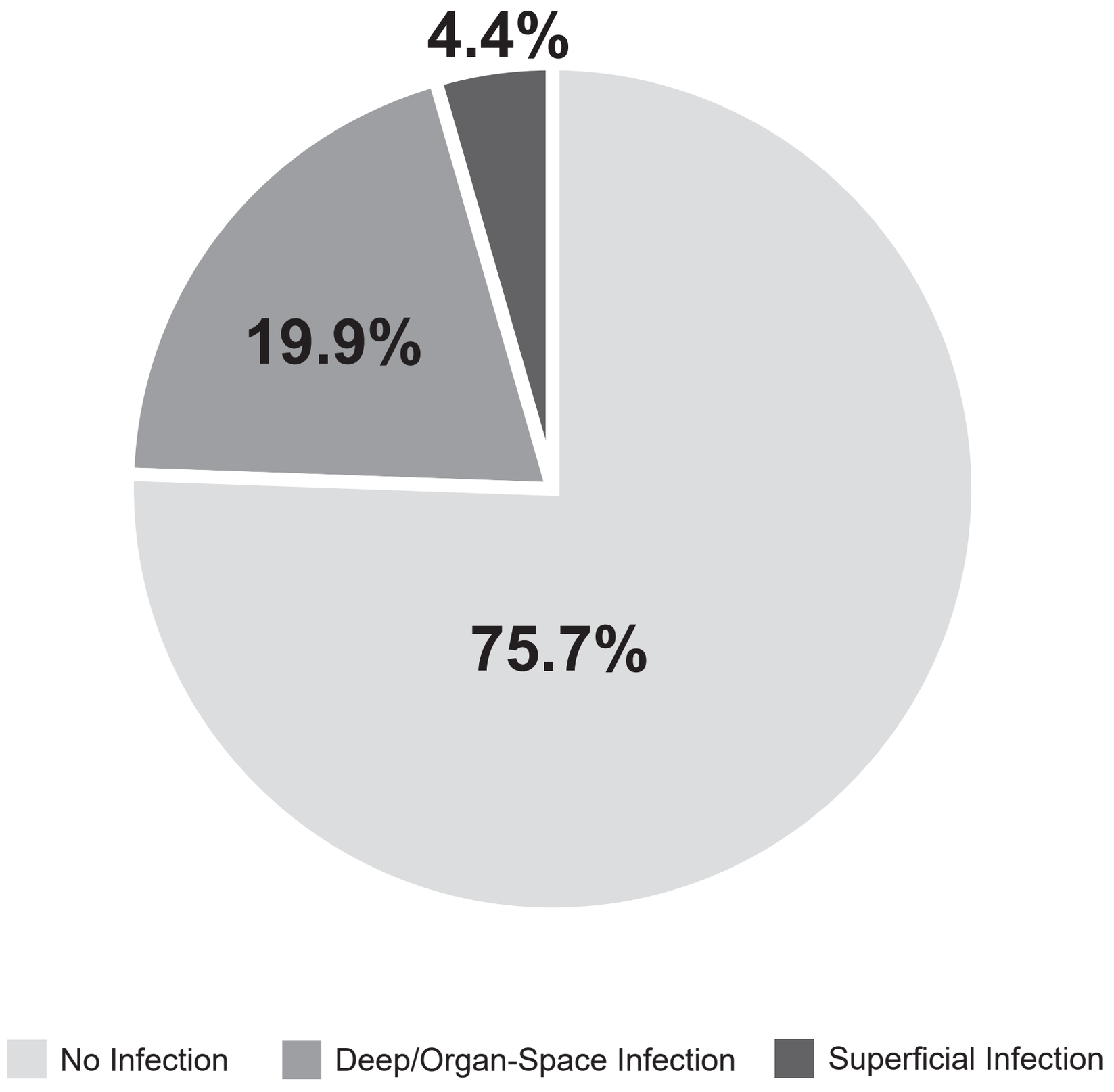
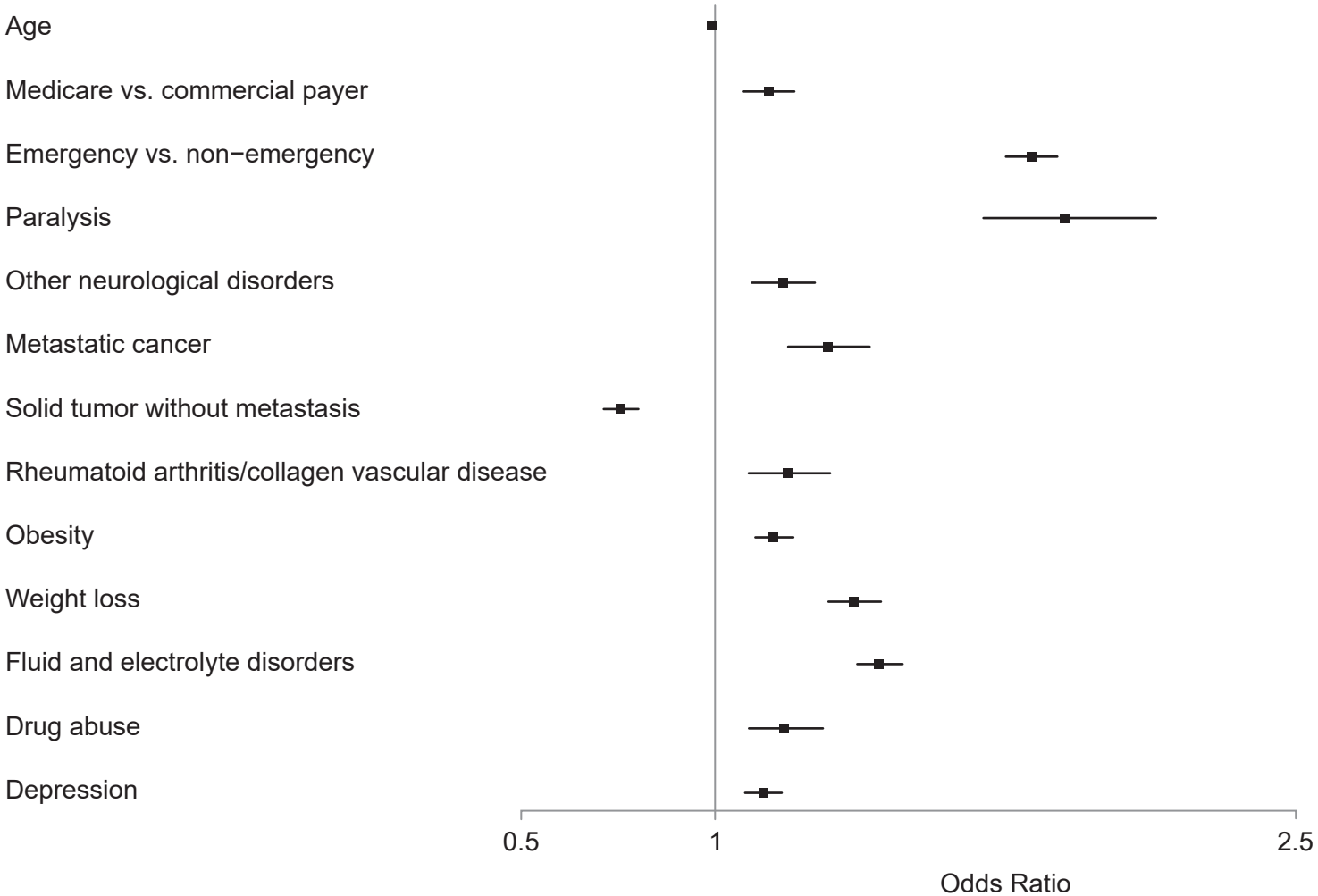
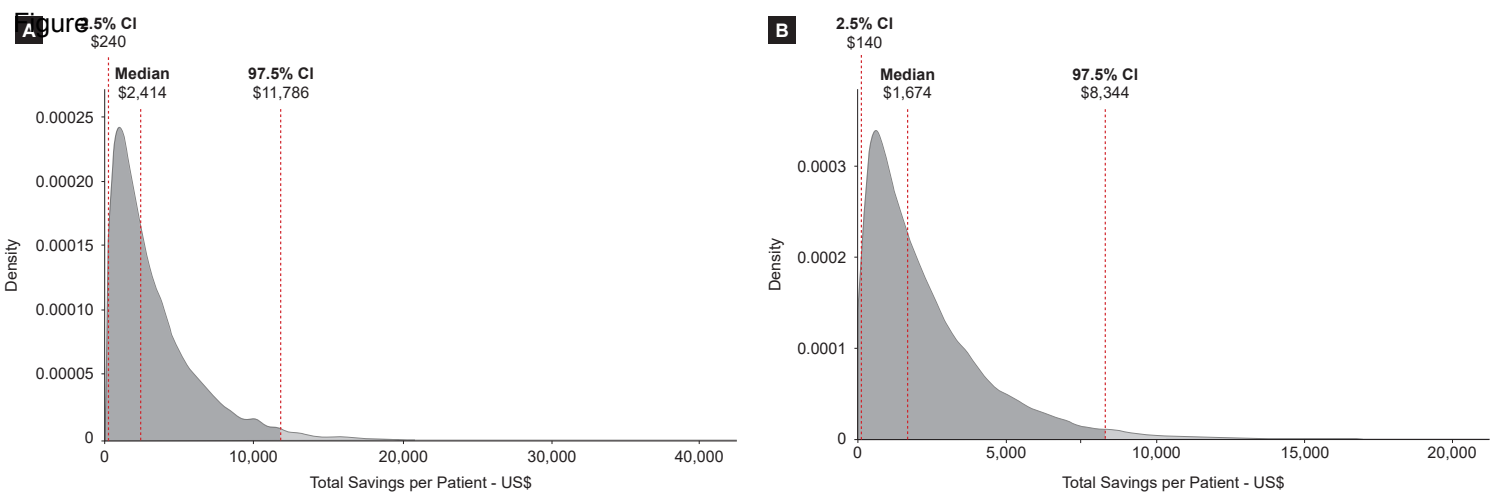


Figure
Figure 4:



Figure


A
2.5% CI
$240
Median
$2,414
97.5% CI
$11,786
Density
0.00025
0.00020
0.00015
0.00010
0.00005
0
0
10,000
20,000
30,000
40,000
Total Savings per Patient - US$
B
2.5% CI
$140
Median
$1,674
97.5% CI
$8,344
Density
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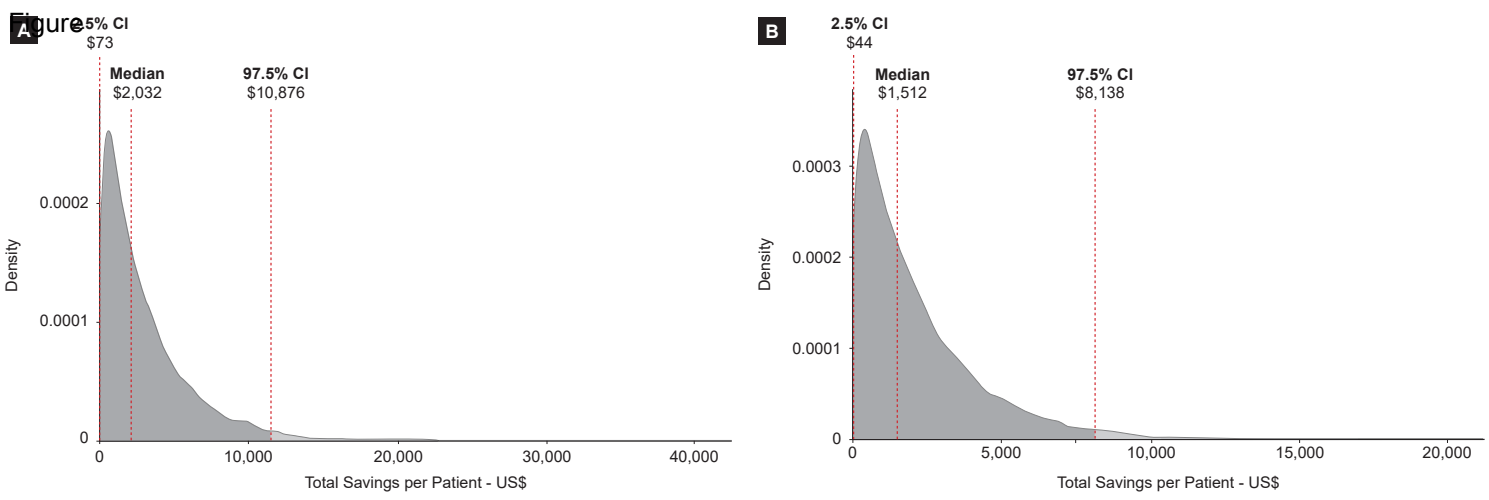
0.0001
0
0
5,000
10,000
15,000
20,000
Total Savings per Patient - US$

Figure


A
2.5% CI
$73
Median
$2,032
97.5% CI
$10,876
Density
0.0002
0.0001
0
0
10,000
20,000
30,000
40,000
Total Savings per Patient - US$
B
2.5% CI
$44
Median
$1,512
97.5% CI
$8,138
Density
0.0003
0.0002
0.0001
0
0
5,000
10,000
15,000
20,000
Total Savings per Patient - US$

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4, 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4, 5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	4, 5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4, 5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4, 5
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4, 5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4, 5
		(*b*) Describe any methods used to examine subgroups and interactions	4, 5
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	5
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6 Supplement
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Figure 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6 (Table 1)
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	6
Outcome data	15*	Report numbers of outcome events or summary measures over time	6, 7 Figure 3, 4 Table 3

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	6, 7 NA NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6, 7
Discussion			
Key results	18	Summarise key results with reference to study objectives	7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	7-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	7-10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1, 11

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Authorship Criteria Form for More than 8 Authors (available at http://journals.lww.com/dcrjournal/Documents/DCR%20Authorship

Each author must check at least one box in each of the 4 categories

Author Name	1			2		3	4	Author Signature
	Study conception design	Data acquisition	Data analysis and interpretation	Drafting the article	Critical revision for intellectual content	Final approval of the manuscript	Agree to be accountable for all aspects of work to ensure that questions regarding accuracy & integrity investigated & resolved	
Andrew Hogan			X	X	X	X	X	A Hogan
George Wright			X	X	X	X	X	G Wright
Brian [illegible] Chen	X	X	X		X	X	X	
Abhishek Chinnis	X	X	X		X	X	X	
Chantal Holy	X	X	X		X	X	X	
Maureen Spencer				X	X	X	X	Maureen Spencer
DAVID LEAPER	X			X	X	X	X	
Charles Edmiston	X			X	X	X	X	Charles Edmiston

Potential authors who do not fulfill the above criteria (at least one box checked in each of the 4 categories) should be listed in the "Acknowledgments" section. DCR follows the recommendations of the International Committee of Medical Journal Editors (ICMJE) http://www.icmje.org/recommendations/browse/roles-and-responsibilities/defining-the-role-of-authors-and-contributors.html