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Adverse impact of surgical site infections in English hospitals

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Summary Between October 1997 and June 2001, 140 English hospitals participating in the surveillance of surgical site infection (SSI) with the Nosocomial Infection National Surveillance Service (NINSS) reported 2832 SSIs following 67 410 surgical procedures in nine defined categories of surgery. Limb amputation had the highest incidence of SSI with 14.3 SSIs per 100 operations. For all categories of surgery, except knee prosthesis ($P=0.128$), there was a linear increase in the incidence of SSI when the American National Nosocomial Infections Surveillance risk index increased. Superficial incisional SSI was more common than deep incisional and organ/space SSI, and accounted for more than half of all SSIs for all categories of surgery. The postoperative length of stay (LOS) was longer for patients with SSI, and when adjusted for other factors influencing LOS, the extra LOS due to SSI ranged from 3.3 days for abdominal hysterectomy to 21.0 days for limb amputation, and was at least nine days for the other categories. The additional cost attributable to SSI ranged from £959 for abdominal hysterectomy to £6103 for limb amputation. Deep incisional and organ/space SSI combined incurred a greater extra LOS and cost than superficial incisional SSI for all categories of surgery, except limb amputation. The crude mortality rate was higher for patients with SSI for all categories of surgery but, after controlling for confounding, only patients with SSI following hip prosthesis had a mortality rate that was significantly higher than those without SSI [odds ratio (OR) = 1.8,

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$P=0.002$]. However, the adjusted mortality rate for patients with deep incisional and organ/space SSI compared with those without SSI was significantly higher for vascular surgery (OR=6.8, $P<0.001$), hip prosthesis (OR=2.5, $P=0.005$) and large bowel surgery (OR=1.8, $P=0.04$). This study shows that the adverse impact of SSI differs greatly for different categories of surgery, and highlights the importance of measuring the impact for defined categories rather than for all SSIs and all surgical procedures.

Introduction

It is estimated that, on average, 2-5% of surgical patients will develop surgical site infection (SSI).[1-6] In the USA, Martone *et al.*[7] estimated that 0.64% of hospital deaths were directly attributable to these infections. In a recent study from Europe, 38% of deaths in patients with SSI were due to the infection, giving an attributable mortality of 0.9%.[6] In addition, patients with SSI have a prolonged length of hospital stay with an associated increased cost of hospitalization. The magnitude of these adverse events varies according to the surgical procedure, country of study, year of publication and the methods used.[8-19]

Hitherto, there has been inadequate information for English hospitals on the adverse effects of SSI in defined categories of surgical procedures. However, the Nosocomial Infection National Surveillance Service (NINSS) provided English hospitals for the first time with standard methods for the surveillance of SSI and comparative data to assess their infection rates.[20] NINSS was established in 1996 by the Department of Health (DH) and the Public Health Laboratory Service—now part of the Health Protection Agency (HPA)—and was available to English hospitals until September 2002 when NINSS was suspended by the DH. However, the surveillance of SSI based on the same methodology has continued with the new Surgical Site Infection Surveillance Service based at the Health Care Associated Infection and Antimicrobial Resistance Department at the Communicable Disease Surveillance Centre within the HPA.

The NINSS surveillance of SSI[21,22] was targeted at 12 categories of surgery, and since October 1997, more than 150 English hospitals have participated in the surveillance of one or more of these 12 categories. This provided a unique opportunity to determine the incidence of SSI for defined categories of surgery based on a large number of hospitals, and to estimate the adverse consequences following the development of SSI, namely the associated extra postoperative hospital stay, additional cost and mortality.

Materials and methods

NINSS surveillance of SSI

The NINSS surveillance system for SSI is described in detail elsewhere,[21,22] and was based on the National Nosocomial Infections Surveillance (NNIS) system at the Centers for Disease Control and Prevention (CDC) in the USA.[23] Definitions of SSI as superficial incisional, deep incisional or organ/space are described elsewhere,[21] and were based on the CDC 1992 definitions for SSI.[24]

Participation in the NNISS surveillance of SSI was voluntary but participating hospitals were required to carry out surveillance for at least three consecutive calendar months. Hospitals could choose one or more of the 12 categories of surgery available for surveillance, i.e. abdominal hysterectomy, bile duct/liver/pancreatic surgery, non-laparoscopic cholecystectomy, coronary artery bypass graft (CABG), gastric surgery, hip prosthesis, knee prosthesis, large bowel surgery, limb amputation, open reduction of long bone fracture, small bowel surgery and vascular surgery.

Demographic, discharge and potential risk factor data were recorded for each patient undergoing surgery in any of the chosen surgical categories. Additional infection data were collected for patients who developed SSI. Data were collected locally on forms designed to be scanned centrally by NINSS using an optical mark recognition system. Data were then transferred to an Access™ database where they were checked for inaccuracies, logical inconsistencies and missing values.

This study is based on the surveillance data provided by 140 hospitals between October 1997 and June 2001. To be included in the study, the hospital must have contributed more than 10 surgical procedures in a chosen category, and the total number of surgical procedures contributed by all hospitals to a given category must be at least 500. For this reason, bile duct/liver/pancreatic surgery, non-laparoscopic cholecystectomy and gastric surgery were excluded from the study. Lastly, because postdischarge follow-up was voluntary, only SSIs diagnosed during the hospital admission for the operation were included.

Analysis of data

Incidence of SSI

Using aggregated data from all participating hospitals, the overall incidence of SSI (i.e. number of SSIs per 100 operations in that category) and 95% confidence intervals (CIs), using the exact binomial method, were estimated for each surgical category.

The incidence of SSI was stratified by the American NNIS risk index[25] which ranges from 0 to 3 according to the presence of three major risk factors, i.e. the American Society of Anesthesiology (ASA) pre-operative score, wound class and duration of operation. However, some procedures could not be classified by this risk index because information, particularly the ASA score, was missing. Due to the relatively small number of procedures in risk group 3, procedures in risk groups 2 and 3 were combined. Chi-square for linear trend was calculated to determine whether there was an association between the risk of developing an SSI and the risk index.

Infections were classified by type as superficial incisional, deep incisional and organ/space SSI. However, deep incisional and organ/space SSIs were combined because of the small number of organ/space infections.

Postoperative length of hospital stay

Patients were followed-up for the development of infection from the day of operation until the date of discharge or death, or until the surveillance was discontinued because of re-operation or completion of the surveillance follow-up. For patients with surgical procedures without implants, the maximum period of surveillance was 30 postoperative hospital days, while for those with implants, surveillance was continued for a maximum of 120 days. A censored normal regression model was used in order to include patients for whom the date of discharge or death was unknown (i.e. 30.4% of patients with limb amputation, 10.9% of open reduction of long bone fracture, 9.6% of small bowel surgery, 7.9% of large bowel surgery, 7.4% of vascular surgery, 3.6% of hip prosthesis, 2.5% of knee prosthesis, 2.0% of CABG and 0.3% of abdominal hysterectomies). The natural log of the number of days was the dependent variable, and the presence of SSI and type of SSI (i.e. superficial incisional SSI, and deep incisional and organ/space SSI combined) were used as explanatory variables to allow direct estimates of the ratios of the geometric mean of the postoperative length of hospital stay of patients with SSI compared with that of patients without SSI. Additional explanatory variables (i.e. age, sex, pre-operative length of hospital stay, ASA score, wound class, duration of operation, elective/emergency surgery, multiple procedures through the same incision, implants and operation due to trauma) were used to ensure that their potential confounding effects were taken into account. Estimates of extra LOS were also obtained for superficial incisional SSI, and deep incisional and organ/space SSI combined. The observed time since operation in those patients who had not died or been discharged were considered to be right censored in the analysis.

Cost of SSI

The additional cost of SSI per bed-day was derived from a study conducted in England during 1995–1996 by Plowman *et al.*,[18] in which the mean additional hospital cost incurred per SSI was calculated to be £1594 and the average extra LOS was 7.1 days. A figure of £224.50 per additional bed-day was obtained by dividing their extra cost by their extra LOS. This figure was then adjusted by the hospital and community health service annual inflation index, published in *Unit cost of health and social care 2003*,[26] to give a current estimate of £290.60 per extra day spent in hospital due to SSI. This estimate was multiplied by the average number of extra postoperative days found in this study to give the additional cost of SSI for each category of surgery and for different types of SSI (superficial incisional, and deep incisional and organ/space combined).

Mortality during surveillance follow-up

Due to the surveillance methodology used by NINSS, the estimates of mortality were based on whether the patient died or was still alive at discharge or at the end of the surveillance follow-up. This provided minimum estimates of the mortality rates during hospital admission. A multivariable logistic regression analysis was used to provide estimates for the odds ratio (OR) as a measure of the association between development of SSI and mortality. The same additional explanatory variables used in the postoperative LOS were used in the logistic regression model to control for their confounding effect on the association between mortality and SSI. The OR and its 95% CIs were calculated for each category of surgery.

Analysis was performed using STATA for Windows version 8 (Stata Corp., College Station, TX, USA).

Results

Between October 1997 and June 2001, 67 410 surgical procedures and 2832 SSIs were reported by 140 of the English hospitals participating in the SSI surveillance of one or more of the nine categories of surgery shown in Table I.

Incidence of SSI

Table I shows the number of hospitals that had participated in each category of surgery, and this ranged from 102 hospitals (72.9%) that had performed surveillance of hip prosthesis to 14 (10.0%) that had performed surveillance of small bowel surgery. Limb amputation had the highest incidence of SSI (14.3 per 100 operations), followed by small and large bowel surgery, both with a 10% incidence. Infections were least common after abdominal hysterectomy (2.5%), and hip and knee prostheses (3.1% and 1.9%, respectively).

Table II shows the incidence of SSI stratified by three risk index groups (0, 1, and 2 and 3 combined) for 54 642 procedures for which complete risk factor information was provided. Of the remaining 12 768 procedures, the percentage that could not be classified ranged from 9% for CABG procedures to 31% for small bowel procedures. The proportion of patients for whom risk factor information was not recorded was similar for all participating hospitals. There was, in general, an increase in the incidence of SSI as the risk index group increased, with the lowest incidence for procedures in risk index group 0 and the highest incidence for those in risk index groups 2 and 3. The Chi-square for linear trend (Table II) shows that this linear increase in the incidence of SSI with increasing risk index was statistically significant for all categories except knee prosthesis ($P=0.128$). There was only weak evidence of a linear increase for small bowel surgery ($P=0.058$). The influence of the number of risk factors on the incidence of SSI was particularly apparent for large bowel surgery, vascular surgery, CABG and abdominal hysterectomy, where the incidence increased more than three-fold for procedures in risk index groups 2 and 3 compared with those in risk index group 0.

Superficial incisional SSI was the most common type of SSI (Figure 1) and accounted for more than two-thirds of all types of SSI for all categories, except large and small bowel surgery where 57.9% and 51.8% of SSIs, respectively, were superficial. Deep incisional SSI was more common following small bowel surgery, limb amputation, large bowel surgery and CABG, accounting for 33.9%, 30.7%, 26.6% and 25.3% of all SSIs, respectively. Organ/space SSI accounted for less than 10% of all SSIs for all categories of surgery, except for large and small bowel surgery where these infections accounted for 15.5% and 14.3% of all SSIs, respectively.

Postoperative LOS and hospital cost

Table III gives the postoperative LOS for patients without SSI by category of surgery, and the adjusted extra postoperative LOS for those with SSI after

Table I Distribution of participating hospitals and incidence of surgical site infection (SSI) per 100 operations by surgical procedure

Surgical procedure	No. (%) participating hospitals ($N=140$)	No. operations	No. SSIs	Incidence of SSI per 100 operations (95% CI)
Limb amputation	27 (19.3)	1162	166	14.3 (12.3-16.4)
Small bowel surgery	14 (10.0)	558	56	10.0 (7.7-12.8)
Large bowel surgery	50 (35.7)	6528	653	10.0 (9.3-10.8)
Vascular surgery	40 (28.6)	3732	286	7.7 (6.8-8.6)
Coronary artery bypass graft	19 (13.6)	10 280	428	4.2 (3.8-4.6)
Open reduction of long bone fracture	22 (15.7)	2574	114	4.4 (3.7-5.3)
Hip prosthesis	102 (72.9)	24 002	734	3.1 (2.8-3.3)
Knee prosthesis	83 (59.3)	11 785	227	1.9 (1.7-2.2)
Abdominal hyster-ectomy	61 (43.6)	6789	168	2.5 (2.1-2.9)

CI, confidence interval.

Table II Incidence of surgical site infection (SSI) per 100 operations by risk index* and surgical procedure

Surgical procedure	Risk index 0		Risk index 1		Risk index 2 and 3		Chi square for linear trend	*P* value
	No. operations	Incidence (95% CI)	No. operations	Incidence (95% CI)	No. operations	Incidence (95% CI)		
Small bowel surgery	133	9.0 (4.7-15.2)	173	7.5 (4.1-12.5)	78	19.2 (11.2-29.7)	3.6	0.058
Limb amputation	134	8.2 (4.2-14.2)	408	14.5 (11.2-18.2)	307	16.9 (12.9-21.6)	4.5	0.035
Large bowel surgery	2161	5.6 (4.7-6.7)	2116	10.7 (9.4-12.1)	863	17.8 (15.3-20.6)	95.7	<0.001
Vascular surgery	675	4.3 (2.9-6.1)	1629	5.9 (4.8-7.2)	676	14.9 (12.3-17.8)	50.2	<0.001
Coronary artery bypass graft	526	2.5 (1.3-4. 2)	8267	4.0 (3.6-4.5)	536	8.0 (5.9-10.6)	19.8	<0.001
Open reduction of long bone fracture	978	3.2 (2.2-4.5)	900	5.0 (3.7-6.6)	173	8.7 (4.9-13.9)	10.5	0.001
Hip prosthesis	11 058	2.4 (2.1-2.7)	7376	3.6 (3.2-4.1)	999	5.0 (3.7-6.6)	37.0	<0.001
Knee prosthesis	5970	1.8 (1.4-2.1)	2745	2.1 (1.6-2.7)	380	2.6 (1.3-4.8)	2.3	0.128
Abdominal hysterectomy	4684	2.2 (1.8-2.7)	629	3.5 (2.2-5.2)	68	8.8 (3.3-18.2)	11.9	0.001

*Based on 54 642 procedures for which information on the risk factors needed to calculate the risk index were available.

controlling for factors that may influence LOS (age, sex, pre-operative LOS, ASA score, wound class, duration of operation, elective/emergency surgery, multiple procedures, implants and operations due to trauma). It also shows the additional cost due to SSI for different categories of surgery.

For patients without SSI, those undergoing limb amputation had the longest postoperative LOS (13.2 days), followed by those having small or large bowel

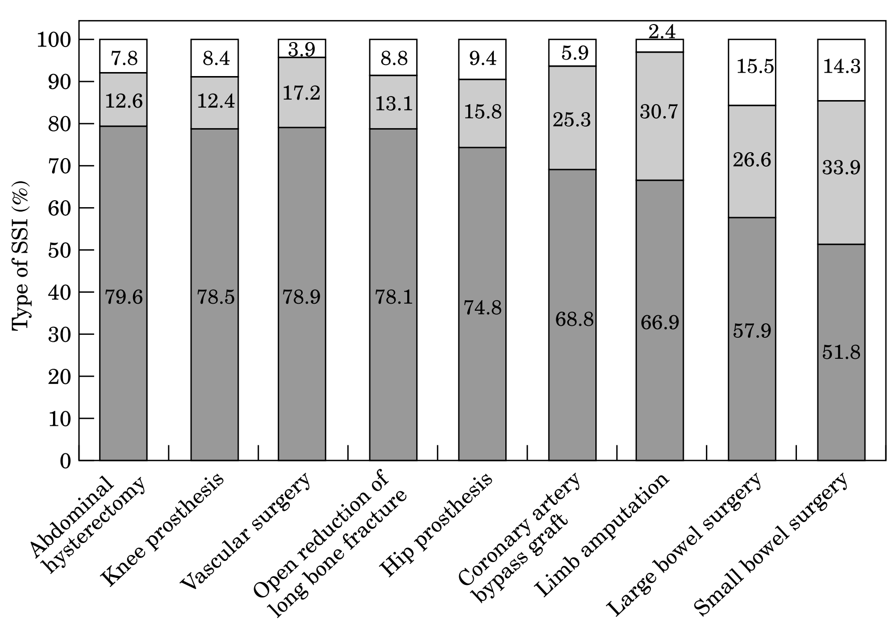

Figure 1 Distribution of surgical site infection (SSI) by type of SSI and category of surgery. ■, superficial incisional SSI; ▢, deep incisional SSI; □, organ/space SSI.

Table III Postoperative mean* length of stay (LOS) for patients with and without surgical site infection (SSI), and adjusted† extra LOS and cost‡ of hospitalization for patients with SSI by surgical procedure

Surgical procedure	Mean LOS for patients without SSI (days)	Extra LOS (95% CI) for patients with SSI (days)	Extra cost attributable to each SSI (£)
Limb amputation	13.2	21.0 (13.2–31.1)	6103
Small bowel surgery	11.5	13.2 (6.5–22.4)	3836
Vascular surgery	7.9	12.2 (9.8–15.0)	3545
Large bowel surgery	11.3	9.4 (8.1–10.8)	2732
Coronary artery bypass graft	7.4	13.4 (12.4–14.6)	3894
Hip prosthesis	11.1	11.5 (10.3–12.8)	3342
Knee prosthesis	10.3	10.9 (9.0–13.0)	3168
Open reduction of long bone fracture	9.6	9.9 (6.1–14.6)	2877
Abdominal hysterectomy	5.1	3.3 (2.7–4.0)	959

*Geometric mean. †Adjusted by age, sex, pre-operative length of hospital stay, American Society of Anesthesiology score, wound class, duration of operation, elective/emergency surgery, multiple procedures through the same incision, implants and operation due to trauma. ‡A cost of £290.60 per bed-day derived from Plowman *et al.*[16]

surgery (11.5 and 11.3 days, respectively). The shortest LOS (5.1 days) was for abdominal hysterectomy patients. For those patients with SSI, the unadjusted postoperative LOS was longer than in uninfected patients for all categories of surgery, and ranged from 9.5 days for abdominal hysterectomy to 51.1 days for limb amputation. Of 166 patients with limb amputation and SSI, 44% were still in hospital after the 30th postoperative day, which explained the long estimate of LOS in these patients. For patients in other surgical categories with SSI, the unadjusted postoperative LOS was at least 20 days (i.e. 37.7 days for open reduction of long bone fracture, 25.6 days for vascular surgery, 24.6 days for hip prosthesis, 23.8 days for small bowel surgery, 22.0 days for large bowel surgery, 21.7 days for CABG and 20.7 days for knee prosthesis). However, after controlling for factors that may influence the postoperative LOS, the adjusted extra LOS attributable to SSI decreased and ranged from 3.3 days for abdominal hysterectomy to 21 days for limb amputation, and was at least nine extra days for the other categories (Table III).

The additional cost attributable to the development of SSI is also shown in Table III and ranged from £959 for abdominal hysterectomy to £6103 for limb amputation.

The extra postoperative LOS, and the consequent extra cost attributable to SSI, varied according to the type of SSI (Table IV). The extra LOS for patients with deep incisional and organ/space SSI was much longer than for those with superficial incisional SSI for all surgical categories, with the exception of limb amputation with 21.2 extra days for superficial SSI and 20.2 days for deep and organ/space SSI. For example, for patients undergoing hip prosthesis, knee prosthesis, abdominal hysterectomy or CABG who developed deep incisional and organ/space SSI, the extra LOS was 2.6, 2.5, 2.4 and 2.0 times longer, respectively, than for those who developed superficial incisional SSI. The largest additional costs per SSI were for deep incisional and organ/space SSI after hip prosthesis (£6626) and CABG (£6422). The least extra cost for deep incisional and organ/space SSI was incurred in patients after abdominal hysterectomy (£1947).

Mortality

Table V shows the mortality rates for patients with and without SSI. For all categories of surgery, the mortality rate was higher for patients with SSI. However, after controlling for age, sex, preoperative LOS, ASA score, wound class, duration of operation, elective/emergency surgery, multiple procedures, implants and operations due to trauma, only patients with SSI following hip prosthesis had a mortality that was statistically significantly higher than those without SSI (OR$=$1.8, $P=0.002$). The number of deaths for abdominal hysterectomy was very small, and it was not possible to compare mortality in infected and uninfected patients.

Table V also shows the mortality rates for patients with superficial incisional SSI and for those with deep incisional and organ/space SSI combined, and the adjusted ORs compared with the mortality rates of patients without SSI. For superficial incisional SSI, only those undergoing hip

Table IV Adjusted* extra postoperative length of stay (LOS) and extra cost of hospitalization by type of surgical site infection (SSI) and surgical procedure

Surgical procedure	Extra LOS (95% CI) (days)		Extra cost per SSI (£)	
	Superficial incisional SSI	Deep incisional and organ/space SSI	Superficial incisional SSI	Deep incisional and organ/space SSI
Limb amputation	21.2 (12.3-33.6)	20.2 (8.3-39.2)	6161	5870
Vascular surgery	11.4 (8.8-14.3)	18.4 (11.7-27.3)	3313	5347
Small bowel surgery	12.9 (4.6-25.6)	13.4 (4.4-27.7)	3749	3894
Large bowel surgery	7.8 (6.4-9.4)	12.6 (10.1-15.3)	2267	3662
Coronary artery bypass graft	10.8 (9.7-11.9)	22.1 (19.2-25.2)	3138	6422
Hip prosthesis	8.9 (7.7-10.2)	22.8 (19.2-26.9)	2586	6626
Knee prosthesis	8.6 (6.6-10.7)	21.1 (15.5-27.9)	2499	6132
Open reduction of long bone fracture	8.4 (4.5-13.5)	15.4 (6.6-29.3)	2441	4475
Abdominal hyster-ectomy	2.8 (2.2-3.5)	6.7 (4.7-8.9)	814	1947

*Adjusted by age, sex, pre-operative length of hospital stay, American Society of Anesthesiology score, wound class, duration of operation, elective/emergency surgery, multiple procedures through the same incision, implants and operation due to trauma.

prosthesis had a mortality that was statistically significantly higher than those without SSI (OR$=$1.6, $P=0.04$). The mortality rate for patients with deep incisional and organ/space SSI compared with those without SSI was statistically significantly higher for vascular surgery (OR$=$6.8, $P<0.001$), large bowel surgery (OR$=$1.8, $P<0.04$) and hip prosthesis (OR$=$2.5, $P=0.005$). Overall, for all categories of surgery, with the exception of CABG, the mortality rates were higher for those patients who developed deep incisional and organ/space SSI than for those with superficial incisional SSI (Table V).

Discussion

The NINSS provided English hospitals for the first time with standard case definitions and methods for the surveillance of SSI, and many hospitals collected data for one or more of the 12 defined surgical categories made available for surveillance. At the time of this study, 140 hospitals had provided information on nearly 70 000 operations from nine categories of surgery. This database is presently one of the largest national databases on SSI outside of the USA and gave a unique opportunity to estimate the adverse impact of SSI, namely the extra postoperative length of hospital stay, cost and mortality attributable to these infections.

The extra LOS and cost of SSI have been estimated previously in the UK,[11,15,18] but only for all SSIs occurring after different procedures combined and not for defined surgical categories. This is probably because these studies were conducted in single hospitals where the number of operations was not large enough to obtain estimates for specific categories of surgery. However, the incidence of SSI varies according to the surgical category and it is to be expected that the adverse impact associated with these infections also depends on the category of surgery, as shown for the English hospitals included in this study.

We found that the incidence of SSI, both overall and when stratified by the risk index, was higher than the incidence published by the NNIS system in the USA[27] for similar categories of surgery. It was particularly high for limb amputation, open reduction of long bone fracture and vascular surgery, with an overall incidence that was 4, 3.4 and 3.2 times higher, respectively, than the American NNIS system. In contrast, we found that incidence of SSI in English hospitals for hip and knee prostheses, open reduction of long bone fracture and abdominal hysterectomy was similar to that published by the Dutch national surveillance network 'PREZIES'.[5] For large bowel surgery, the incidence of SSI was lower in English hospitals than in Dutch hospitals.

It is not clear why there are large differences in the incidence of SSI between the English and the American systems, especially as the English NINSS was based on the American NNIS system and the categories of surgery include similar surgical procedures. However, differences may in part be explained by the modifications made to the CDC definitions of SSI for the purposes of the English surveillance system. International comparisons may also be limited because of differences in the

Table V Mortality rates for patients with superficial or deep and organ/space surgical site infection (SSI) compared with those without SSI

Surgical procedure	No. of deaths (and rate per 100 operations) for patients				Adjusted* OR (95% CI)					
	Without SSI	With SSI	With superficial SSI	With deep and organ/space SSI	Patients with SSI vs. no SSI	*P* value	Superficial SSI vs. no SSI	*P* value	Deep and organ/space SSI vs. no SSI	*P* value
Limb amputation	80 (8.1)	20 (12.1)	10 (9.0)	10 (18.2)	1.1 (0.4-2.9)	0.79	0.65 (0.2-2.4)	0.51	2.3 (0.7-8.0)	0.17
Vascular surgery	257 (7.5)	29 (10.2)	15 (6.7)	14 (23.3)	1.4 (0.8-2.3)	0.25	0.67 (0.3-1.4)	0.27	6.8 (3.0-15.4)	$<$0.001
Large bowel surgery	357 (6.1)	44 (7.0)	15 (4.0)	29 (10.7)	0.89 (0.6-1.4)	0.64	0.36 (0.1-0.8)	0.02	1.8 (1.1-3.2)	$<$0.04
Small bowel surgery	29 (5.9)	7 (13.0)	2 (6.9)	5 (18.5)	1.4 (0.3-7.7)	0.69	0.91 (0.07-11.4)	0.94	2.0 (0.2-16.2)	0.52
Coronary artery bypass graft	235 (2.4)	21 (5.5)	15 (5.1)	6 (4.5)	0.96 (0.5-1.7)	0.89	0.85 (0.4-1.8)	0.66	1.2 (0.5-3.2)	0.67
Open reduction of long bone fracture	89 (3.6)	11 (9.8)	8 (9.0)	3 (12.0)	1.6 (0.7-3.9)	0.27	1.9 (0.7-4.8)	0.22	1.1 (0.2-7.3)	0.89
Hip prosthesis	551 (2.4)	53 (7.4)	31 (5.7)	22 (11.9)	1.8 (1.3-2.7)	0.002	1.6 (1.1-2.6)	0.04	2.5 (1.3-4.6)	0.005
Knee prosthesis	40 (0.3)	1 (0.4)	0 (0.0)	1 (2.1)	1.5 (0.2-11.1)	0.72	-	-	7.2 (0.9-56.7)	0.06
Abdominal hysterectomy	14 (0.2)	2 (1.2)	1 (0.8)	1 (2.9)	-	-	-	-	-	-

*Adjusted by age, sex, pre-operative length of hospital stay, American Society of Anesthesiology score, wound class, duration of operation, elective/emergency surgery, multiple procedures through the same incision, implants and operation due to trauma.

healthcare systems, practices, patient-mix, type of hospital, and reasons for participating in a national surveillance network.[28] In addition, the total number of operations in the English system for some surgical categories, such as limb amputation, vascular surgery, small bowel surgery and open reduction of long bone fracture, is still small, giving an imprecise estimate of the incidence of SSI which is reflected by wide confidence intervals. Lastly, it is likely that the postoperative LOS differs between countries; if patients, in general, remain longer in hospital in England, it is likely that more infections will be detected. For example, the postoperative LOS for uninfected patients was longer in our study for large bowel surgery, open reduction of long bone fracture and joint replacement than that found by Kirkland *et al.*[16] in the USA for similar categories of surgery. Interestingly, the LOS for uninfected patients undergoing similar categories of surgery was shorter in our study than that found by the Dutch surveillance network.[5]

The LOS for patients with SSI was at least twice that of those without SSI for most of the categories of surgery. However, the estimated extra LOS was imprecise for some procedures (e.g. limb amputation, small bowel surgery and open reduction of fracture) because of the relatively small sample size. In addition, for these categories of surgery, the date of discharge was unknown for a large proportion of patients, contributing to the imprecision of these estimates of extra LOS.

There is a wide variation in the extra postoperative LOS attributable to SSI in published studies, particularly when considering specific categories of surgery. For example, the extra LOS attributable to SSI for CABG varies from 3 to 18.5 days,[16,29] and was 13.4 days in our study. For colon surgery, the published extra LOS varies from 6 to 13.8 days,[9,16] and was 9.4 days in our study. For abdominal hysterectomy, the extra LOS attributable to SSI in English hospitals was 3.3 days; about half of that found by Green and Wenzel (6.5 days)[9] in the USA. These differences may relate to differences in the healthcare systems between countries, to the methodology used to determine the extra LOS, and to the year of the study. Not surprisingly, and in line with others,[5,30] we found that patients with deep incisional and organ/space SSI stay in hospital for longer than those with superficial SSI, and this stay was at least 1.6 times longer for all categories of surgery, with the exception of small bowel surgery and limb amputation where the extra LOS was similar for all types of SSI.

Several studies in the UK[11,15,18] found that the extra LOS accounted for about 90% of the additional cost attributable to SSI. Thus, the most costly SSIs are to be found in those categories of surgery with the largest extra LOS attributable to SSI. Overall, we found a wide variation in the extra cost attributable to SSI for the different categories of surgery, ranging from £959 for abdominal hysterectomy to £6103 for limb amputation. Deep incisional and organ/space SSIs have a higher extra LOS than superficial incisional SSI and therefore a higher attributable cost. This was particularly so for CABG and hip and knee prostheses, where the estimated cost was more than doubled. The estimate of the cost of SSI per extra bed-day in this study was derived from the figures for the mean additional cost and LOS found in the study by Plowman *et al.*,[18] who also used logistic regression techniques to control for those factors which may impact on resource use. However, as Plowman *et al.*'s estimate was derived from all surgical procedures and all types of SSI in a single district general hospital, these costs may have been an underestimate for the teaching and specialist hospitals that were included in our study.

When assessing costs, it is important to take into account the volume of operations. Categories of surgery with many operations and a low incidence of infection may be more costly overall than categories with very few operations, even though they have a high incidence of SSI and large extra LOS.

We found that for all categories of surgery, the crude mortality rates were higher for patients with SSI (all types combined) than those without SSI. However, the adjusted ORs show that only patients with hip prosthesis and SSI have a mortality rate that was significantly higher, nearly twice that of those without SSI. In addition, for hip prosthesis, patients with superficial incisional SSI and those with deep incisional and organ/space SSI also have a significantly higher mortality rate than those without SSI. Although we controlled for several major risk factors, it is possible that there were other factors not included in this study that also influence mortality. This may explain our finding that, for patients with hip prosthesis, those with superficial SSI apparently had a significantly higher mortality rate than those without SSI. Large bowel and vascular surgery also had an adjusted mortality rate associated with deep incisional and organ/space SSI that was significantly higher than for patients without SSI.

The overall crude mortality rates for all patients who underwent abdominal hysterectomy, large and small bowel surgery, and hip and knee prostheses in our study were similar to those found by Astagneau *et al.*[6] for similar categories. However, the crude mortality rates for patients with SSI in our study compared with those published by Astagneau *et al.* varied depending on the category of surgery. For example, the mortality rate for patients who developed SSI following small bowel surgery was higher in our study than that of Astagneau *et al.* (12.9% vs. 3.9%, respectively), but was lower for patients with SSI after hip and knee prostheses (5.7% vs. 16.8%, respectively), and large bowel surgery (7.0% vs. 8.4%, respectively). Unfortunately, Astagneau *et al.* did not provide adjusted ORs for patients with SSI compared with those without SSI by surgical categories. Unlike Hollenbeak *et al.*,[31] we could not find any increased mortality associated with deep and organ/space SSI following CABG.

The NINSS surveillance of SSI in English hospitals was not primarily designed to measure the adverse impact associated with the development of SSI. Therefore, several limitations are inherent in this study. Firstly, because of the voluntary participation of hospitals and their choice of surgical category, the possibility of selection bias cannot be excluded. For example, hospitals may have chosen a particular category of surgery because they suspected that they had specific problems in that type of surgery. If so, this might result in higher rates of SSI. Conversely, this study did not attempt to include infections detected after discharge from hospitals or on re-admission, and this implies an underestimation of the overall incidence of SSI as it is well known that a large proportion of SSIs are only detected after discharge.[32-35] Secondly, the extra LOS would be increased if re-admissions were taken into account, as was shown by Kirkland *et al.*[16] Thirdly, this study is based on surveillance data and the actual date of discharge was not known for all patients; thus the estimated extra LOS was imprecise for some categories of surgery, such as limb amputation, small bowel surgery and open reduction of fracture, partially due to the fact that date of discharge was unknown for a relatively large proportion of patients.

In conclusion, despite the limitations, this study provides useful information on the incidence of SSI and the adverse consequences of these infections based on a large number of English hospitals. It shows for the first time that the extra LOS, cost and mortality associated with SSI vary widely depending on the surgical category. By determining which surgical procedures are associated with a more severe adverse impact of SSI, such information should be useful in establishing priorities for the surveillance and prevention of these infections.

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