

Infection of the surgical site after arthroplasty of the hip

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We wished to estimate the incidence of surgical-site infection (SSI) after total hip replacement (THR) and hemiarthroplasty and its strength of association with major risk factors. The SSI surveillance service prospectively gathered clinical, operative and infection data on inpatients from 102 hospitals in England during a four-year period.

The overall incidence of SSI was 2.23% for 16 291 THRs, 4.97% for 5769 hemiarthroplasty procedures, 3.68% for 2550 revision THRs and 7.6% for 198 revision hemiarthroplasties. *Staphylococcus aureus* was identified in 50% of SSIs; 59% of these isolates were methicillin-resistant (MRSA). In the single variable analysis of THRs, age, female gender, American Society of Anesthesiologists (ASA) score, body mass index, trauma, duration of operation and pre-operative stay were significantly associated with the risk of SSI ($p < 0.05$). For hemiarthroplasty, the ASA score and age were significant factors. In revision THRs male gender, ASA score, trauma, wound class, duration of operation and pre-operative stay were significant risk factors. The median time to detection of SSI was eight days for superficial incisional, 11 days for deep incisional and 11 days for joint/bone infections. For each procedure the mean length of stay doubled for patients with SSI. The multivariate analysis identified age group, trauma, duration of operation and ASA score as significant, independent risk factors for SSI. There was significant interhospital variation in the rates of SSI. MRSA was the most common pathogen to cause SSI in hip arthroplasty, especially in patients undergoing hemiarthroplasty, but coagulase-negative *Staph. aureus* may be more important in deep infections involving the joint.

More than 40 000 total hip replacements (THRs) are performed in England each year and are generally effective in reducing pain and increasing mobility.¹ In addition, more than 50 000 patients are admitted to hospital annually with fractures of the proximal femur, a large proportion of whom require a hemiarthroplasty.² Surgical-site infection (SSI) after hip arthroplasty can have serious consequences for the patient, may lead to revision surgery and have long-term effects on health and mobility.¹ These infections impose a considerable economic cost both to health care and to patients and their families, while treatment contributes towards antimicrobial resistance.^{3,4}

A low incidence of infection may depend upon the design of the operating theatre, meticulous surgical technique and rigid aseptic discipline.⁵ Surveillance has an important role in the reduction of the risk of hospital-acquired infection and has allowed the incidence of SSI to be reduced by up to 38%.^{6,7} Understanding the risk factors associated with SSI is impor-

tant for meaningful comparisons of rates and to allow proper prevention.⁸

In 1996, the Department of Health and the Public Health Laboratory Service (Health Protection Agency) established a surveillance service in England. This was originally called the Nosocomial Infection National Surveillance (NINS) Service and has now been renamed the Surgical Site Infection Surveillance Service (SSISS). This is based upon the protocols used by the Center for Disease Control (CDC) in the United States. The key aims were to facilitate hospitals to undertake surveillance of hospital-acquired infection and to enable them to compare their results with those of other participating institutions.⁹ A fundamental requirement was the development of standard surveillance methods and definitions for all the participating hospitals as well as establishing the usefulness of methods for adjusting the rates associated with the major risk factors.

We have therefore analysed the data collected from 24 808 primary and revision THRs and hip hemiarthroplasties from 102 hospitals

Table I. Definitions of SSI* (note: 1, stitch abscesses, defined as minimal inflammation and discharge confined to the points of suture penetration, and localised infection around a stab wound are not classified as SSI and are excluded; and 2, an infection which involves more than one site will be classified according to the deepest level of SSI)

Superficial incisional	<p>Occurs within 30 days of surgery</p> <p>Involves only skin and subcutaneous tissue and meets at least one of the following criteria:</p> <ol style="list-style-type: none"> 1. Purulent drainage from superficial incision 2. Organisms are grown and pus cells seen from aseptically obtained swab/tissue from the superficial incision 3. At least two of the following symptoms and signs: <ul style="list-style-type: none"> Pain or tenderness, localised swelling, redness or heat, and a) the clinician diagnoses an infection or b) the superficial incision is deliberately opened by a surgeon to manage the infection, unless the incision is culture-negative
Deep incisional	<p>Occurs within 30 days (no implant) or one year (implant) of surgery</p> <p>Involves deep fascia and muscle layers</p> <p>Appears to be related to the procedure and meets at least one of the following criteria:</p> <ol style="list-style-type: none"> 1. Purulent drainage from the deep tissue but not the joint or bone 2. Organisms are grown and pus cells seen from aseptically obtained swab/tissue from the deep incision 3. A deep incision which spontaneously dehisces or is opened by the surgeon when the patient has fever (> 38°C), localised pain or tenderness, unless the incision is culture-negative 4. An abscess or other evidence of deep infection found during re-operation, or by histopathological or radiological examination
Joint/bone infection	<p>Occurs within 30 days (no implant) or one year (implant) of surgery</p> <p>Involves joint and/or bone related to the site of the operation with any other tissues</p> <p>Appears to be related to the procedure and meets at least one of the following criteria:</p> <ol style="list-style-type: none"> 1. Purulent drainage from a drain which is placed through a stab incision into the joint 2. Organisms are grown and pus cells seen from aseptically obtained swab/tissue from the joint/bone 3. An abscess or other evidence of joint/bone infection found during re-operation, or by histopathological or radiological examination 4. The patient has at least two of the following signs or symptoms with no other recognised cause: joint pain, swelling, tenderness, heat, evidence of effusion or limitation of movement and at least one of the following: <ul style="list-style-type: none"> a) Organisms and white blood cells seen on Gram stain of the joint b) Positive antigen test on blood, urine, or joint fluid c) Cellular profile and chemistry of joint fluid compatible with infection and not explained by an underlying rheumatological disorder d) Radiological evidence of infection, e.g. abnormal findings on radiographs, CT scans, MRI, radiolabelled scan (gallium, technetium, etc)

* SSI, surgical site infection

in England in order to estimate the incidence of SSI and its strength of association with major risk factors.

Patients and Methods

Hospitals participating in this surveillance were required to collect data for a minimum period of three months. A basic set of 17 items of clinical and surgical data was collected for all patients undergoing an eligible surgical procedure during this time. These patients were then monitored three times a week during their post-operative stay in hospital for signs and symptoms of SSI which met standard definitions (Table I). The latter were based on internationally recognised definitions of SSI. The surveillance methodology was described in a detailed protocol while surveillance personnel attended a training programme. These active, prospective methods improved the reliability of identifying cases.¹⁰ In the absence of standard methods for post-discharge surveillance, only those infections which developed during the inpatient stay were identified and therefore mostly reflected SSIs which occurred in the immediate post-operative period (Coventry type 1).¹¹

The categories of arthroplasty included THR, hemiarthroplasty, and revision procedures. These were specified by the Office of Population Censuses and Surveys surgical operation codes.¹² The classification of physical status of

the American Society of Anesthesiologists (ASA) was used as a measure of the severity of any underlying illness.¹³ Operations were allocated a risk group score based on the NINS risk index which comprised an ASA score of ≥ 3 , an operating time of more than two hours and a wound class of either contaminated or dirty.¹³ A classification of 'operations due to trauma' was added to the dataset after the first year of collection of data. This was defined as 'an operation performed because of blunt or penetrating traumatic injury to the patient'. Patients meeting these criteria did not include those with pathological fractures, or those which had occurred without a history of injury. Operations were allocated a wound class ranging from clean to dirty depending upon the likelihood of micro-organisms being present in the wound at the time of surgery.¹⁴ The duration of the operation was defined as the time between incision and closure. Peri-operative antibiotics were defined as the administration of one or more antibiotics during the peri-operative period, intended for prophylaxis. Data on specific antibiotics, the use of antibiotic-impregnated cement, the type of implant and the indication for revision were not collected.

The data were submitted to a validation process at the co-ordinating centre, checked for inaccuracies using an automated system and missing, incompatible or improbable data queries were reviewed, referred back to participat-

Table II. Incidence of SSI* in hip arthroplasty procedures by procedure and type of SSI, by number and *percentage* (95% confidence intervals (CI))

Procedure	Number of operations	SSIt		Type of SSI†		
		Number	95% CI	Superficial incisional	Deep incisional	Joint
THR	16 291	363 (2.23)	2.0 to 2.5	294 (1.80)	38 (0.23)	30 (0.18)
Hemiarthroplasty	5 769	288 (4.97)	4.47 to 5.47	190 (3.29)	62 (1.07)	35 (0.61)
Revision of THR	2 550	95 (3.73)	2.99 to 4.37	70 (2.75)	19 (0.75)	5 (0.2)
Revision of hemiarthroplasty	198	15 (7.58)	4.7 to 10.46	12 (6.06)	1 (0.51)	2 (1.01)
Total	24 808	761		566	120	72

* SSI, surgical site infection

† type of SSI was not reported for three infections (1 THR, 1 hemiarthroplasty, 1 revision THR)

ing hospitals and the database amended accordingly. Using this system, 0.94% of records were deleted when errors could not be corrected.

Statistical analysis. Stata statistical software (Stata v 8.0, Stata Corporation, College Station, Texas) was used for all analyses.¹⁵ A generalised linear model was used to determine significant, independent predictors of the risk of SSI, while taking into account the confounding effect of other predictors. Backward stepwise logistic regression was applied to data on all arthroplasty procedures, with the type of procedure included as a predictor. Length of stay could not be included in the linear model since it appeared after the outcome of SSI and was therefore not a predictor. Body mass index (BMI) was also not included in the logistic regression model, since it would have restricted the application of the model to the 33% of patients for whom data were available. Poisson regression analysis, using length of post-operative stay as the exposure variable, was also performed to estimate whether differences in length of stay explained variations in rates of SSI between hospitals. A *p* value ≤ 0.05 was regarded as significant.

Results

Between October 1997 and October 2001, 102 hospitals contributed data on 24 808 hip arthroplasty operations thereby allowing calculations of the incidence of surgical site infection to be made. The superficial incision was affected in 74% (566) of SSIs, the deep incision in 16% (120) and the joint in 10% (72) (Table II). The incidence of SSI varied significantly between hospitals for both primary THR (interquartile range (IQR) 1.6% to 3.4%) and primary hemiarthroplasty (IQR 2.1% to 7.1%).

Characteristics of patients undergoing THR. Patients undergoing a hemiarthroplasty were older with a median age of 83 years (IQR 11) compared with 70 years (IQR 15) for those undergoing THR. A greater proportion of those aged 75 years or older received a THR (82%) than a hemiarthroplasty (32%). Of the hemiarthroplasty patients, 85% had their procedures performed because of trauma compared with only 4% of patients with THR. Patients who underwent a hemiarthroplasty also had a higher median ASA score (3 *vs* 2); were more likely to be women (80% *vs* 62%) and to be in a higher risk group. In addition, patients undergoing a hemiarthroplasty stayed in hospital for longer (median, 14

Table III. Single variable analysis of risk factors for SSI* in primary THR

Variable	SSI			Odds ratio	95% CI†	<i>p</i> value
	No SSI	Number	(%)			
Risk index						
0 or 1	12565	276	(2.2)	1.00	Baseline	
2 or 3	499	27	(5.4)	2.46	1.64 to 3.69	
N/A	2864	60	(2.1)	0.95	0.72 to 1.26	<0.01
Gender						
Male	6073	117	(1.9)	1.00	Baseline	
Female	9797	245	(2.5)	1.30	1.04 to 1.62	0.02
Peri-operative prophylaxis						
No	192	6	(3.1)	1.00	Baseline	
Yes	15352	347	(2.3)	0.72	0.32 to 1.64	0.44
Trauma						
No	13038	287	(2.2)	1.00	Baseline	
Yes	562	27	(4.8)	2.18	1.46 to 3.27	<0.01
Age (yrs)						
< 65	5198	91	(1.8)	1.00	Baseline	
65 to 74	5488	101	(1.8)	1.05	0.79 to 1.40	
75 to 79	2605	82	(3.1)	1.80	1.33 to 2.43	
≥ 80	2499	85	(3.4)	1.94	1.44 to 2.62	<0.01
Body mass index						
< 20	298	5	(1.7)	1.11	0.44 to 2.78	
20 to 30	4440	67	(1.5)	1.00	Baseline	
> 30	1491	44	(3.0)	1.96	1.33 to 2.87	<0.01
Pre-operative delay (days)						
0	1301	26	(2.0)	0.92	0.61 to 1.38	
1	13248	288	(2.2)	1.00	Baseline	
2	574	19	(3.3)	1.52	0.95 to 2.44	
3	271	9	(3.3)	1.53	0.78 to 3.00	
> 3	534	21	(3.9)	1.81	1.15 to 2.84	0.03
ASA score (grouped)						
Class < 3	10683	214	(2.0)	1.00	Baseline	
Class ≥ 3	2628	94	(3.6)	1.79	1.40 to 2.28	<0.01
Duration of surgery (min)						
< 60	1923	47	(2.4)	1.33	0.93 to 1.89	
60 to 89	5108	94	(1.8)	1.00	Baseline	
90 to 119	5030	106	(2.1)	1.15	0.87 to 1.52	
≥ 120	3476	106	(3.0)	1.66	1.25 to 2.20	<0.01
Wound class (grouped)						
Clean	15839	361	(2.3)	1.00	Baseline	
Other	89	2	(2.2)	0.99	0.24 to 4.02	0.98
Cement						
No	2371	40	(1.7)	1.00	Baseline	
Yes	13191	309	(2.3)	1.39	1.00 to 1.94	0.07

* SSI, surgical site infection

† CI, confidence interval

Table IV. Single variable analysis of risk factors for SSI* in primary hemiarthroplasty

Variable	SSI		Odds ratio	95% CI†	p value
	No SSI	Number (%)			
Risk index					
0 or 1	4324	223 (5.2)	1.00	Baseline	
2 or 3	79	2 (2.5)	0.49	0.12 to 2.01	
N/A	1078	63 (5.8)	1.13	0.85 to 1.51	0.40
Gender					
Male	1096	69 (6.3)	1.00	Baseline	
Female	4370	219 (5.0)	0.80	0.60 to 1.05	0.11
Peri-operative prophylaxis					
No	112	3 (2.7)	1.00	Baseline	
Yes	5227	275 (5.3)	1.96	0.62 to 6.22	0.25
Trauma					
No	716	28 (3.9)	1.00	Baseline	
Yes	4042	234 (5.8)	1.48	0.99 to 2.21	0.06
Age (yrs)					
< 65	228	5 (2.2)	1.00	Baseline	
65 to 74	771	30 (3.9)	1.77	0.68 to 4.63	
75 to 79	1005	55 (5.5)	2.50	0.99 to 6.30	
≥ 80	3423	196 (5.7)	2.61	1.06 to 6.41	0.05
Body mass index					
< 20	147	4 (2.7)	0.40	0.14 to 1.13	
20 to 30	633	43 (6.8)	1.00	Baseline	
> 30	63	4 (6.3)	0.93	0.32 to 2.69	0.20
Pre-operative delay (days)					
0	731	37 (5.1)	0.98	0.68 to 1.42	
1	2773	143 (5.2)	1.00	Baseline	
2	910	40 (4.4)	0.85	0.60 to 1.22	
3	417	24 (5.8)	1.12	0.72 to 1.74	
> 3	650	44 (6.8)	1.31	0.93 to 1.86	0.38
ASA score (grouped)					
Class < 3	2015	87 (4.3)	1.00	Baseline	
Class ≥ 3	2451	144 (5.9)	1.36	1.04 to 1.79	0.03
Duration of surgery (min)					
< 60	2260	111 (4.9)	0.93	0.71 to 1.22	
60 to 89	2077	110 (5.3)	1.00	Baseline	
90 to 119	699	40 (5.7)	1.08	0.75 to 1.57	
≥ 120	238	11 (4.6)	0.87	0.46 to 1.65	0.84
Wound class (grouped)					
Clean	5431	282 (5.2)	1.00	Baseline	
Other	50	6 (12.0)	2.31	0.98 to 5.44	0.06
Cement					
No	2492	145 (5.8)	1.00	Baseline	
Yes	2783	131 (4.7)	0.81	0.63 to 1.03	0.09

* SSI, surgical site infection

† CI, confidence interval

Table V. Single variable analysis of risk factors for SSI* in revision of THR

Variable	SSI		Odds ratio	95% CI†	p value
	No SSI	Number (%)			
Risk index					
0 or 1	1733	52 (3.0)	1.00	Baseline	
2 or 3	290	21 (7.2)	2.41	1.43 to 4.07	
N/A	432	22 (5.1)	1.7	1.02 to 2.82	< 0.01
Gender					
Male	924	48 (5.2)	1.00	Baseline	
Female	1529	47 (3.1)	0.59	0.39 to 0.89	0.01
Peri-operative prophylaxis					
No	41	1 (2.4)	1.00	Baseline	
Yes	2351	91 (3.9)	1.59	0.22 to 11.66	0.65
Trauma					
No	1911	65 (3.4)	1.00	Baseline	
Yes	101	14 (3.9)	4.08	2.21 to 7.51	< 0.01
Age (yrs)					
< 65	699	22 (3.1)	1.00	Baseline	
65 to 74	768	26 (3.4)	1.08	0.60 to 1.92	
75 to 79	469	21 (4.5)	1.42	0.77 to 2.62	
≥ 80	501	23 (4.6)	1.46	0.80 to 2.65	0.94
Body mass index					
< 20	64	2 (3.1)	0.85	0.20 to 3.69	
20 to 30	651	24 (3.7)	1.00	Baseline	
> 30	168	7 (4.2)	1.13	0.48 to 2.67	0.93
Pre-operative delay (days)					
0	190	7 (3.7)	1.10	0.50 to 2.44	
1	1823	61 (3.3)	1.00	Baseline	
2	119	0 (0.0)			
3	40	3 (7.5)	2.24	0.67 to 7.44	
> 3	283	24 (8.5)	2.53	1.55 to 4.13	< 0.01
ASA score (grouped)					
Class < 3	1580	48 (3.0)	1.00	Baseline	
Class ≥ 3	495	32 (6.5)	2.13	1.35 to 3.37	< 0.01
Duration of surgery (min)					
< 60	157	7 (4.5)	1.37	0.53 to 3.48	
60 to 89	398	13 (3.3)	1.00	Baseline	
90 to 119	450	14 (3.1)	0.95	0.44 to 2.05	
≥ 120	1252	46 (3.7)	1.12	0.60 to 2.10	< 0.01
Wound class (grouped)					
Clean	2369	87 (3.7)	1.00	Baseline	
Other	86	8 (9.3)	2.53	1.19 to 5.39	0.02
Cement					
No	592	17 (2.9)	1.00	Baseline	
Yes	1782	65 (3.6)	1.27	0.74 to 2.18	0.39

* SSI, surgical site infection

† CI, confidence interval

days) than those undergoing a THR (median, 9 days) regardless of whether they developed SSI. Patients receiving a revision THR were generally younger with 61% aged under 75 years and 19% aged over 80 years. In the revision hemiarthroplasty patients, 34% were younger than 75 years of age and 43% more than 80 years of age.

Risk factors associated with SSI in primary THR (Table III).

Most patients undergoing a THR were women and had a significantly higher rate of SSI compared with men. The risk of infection also increased significantly with age and ASA score. Data for calculation of the BMI were only available for 38% of patients included in the surveillance. The risk of

SSI was significantly higher in patients with a BMI > 30 compared with values between 20 and 30. Only 4.1% of THRs were performed after trauma but their incidence of SSI was significantly higher (4.8%) when compared with elective procedures (2.2%). The risk of SSI varied according to the length of surgery, with the greatest risk for procedures which lasted 120 minutes or more. Although only 4% of patients were in the highest NINS risk index groups (2 and 3), they were significantly more likely to develop SSI. Most patients were admitted to hospital on the day before their operation (83%), but the longer patients were in hospital before surgery the higher was the incidence of SSI.

Table VI. Length of post-operative stay by type of operation and SSI*

	Median length of stay (days)		Interquartile range (days)	
	No SSI	SSI	No SSI	SSI
Primary THR	9	17	5	15
Primary hemiarthroplasty	14	31.5	14	26
Revision THR	11	22	6	20
Revision hemiarthroplasty	14	18	17	35
Total	10	23	6	20

* SSI, surgical site infection

Table VII. Micro-organisms identified as causing SSI* by type of procedure (%)

	Total hip replacement	Hip hemiarthroplasty	Revision THR	Revision hemiarthroplasty
MRSA†	24.3	20.3	41.3	39
MSSA‡	21.9	20.3	22.6	11
Coag. negative staph.	15.3	13.5	6.5	5.5
Enterococcus Spp.	8.6	6	8.7	5.5
Coliforms	7.7	7.5	5.9	5.5
Pseudomonas Spp.	7.5	4.5	3.9	11
Proteus Spp.	1.5	2.2	1.9	5.5
Bacillus Spp.	2	3	1	0
Other	11.1	21.8	9	17

* SSI, surgical site infection

† MRSA, methicillin-resistant *Staphylococcus aureus*‡ MSSA, methicillin-sensitive *Staphylococcus aureus***Table VIII.** Multivariate analysis of risk factors for SSI* in all types of hip replacement

Variable	Odds ratio	95% CI†	p value
Trauma			
No	1.00	Baseline	
Yes	1.87	1.50 to 2.34	< 0.001
Age (yrs)			
< 65	1.00	Baseline	
65 to 74	1.13	0.85 to 1.50	
75 to 79	1.56	1.16 to 2.10	
≥ 80	1.66	1.24 to 2.21	0.001
ASA score (grouped)			
Class < 3	1.00	Baseline	
Class ≥ 3	1.55	1.29 to 1.88	< 0.001
Duration of surgery (min)			
< 60	1.04	0.82 to 1.34	
60 to 90	1.00	Baseline	
90 to 120	1.23	0.96 to 1.57	
> 120	1.58	1.23 to 2.03	0.004

* SSI, surgical site infection

† CI, confidence interval

Primary hemiarthroplasty (Table IV). Of the 5769 patients who had hemiarthroplasty, 80% were women. The risk of SSI increased significantly with age. The odds ratio of developing SSI after hemiarthroplasty in patients aged 80 years or more was 2.61 compared with those aged 65 years or less. Data on BMI were only available for 16% of patients, and while there appeared to be a trend in the risk of SSI with increasing BMI, the numbers were too small to conclude statistical significance. The risk of SSI was significantly greater in those patients with an ASA score of three or more. There was no significant association between the

risk of SSI in hemiarthroplasty procedures and the duration of surgery. Most hemiarthroplasties (86%) were performed after trauma and, although the risk of SSI was higher in this group, the difference was not significant.

Revision procedures (Table V). For the 2550 revision THRs, significant risk factors for SSI were an ASA score of three or more, a pre-operative stay of three or more days compared with admission on the day before surgery, a wound class other than clean, surgery as a result of trauma and male gender.

Procedures in the NINS risk groups 2 or 3 were at a significantly increased risk of infection compared with those in groups 0 or 1. There was no linear relationship between the risk of SSI and the duration of surgery, although procedures which lasted less than one hour had a significantly higher risk.

There were only 198 revision hemiarthroplasty procedures and an ASA score of three or more was the only significant risk factor for SSI identified in this group. Because of the small numbers involved, no results have been presented, although the data have been included in the multivariate regression.

Length of stay in hospital, time to infection and causative micro-organisms. The median length of stay for patients undergoing primary THR, hemiarthroplasty and revision THR was approximately doubled in those who developed a SSI (Table VI). For the small group of patients who underwent a revision hemiarthroplasty, the median length of stay increased by only four days for those who developed a SSI. This smaller increase could have been due to differences in underlying illness in this group, which affected their length of stay in hospital. For all procedures the median time to diagnosis of superficial infections was eight days (IQR 5 to 12), for deep incisional infections 11 days (IQR 8 to 16), and for infections of the joint/bone 11 days (IQR 7 to 14).

One or more causative micro-organisms were identified in 88% of SSIs. *Staphylococcus aureus* was the main pathogen (Table VII) and was identified in 50% of SSIs. Of these isolates 59% (29.5% of all SSIs) were methicillin-resistant *Staph. aureus* (MRSA). This was a more common cause of SSI in hemiarthroplasty procedures than THR, and was responsible for 40% of SSIs in primary hemiarthroplasty, for 39% in revision hemiarthroplasty, but only for 23% in primary THR and for 21% in revision THR.

Multivariable analysis. Analysis using logistic regression found four significant, independent risk factors associated with the risk of SSI, namely, ASA score, age group of the patient, duration of the procedure and procedures performed after trauma (Table VIII). The type of procedure did not have a significant effect on the risk of SSI once these other risk factors had been taken into account. In a Poisson regression analysis, normalising for the length of post-operative stay, both trauma and ASA score remained significant predictors of SSI. Age group and duration of procedure were no longer significant predictors. If the hospital where the procedure was performed was included in the models there was a significant difference in the risk of SSI between hospitals. This suggests that there is a considerable hetero-

generality between hospitals in their rates of SSI which cannot be explained by the other predictors in these models.

Discussion

Clinical governance has increased awareness of the importance of quality and the need for monitoring outcomes. The recent National Audit Office study of the management of the control of infection in acute NHS Trusts in England suggested that there was scope for hospitals to reduce rates of infection and that systems for monitoring healthcare-associated infections were a key requirement.¹⁶ Many hospitals have developed local audit systems to focus on particular issues, but data collected by hospitals participating in the surveillance service allowed comparisons to be made with other institutions and also information to be added to a national dataset for England. This provided a unique opportunity for evaluating the risk factors for SSI in different types of procedure for hip replacement. In the surgical literature, risk factors for SSI are often used to describe those which are associated with the development of SSI, but these are not necessarily shown to be independent predictors of infection. The multivariate methods used in our analysis have allowed factors to be identified which have both a significant and an independent association with SSI after prosthetic surgery on the hip. Although the ability of the standard case-definition used for SSI surveillance, to discriminate between SSIs affecting the incision and those affecting the joint may be contentious, our analysis has focused on the risk factors associated with the development of any SSI.

The rates of infection from this dataset are similar to those reported by surveillance schemes in the USA and other European countries, although differences between types of arthroplasty are rarely reported or investigated.^{17,18} Conventionally, hemiarthroplasty procedures are considered to differ greatly from THRs. Indeed, the crude incidence of SSI for a primary hemiarthroplasty in this dataset is more than twice that for a primary THR. However, our multivariate analysis suggested that differences in the incidence of SSI, are explained by the underlying characteristics of the patients rather than being related to the type of procedure. Thus, the high risk of SSI in patients undergoing a hemiarthroplasty is likely to be due to three factors, namely, age, underlying illnesses (as reflected by an increased ASA score) and traumatic injury. The last, as well as being an independent predictor of SSI, more than doubles the odds of developing SSI in patients undergoing a THR. This suggests that local and systemic reactions to trauma may predispose to an increased risk of infection. The fourth independent predictor of the risk of SSI is the duration of the operation, with the risk significantly increased in procedures which lasted for 120 minutes or more. This perhaps reflects more complex surgery, in which a combination of prolonged surgical exposure and tissue damage during the procedure, increases the risk of SSI.

Our results suggest that, although the prevention of SSI in patients undergoing elective THR is important, the

underlying characteristics of patients undergoing a hemiarthroplasty make them more vulnerable to SSI. This reinforces the need for the highest standards of the prevention of infection in the management of such patients.

Other factors which emerge from our analyses include a significant association between the risk of SSI and periods of pre-operative stay longer than 48 hours for hemiarthroplasty patients, prolonged operations in both primary and revision THRs, and the increased risk associated with operating on wounds which were not classified as clean.

Significant variation between hospitals remained, even after adjustment for the risk factors included in the multivariate analysis. This may be explained by other components of case-mix which varied between hospitals but which were not taken into account by the factors included in our analysis. Mangram et al⁵ reviewed the evidence for risk factors for SSI.⁷ For some of these, such as age, pre-operative stay and duration of operation, data have been included in our analyses. Diabetes, although often not shown to be an independent predictor, was frequently cited as a risk factor for SSI. However, in our analysis diabetes would probably influence the ASA score. Data on the use of steroids, or the presence of malnutrition were found to be inconsistent. In orthopaedic surgery, rheumatoid arthritis may be an important risk factor for SSI. Again, because it is a systemic disease its influence should be reflected within the ASA staging. Evaluation of rheumatoid arthritis as an independent factor is difficult because of the number of confounding covariables such as the use of steroids, methotrexate and other immunocompromising drugs. In our study, a single variable analysis indicated that the body mass index was significantly associated with the risk of SSI, for both hemiarthroplasty and THR. However, because of insufficient data this variable could not be included in the multivariate analysis, even although it is possible that BMI will one day be shown to be an important, independent predictor of SSI.

It would therefore seem to be likely that our analysis has included the main patient-related risk factors for SSI. Even if the key factors were missing, the proportion of patients with these characteristics would need to vary significantly between different facilities if they were to explain the variation in incidence of SSI between hospitals. Mangram et al⁵ also cited evidence for the effect of a range of factors related to surgery, and how it is performed, on the risk of SSI. These included the operating theatre environment (e.g. ultra clean air), pre-operative factors such as prophylactic antimicrobial therapy and skin preparation, intra-operative factors such as surgical technique (effective haemostasis, gentle handling of tissues) and post-operative management of the wound. Since trauma is a significant risk factor, it may be that hospitals with separate facilities for trauma and elective patients may one day be shown to be a significant factor in the analysis of risk. The extent to which some of these practices are adopted in different hospitals may explain some of the variation in rates of infection. This variation can therefore provide a useful opportunity for evaluating

local clinical practice in relation to current recommendations to ensure that the risk of SSI is minimised.

Our study also highlights the impact of SSI on morbidity and the subsequent use of resources. The length of hospital stay for patients with SSI was more than twice that of those without SSI for all types of hip arthroplasty. However, it was not possible to establish the exact relationship between the length of stay in hospital, the severity of underlying illness and the development of SSI.³ The factors included in our model predict the risk of SSIs which develop during a stay in hospital. The data for time to diagnosis and mean length of hospital stay show that there is often a small interval between the detection of a SSI and the discharge of the patient from hospital, particularly with deep and joint infections. Patients who stay in hospital longer are more likely to have their SSI detected. In the simplistic adjustment for length of post-operative stay using a Poisson regression, age group was no longer a significant predictor of SSI. This suggests that part of the increased risk of SSI in older patients was related to their increased length of post-operative stay and the resulting, increased opportunity for SSI to be detected.

Our study has also demonstrated the extent to which the emerging problem of infection due to methicillin-resistant strains of *Staph. aureus* has affected orthopaedic surgery. Nearly two-thirds of isolates of *Staph. aureus* were methicillin-resistant, which has important implications for both antimicrobial prophylaxis and the treatment of SSI in orthopaedic surgery. The risk of acquiring SSI caused by MRSA was particularly high in patients undergoing a hemiarthroplasty. The characteristics of these patients probably increases the likelihood that they will be colonised with MRSA before surgery. There may, for example, be a history of exposure from an earlier hospitalisation, chronic wounds and other underlying illness.¹⁹ However, the relationship between colonisation with MRSA and risk of subsequent SSI in patients undergoing surgery requires further study.

With continuing emphasis on clinical governance and quality control, there is increasing demand from both patients and government for methods of assessing surgical results. Rates of morbidity and mortality may play important roles in these assessments. However, our study has indicated that, when crude comparisons between hospitals in the incidence of SSI are made, these should at least be stratified by the type of procedure. A better comparison can be made by combining data for all types of hip arthroplasty, and standardising the rates of SSI, in order to allow for the significant factors (i.e. age, trauma, duration of operation and ASA score) which may vary between hospitals. These factors can be taken into account when making comparisons and should perhaps be considered when allocating special care to high-risk patients.

There are some limitations to our study. Currently, there is no satisfactory and cost-effective system for the routine surveillance of post-operative patients who have been discharged from hospital. For this reason post-discharge SSIs were not included in our study. While the rates of post-

discharge SSI do not represent all SSIs which develop after hip arthroplasty, it is likely that a considerable proportion will have become apparent before the patient is discharged from hospital. However, it is also possible that the risk factors for SSI which we identified in this analysis may not apply to SSIs detected after discharge. Risk factors included in our analysis were only those for which data were available, although most major factors appear to have been incorporated. Hospitals contributing data were a self-selected group, which may introduce a small element of bias (e.g. participating because they consider their rates to be low or high). However, a large proportion of the NHS Trusts in England have contributed data and, for many, the reason for participation was an interest in auditing rates of SSI rather than particular concerns about its magnitude.

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