Surgical site infection – a European perspective of incidence and economic burden

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ABSTRACT

This retrospective review of reported surgical site infection (SSI) rates in Europe was undertaken to obtain an estimated scale of the problem and the associated economic burden. Preliminary literature searches revealed incomplete datasets when applying the National Nosocomial Infection Surveillance System criteria. Following an expanded literature search, studies were selected according to the number of parameters reported, from those identified as critical for accurate determination of SSI rates. Forty-eight studies were analysed. None of the reviewed studies recorded all the data necessary to enable a comparative assessment of the SSI rate to be undertaken. The estimated range from selected studies analysed varied widely from 1·5–20% – a consequence of inconsistencies in data collection methods, surveillance criteria and wide variations in the surgical procedures investigated – often unspecified. SSIs contribute greatly to the economic costs of surgical procedures – estimated range: €1·47–19·1 billion. The analysis suggests that the true rate of SSIs, currently unknown, is likely to have been previously under-reported. Consequently, the associated economic burden is also likely to be underestimated. A significant improvement in study design, data collection, analysis and reporting will be necessary to ensure that SSI baseline rates are more accurately assessed to enable the evaluation of future cost-effective measures.

Key words: Epidemiology • Incidence • Nosocomial (health care-associated) infection • Prevalence • Surgical site infection • Wound infection

INTRODUCTION

In 1979, Altemeier stated that 'the development of infection in incisional wounds continues to be one of the most serious complications that can occur in surgical patients' (1). It is generally accepted that surgical site infections (SSIs) – also known as surgical wound infections – the majority of which are superficial in nature, contribute significantly to the morbidity and mortality associated with surgical procedures (1–7). One long-term study conducted by the Inter-regional Co-ordination Centre for Nosocomial Infection Control (INCISO) Network Study group reported that over a 3-year period, 38% of the deaths that occurred in

Key Points

- development of infection is a serious complication for surgical patients
- surgical site infections (SSI) contribute significantly to the morbidity and mortality of patients
- one study showed that over a 3 year period 38% of deaths that occurred in patients with an SSI were directly attributable to the infection

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Key Points

- some national prevalence studies exist but little from a European perspective
- aim of this review is to provide European perspective
- specifics and strict inclusion criteria were applied
- costs associated with SSI were also evaluated
- forty-eight studies were selected for analysis

patients with an SSI were directly attributable to the infection (7). A patient who develops an SSI is more likely to have an extended length of stay (5,6,8–10), incurring increased economic costs in terms of bed stay, physician time, nursing care and diagnostic and therapeutic interventions.

Whilst some national prevalence studies have been conducted (11–15), little work exists providing a pan-European perspective. Compiling data across countries and regions has been hampered by the absence of a pan-European network such as that of the United States (US) Centers for Disease Control and Prevention's (CDC's) National Nosocomial Infections Surveillance (NNIS) (16) system which provides a single recognised framework for monitoring and reporting. Therefore, most large-scale studies conducted to evaluate the clinical and economic impact of SSIs have been conducted in the US (3,9,17–20).

The aim of this review is to provide a clearer understanding of the current situation that exists in Europe with regard to the monitoring, detection and recording of SSI as well as the associated cost burden by assembling the key studies conducted on this topic over the last 15 years.

METHODOLOGY

The criteria drawn up to aid identification of suitable European studies for inclusion were based specifically on the CDC's guidelines derived from the NNIS manual, as reported by Mangram *et al*. (21) in 1999 and Horan *et al*. (16) in 1992.

Original proposed criteria for study selection

Contemporary date of study – studies published during or after 1988: specified study protocol – e.g. incidence, prevalence, prospective cohort surveillance: defined criteria for infection – explicit case definition of an SSI or use of a scoring system, e.g. ASEPSIS (22): identified surgical procedures – surgical site and procedure: wound classification – categorisation of the procedures involved as clean, clean-contaminated, contaminated or dirty-infected (23–25): used patient risk assessment – American Society of Anaesthesiologists (ASA) class, POSSUM, NNIS Risk Index (26,27): employed independent, trained and validated observers: specified surveillance period.

During the analysis of the studies, it became apparent that none fulfilled all of the original study selection criteria. The decision was taken to review a wide range of studies that were selected for inclusion if a majority of the key variables associated with assessing SSI rates were reported. Summaries of these data comprise the initial results section (Table 1). It was not within the scope of this review to analyse all factors that could be important in understanding infection rates. For example, no evaluation was carried out on the impact of hospital type or size, although, where available, these data are included in a supplementary table (Table 2).

This review also seeks to provide an overview of the costs associated with SSI. SSIs result in a number of costs: to the patient, the health care system and the community. Quantifying all of these costs is a monumental task and although they contribute to the true burden of SSI, discussion of the costs to the patient (e.g. quality of life, financial) and community (e.g. additional health care resources, paid benefits and lost taxes) is also beyond the scope of this review. Focus was placed on the cost attributable to the additional length of stay in hospital as a number of studies indicate that this variable is responsible for the majority (more than 90%) of economic cost (5,6,28,29).

To provide an indication of the cost associated with the extended length of stay, the mean value in extra days was calculated (unweighted) and then factored by the average cost of a hospital bed day in a general surgery ward for a variety of countries. Whilst this calculation can only provide an estimate of the mean cost of an SSI, it indicates a reasonable minimum.

RESULTS

Forty-eight studies were selected, 18 (39%) of them prevalence and 30 (61%) incidence (Table 1). Of those classified as incidence studies, ten were designed as prospective cohort studies and all but three of these were case-matched or case-controlled. Three studies were summary articles based on the German Nosocomial Infection in Germany (NIDEP) prevalence study (15,30,31) which presented different datasets from this national study. All the studies reviewed stated that observers had followed a study definition of SSI but many of these (15) were described as CDC-modified or CDC-based, derived from national health care guidelines or cited from other articles.

Table 1 Selected studies summary

Source	Study protocol	Focus	Definition of wound infection used	Surgical procedures defined	Wound classification	Duration of surgery	Patient pre/postoperative infection RI	Observer: Identified	Observer: Independence	Observer: Trained/validated	Length of study	Surveillance period
Klavs *et al.* (60)	Prevalence	HAI	CDC	Recorded not specified	N/S	N/S	Severity of illness assessment– McCabe and Jackson	Coordinators– 17 physicians; two ICNs	Hospital-associated teams led by own hospital coordinators	4 IDC; 4 CM; 5C with PGIC/no	1-day survey; noted procedures carried out $\leq$30 days	1 day
Lizioli *et al.* (46)	Prevalence	HAI	CDC	General classifications only	C/CCon/ Con/D	N/S	ASA	Group of investigators for each hospital	Hospital associated	Hospital teams trained separately	1-day survey	1 day
Rios *et al.* (10)	Incidence – case-case study	SSI	CDC	Yes	N/S	N/S	N/S	ICN	Hospital associated and external	N/S	2-year study	Until discharge N/S
SCIEH (61)	Prospective/ incidence	SSI	CDC	Eight categories of clinically similar ops	NNIS	Yes	NNIS	N/S	N/S	N/S	Annual review	Post discharge in 7/8 categories
Eriksen *et al.* (62)	Prevalence	HAI	Norwegian Health Ministry	N/S	N/S	N/S	N/S	ICN	Hospital associated	Standard survey/N/S	N/S	N/A
Gikas *et al.* (45)	Prevalence	HAI	CDC and CDC surgical wound infection	Recorded not detailed	C/CCon/ C/D	No	N/S	Microbiologist, IDS; ICN	Hospital associated	Individual hospital training with final joint meeting	1-day study	1 day
Lallemand *et al.* (63)	Incidence	Prophylaxis in SSI	CDC	General classification only	C/CCon/ C/D	Yes	ASA NNIS	Surgeon-anaesthetist pairs	Hospital associated	N/S	N/S	30 days
Steinbrecher *et al.* (64)	Incidence	SSI	CDC-based	13 specified surgical procedures	NNIS	NNIS	KISS/NNIS	ICN	No	Yes	Ongoing from January 1997	Until discharge– N/S

Table 1 Continued

Source	Study protocol	Focus	Definition of wound infection used	Surgical procedures defined	Wound classification	Duration of surgery	Patient pre/postoperative infection RI	Observer			Length of study	Surveillance period
								Identified	Independence	Trained/validated		
Thibon *et al.* (35)	Incidence	SSI–patients lost to follow-up	CDC/CTIN	General classification only	N/S	N/S	N/S	N/S	Surgeons asked to see each patient post-op or to obtain follow-up information	N/S	N/S	Target of 30 days but 59% lost to follow-up between discharge and 30 days
Astagneau *et al.* (7)	Incidence	SSI	CDC	Yes approximately 30 classifications given	Altemeier	Yes	ASA score; NNIS	Nurses, anaesthetists, surgeons, with ICT	Surgeon used for post discharge assessment	N/S/No	3 months of each year	30 days or follow-up appointment if earlier discharge
Azzam and Dramaix (65)	1-day prevalence	HAI	CDC 1988–1 sign or symptom of infection	Recorded not detailed	C/CCon/Con/D	N/S	N/S	Two investigators only—pharmacist and physician	N/S	N/S/N/S	1 day	1 day
de Boer *et al.* (66)	Incidence	SSI in orthopaedic	CDC-based definition	Yes–two procedures studied–total hip and knee prosthesis	C/CCon/Con/D 1-4	Yes	ASA; NNIS	N/S	N/S	N/S	Over a 3-year study period	Until discharge–time N/S; unknown number monitored post discharge
Mintjes de-Groot *et al.* (67)	Prospective –incidence	HAI in ICU –stay >48 h	CDC-based-WIP	General classification only	N/S	No	APACHE II	N/S	N/S	Yes/yes	July 97 to December 99	Until discharge from ICU–median stay 6 days

Plowman *et al.* (6)	Incidence	HAI	Glenister 1992 not stated as CDC	N/S	N/S	N/S	Cross-referenced Glenister (68)	ICT plus six research assistant plus ward staff	Hospital associated	Research assistants–yes/support staff N/S	April 94 to May 95	Monitored during the inpatient period but this is N/S
Reilly *et al.* (28)	Incidence	SSI in clean, elective surgery	Definitive Glenister 1992 –not stated as CDC	Yes	Clean surgery only	N/S	N/S but data collected from post op wound audit clinics	Cost of audit nurse evaluated–N/S who collected the data	N/S	N/S	1/11/95–31/3/99	30 days
Stockley *et al.* (34)	Incidence	SSI	NINSS*	Yes–five representative procedures	N/S	N/S	NINSS*–some in-house measures also	Infections control audit nurse; post discharge GPs and DNs	Hospital associated/GPs, DNs in the community	YeS/N/S	Over a 5-year period	25-35 days including post discharge and telephone call
Andersen *et al.* (69)	Repeated point-prevalence 4/year for 3 years	HAI CAI	Modified CDC–12 types specified	N/S	N/S	N/S	N/S	ICN and/or clinicians responsible for infection control	Hospital associated	N/S/N/S	Same day and hour in all hospitals	Repeated 1-day studies
FPSSG (13)	Prevalence	HAI	CDC modified	Recorded not detailed	N/S	N/S	N/S	Team including ICP and ICNs–data collection supported by doctors and nurses	Hospital associated	Trained by coordinator from hospital local training offered	Same day for unit; within 7 days for hospital; over 1 month for study	1-7 days

Table 1 Continued

Source	Study protocol	Focus	Definition of wound infection used	Surgical procedures defined	Wound classification	Duration of surgery	Patient pre/postoperative infection RI	Observer: Identified	Observer: Independence	Observer: Trained/validated	Length of study	Surveillance period
Geubbels *et al.* (14)	Prospective multicentre incidence	SSI	CDC in Dutch translation	Yes but of 18 063 procedures, 7336 classed as 'other'; Dutch ICD-9-CM	C/CCon/Con/D; 1–4	Yes–data not given linking to SSI rate–good correlation reported	ASA; wound class; data not detailed linking to SSI rate–good correlation reported	ICP and/or clinician; not specified in 1	Hospital associated	Hospital linked/validation carried out by blinded team of 4	June 96 to May 97	All patients followed at least until discharge –but actual time not specified
Mintjes-de Groot *et al.* (70)	Active surveillance over 13 years	HAI	Modified CDC	Classified according to NMR but not detailed	N/S	N/S	Patient-related risk factors assessed but not specified;	One ICP; missing data provided by CRF, nurse or doctor	Hospital associated	N/S/sensitivity/specificity assessed from a multi-centre study	Conducted over 13 years	Over 9-month period–until patient discharge–N/S
Pavia *et al.* (71)	Prevalence	HAI	CDC	Recorded not detailed	C/CCon/Con/D	No	N/S	No	Hospital associated	Yes/No	1-day study over a 2-week period	1 day
Asensio and Torres (29)	Two incidence observation studies–matched and versus controls	Deep SSI	CDC definition–deep SSI only	Open heart–with additional classification	Clean/non-clean	Yes	Clean/non-clean	N/S	N/S	N/S/N/S	January 89 to December 99	To discharge but no standardised period
Golliot *et al.* (72)	Incidence–prospective cohort study	SSI	Altemeier classification, CDC and CTIN*	35 procedures classified–eight general linked to NNIS and SSI rate	C/CCon/Con/D	Yes–fully detailed for all procedures	ASA; NNIS; not linked to SSI rate	Surgeon and hygiene control nurse	Hospital associated	N/S	1 month postoperatively	1 month postoperatively

Pittet *et al.* (73)	Period prevalence– over 1 week	HAI	CDC– asymptomatic bacteriuria not categorised as an NI	N/S	No	No	McCabe and Jackson assessment; Charlson index; Karnofsky index	One study coordinator but CRFs filled in by physicians and nurses involved in care	Two independent observers checked % of records	N/S/yes	1 week with operation in past 30 days or 1 year with implant documented	Documented within 30 days post-operatively or 1 year with implant
Scheel and Stormark (47)	1-day prevalence	HAI	Modified CDC	Recorded not detailed	N/S	No	N/S	'Contact' doctor and/or ward nurses and doctors	Hospital-associated staff	N/S	1 day	1 day
Vaqué *et al.* (12)	1990-97– 1997 data cited–point prevalence	HAI	CDC	Recorded not detailed	Recorded not detailed– clean surgery data only	Recorded not detailed	N/S	Physicians or nurses in ICT	Under the direction of each individual hospital ICT	Uniform standardised protocol by CRF/N/S	2-week data collection in May over an 8-year period	1 day
Frankart *et al.* (74)	3-day prevalence	HAI	CDC	General classification only	C/CCon/Con /D	N/S	ASA	Surgeon, hygiene specialist	Hospital associated	N/S/yes; independent validator	3 days	Documented within 30 days post-operatively or 1 year with implant
Gastmeier *et al.* (30) (NIDEP)	1-day prevalence	HAI	CDC	General classification only	C/CCon/Con /D	N/S	ASA	Physicians jointly trained in diagnosis of HAI– sensitivity and specificity figures given	Yes	Yes/four independent external investigators– independent	All patients assessed in the same ward on the same day	1 day
Cainzos *et al.* (75)	Incidence in a 3-month period	SSI	CDC	Biliary tract stone with specific WHO class	C/CCon/Con /D	No	CC/Con/D	N/S	N/S	N/S	3 months	30 days post surgery

Table 1 Continued

Source	Study protocol	Focus	Definition of wound infection used	Surgical procedures defined	Wound classification	Duration of surgery	Patient pre/postoperative infection RI	Observer			Length of study	Surveillance period
								Identified	Independence	Trained/validated		
Medina *et al.* (76)	Prospective surveillance	SSI	CDC	Herniorrhaphy	C/CCon/Con /D	Yes	ASA; McCabe NNIS/SENIC index	Hospital-associated teams–follow-up by post and outpatient clinics	N/S but surgeon infection risk assessed	N/S/N/S	November 92 to June 94	1-month post discharge
Rüden *et al.* (15) (NIDEP)	Prevalence	HAI	CDC	N/S	N/S	N/S	N/S	Yes	Yes	Yes/yes	1 day	1 day
Emmerson *et al.* (11)	Prevalence	HAI CAI	N/S–cross referenced	General classification only	N/S	N/S	N/S–cross referenced	N/S–cross referenced	N/S–cross referenced	N/S–cross referenced	May 93 to July 94 in 2-month study sessions	N/S
Kampf *et al.* (31) (NIDEP)	Prevalence	HAI	CDC	11 procedures specified	1–4	Yes	Yes–wound 1–4;	Doctors trained in diagnosis of HAI–sensitivity and specificity figures given	Four independent external investigators–independent	Yes/yes	10-month study	1 day (not specified in paper but based on NIDEP)
Ronveaux *et al.* (8)	incidence	SSI over a 3-month recording period	CDC–occurring $\leq$30 days; not including stitch abscesses	$\leq$6 classes of surgery recorded ICD-9-CM codes; 10 detailed	C/CCon/C/D	Yes	ASA and NNIS	Recommended that theatre staff at time of surgery record denominator data prospectively	Hospital associated	Hospitals allowed to customise data forms	October 92 to June 93	Until discharge–N/S –post discharge surveillance optional–mean follow-up 13·7 days

Vaqué *et al.* (50)	Prospective prevalence–1994 data	HAI	CDC	Recorded not detailed	Recorded not detailed–only clean surgery	Recorded not detailed	N/S	Physicians or nurses in ICT	Directed by each individual hospital ICT	Standardised protocol by CRF	2-week period in May–data from 1990 to 1994	2-week period each year over 5 years
Erbaydar *et al.* (77)	Incidence–prospective cohort study	SSI	CDC/WHO	General surgery patients	N/S	N/S	N/S	Yes–ICB	Hospital associated	Yes/N/S	2-year study	Until discharge N/S–study period 2 years
Sartor *et al.* (78)	Period prevalence at two time points	HAI–UTI, LRTI, SSI, BSI	CDC–May; CSHPF—November	Recorded not detailed	Clean surgery and other	No	College of American Surgeons	Ten invest-igators from micro-biology or ICD	Worked within surveyed hospital	4 h training/N/S	May; November 1992	Two 1-day studies
Byrne *et al.* (52)	Incidence	SSI	ASEPSIS >10 (27% fully scored by this method);	N/S	N/S	N/S	C/CC/D	N/S for hospital–post discharge GPs and DNs	Hospital associated	N/S/N/S	32-month period	≤6 weeks post discharge—follow-up postal quest-ionnaire
Merten *et al.* (79)	Incidence	SSI	NSIH protocol and CDC	Various study populations allowed–ICD-9-CM codes used	C/CCon/C/D	Yes	Based on NNIS including ASA and C/CCon/C/D;	ICN and ICP obligatory in every hospital	Hospital associated	Roles and education defined, courses in place	October 14 to December 13 1991	Post discharge surveillance encouraged but time N/S; 32 did post discharge follow-up
Poulsen *et al.* (80)	Incidence	SSI in selected groups	Danish guidelines	Yes	N/S	N/S	Danish guidelines	N/S	N/S	N/S	January 85 to December 88	Until discharge–time period N/S

Table 1 Continued

Source	Study protocol	Focus	Definition of wound infection used	Surgical procedures defined	Wound classification	Duration of surgery	Patient pre/postoperative infection RI	Observer			Length of study	Surveillance period
								Identified	Independence	Trained/validated		
Coello *et al.* (5)	Matched control study–incidence	SSI	CDC–various sources/ modifications	General surgical classifications only	N/S	N/S	N/S	Research nurse in association with ward staff and from CRF	Hospital associated	N/S/NS	Between March and November 1988	Continuous surveillance until discharge
Vegas *et al.* (81)	Matched control prospective study–incidence	HAI in surgical patients	CDC	ICD-9-CM codes for diagnosis and surgical procedure–recorded not detailed	C/CCon/ Con /D	Yes	No	Nurse	Hospital associated	Yes/N/S	First 7 months of 1990	Until discharge–N/S
Aavitsland *et al.* (82)	1 day	HAI*	Slightly adapted CDC	N/S	N/S	N/S	N/S	ICN or clinician	Hospital associated	N/S/N/S	1 day	1 day
Kappstein *et al.* (83)	Prospective cohort study incidence	SSI	CDC–clearly defined	Yes	C/CCon only	Recorded not detailed	N/S	Yes	Hospital doctor not involved in patients treatment	N/S/N/S	November 88 to September 89	Until discharge not specified
Kappstein *et al.* (84)	Incidence prospective cohort studies	SSI/LRTI in ICU	CDC–clearly defined	3 specified	C/CCon/ C/D	N/S	N/S	Physician not involved in the treatment of the patients	Yes	N/S/N/S	June 88 to September 89	Until discharge (time not specified) or death

Moro *et al.* (49)	Incidence	SSI	CDC	Orthopaedic* and general surgery; data for ten most frequent ops	C/CCon/C/D –NRC definition	Yes	N/S	Surgeon or ICN	Hospital associated, wounds ranked by operating surgeon	N/S/N/S	6-month period	Until discharge
Di Palo (85)	Prospective incidence	SSI	N/S	General classification	C/CCon/C/D	N/S	N/S	N/S	Hospital associated	Yes/N/S	1980-88	30 days post surgery
Kjaersgaard *et al.* (48)	Incidence	SSI	CDC	Operations coded–ten most common	C/CCon/C/D	Yes	N/S	Surgeons; ward staff N/S; GPs post discharge	Hospital associated	N/S	1/3/87 to 31/7/88	Approximately 30 day follow-up

Altemeier classification – clean/clean-contaminated/contaminated/dirty; ASA, American Society of Anaesthesiologists; ASEPSIS, Additional treatment, the presence of Serous discharge, Erythema, Purulent exudate, Separation of the deep tissues, the Isolation of bacteria and the duration of inpatient Stay; BS, blood stream infection; C/CC/Con/D, clean/clean-contaminated/contaminated/dirty; CAI, community-associated infection; CDC, Center for Disease Control; CMs, clinical microbiologists; CRF, case record form; CSHPF, Conseil Supérieur d'Hygiène Publique de France; CTIN, Comité Technique National des Infections Nosocomiales; DNs, district nurses; GPs, general practitioners; HAI, health care-associated infection; ICD, infections control department; ICN, infections control nurse or equivalent; ICP, infections control physician/practitioner; ICT, infections control team; ICU, intensive care unit; IDS, infectious disease specialist; LRTI, lower respiratory tract infection; N/A, not applicable; NI, nosocomial infection; N/S, not stated; NINSS, UK Nosocomial Infection National Surveillance Scheme; NMR, National Medical Registry (Netherlands); NNIS, National Nosocomial Infection Surveillance; NRC, National Research Council; NSIH, National Program for the Surveillance of Hospital Infections; PGIC, postgradutate infectious control training; RI, risk assessment; SENIC, four risk factors – duration of intervention >2 hours: ≥3 conditions on admission: abdominal surgery and a contaminated or dirty-infected wound; SSI, surgical site infection; UTI, urinary tract infection; WIP, Werkgroep Infectiepreventie.

*The coding file of the DANOP-DATA system included only four categories for orthopaedic operations.

Table 2 Selected studies summary – supplementary

Source	Wounds classified post op	Hospitals surveyed	Type of hospital	Number of patients	Impact of SSI – cost/length of stay	Re-admission rate
Klavs *et al.* (60)	N/S	19	Acute care	6695	N/S	N/S
Lizioli *et al.* (46)	N/S	88	Public	18 667	N/S	N/S
Rios *et al.* (10)	N/S	1	Private	43	Yes	N/S
SCIEH (61)	N/S	16 acute trusts – i.e. group of hospitals	Acute care	7923	N/S	Yes
Eriksen *et al.* (62)	N/S	45	Somatic	35 712	No	No
Gikas *et al.* (45)	N/S	14	Hospital/regional	3925	N/S	No
Lallemand *et al.* (63)	Probably	18	Various	474	No	No
Steinbrecher *et al.* (64)	N/S	132 surgical units in 89 hospitals	N/S	71 038	N/S	N/S
Thibon *et al.* (35)	N/S	25 units of 10 institutions	N/S	3705	N/S	N/S
Astagneau *et al.* (7)	N/S	221 surgical wards	Teaching, general public and private	38 973	Yes	N/S
Azzam and Dramaix (65)	N/S	14	Public acute or private	834	Yes (but HAI in general)	N/S
de Boer *et al.* (66)	N/S	63 – voluntary basis	Various	36 629	N/S	No
Mintjes de-Groot *et al.* (67)	N/S	16 ICUs	ICU ward	2795	N/S	No
Plowman *et al.* (6)	No	1	District general	3980	Yes for HAI	No
Reilly *et al.* (28)	Probably – at postoperative wound audit clinics	1	N/S	2202	Yes	Yes
Stockley *et al.* (34)	No	1	District general	618 complete follow-up selected for method reporting	Yes	Yes
Andersen *et al.* (69)	N/S	14 – varied over 3 years	Two regional — 14 other	32 248	No	Yes due to HAI — most frequent deep-seated SSI
FPSSG (13)	N/S	830	88% public	236 334	No	No
Geubbels *et al.* (14)	N/S	38	Acute care	18 063	Yes	No
Mintjes-de Groot *et al.* (70)	N/S	1	Acute care	75 517	N/S	No

Pavia *et al.* (71)	No	4	Public acute care	880	No	No
Asensio and Torres (29)	N/S	1	Teaching	701	Yes	Yes
Golliot *et al.* (72)	N/S	120 surgical units	N/S	16 506	No	No
Pittet *et al.* (73)	No	4	University	1349	Yes for HAI	No
Scheel and Stormark (47)	No	71/76	Various – teaching, county; local, specialised	12 755	No	No
Vaqué *et al.* (12)	No	214	Acute care – defined by bed size	51 674	No	No
Frankart *et al.* (74)	N/S	N/S	University of Geneva associated hospitals	994	N/S	N/S
Gastmeier *et al.* (30) (NIDEP)	N/S	72	Selected – acute care	14 996	N/S	No
Cainzos *et al.* (75)	N/S	8	N/S	280	Yes	No
Medina *et al.* (76)	N/S	1	Tertiary	497	N/S	No
Rüden *et al.* (15) (NIDEP)	No	72	Selected acute care	14 966	No	No
Emmerson *et al.* (11)	N/S	157	District general (103); teaching, 0private, other	37 111	No	No
Kampf *et al.* (31) (NIDEP)	N/S	72	72 – selected acute care	5377	No	No
Ronveaux *et al.* (8)	Probably – N/S	57	Acute care	16 799 – (total days of observation 230 524)	Yes	No
Vaqué *et al.* (50)	No	186 (with 74 having participated every year)	Various acute care –defined by bed size	49 689	No	No
Erbaydar *et al.* (77)	N/S	1	University	1482	Yes	Hospital associated
Sartor *et al.* (78)	No	8	University-affiliated	1220; 1389	No	No
Byrne *et al.* (52)	N/S	1	N/S	3489	Yes	N/S

Table 2 Continued

Source	Wounds classified post op	Hospitals surveyed	Type of hospital	Number of patients	Impact of SSI – cost/length of stay	Re-admission rate
Mertens *et al.* (79)	Probably – N/S	85 of 218 invited; 62 choosing the SSI study	Acute care	10 357 operations	Yes	No
Poulsen *et al.* (80)	N/S	1	N/S	8996; 10 surgical groups– 4515 for matched cohort study	Yes	Yes
Coello *et al.* (5) Vegas *et al.* (81)	N/S	1	District general	67	Yes	N/S
Aavitsland *et al.* (82)	N/S	76/84	Somatic/acute care – four speciality	14 977	No	No
Kappstein *et al.* (83) Kappstein *et al.* (84)	N/S	1	University	569 enrolled	Yes	No
Moro *et al.* (49)	No	2	Acute care/university	1452	N/S	No
Di Palo (85)	N/S	1	University	7000	N/S	N/S
Kjaersgaard *et al.* (48)	Probably – data recorded by surgeon immediately following operation	2	N/S	3904	No	No

HAI, health care-associated infection; N/S, not stated; N/A, not applicable; SSI, surgical site infection.

Explanations of how the CDC definitions were modified or adapted were not generally provided. Relatively few studies stated confidently the applied study definition of an SSI. Recording whether trained, unbiased and validated observers were used to record study data were the categories with the most incomplete number of data points. Only the NIDEP study clearly stated that each of the four components had been fulfilled (32). Thus, overall, Table 1 reveals the difficulty encountered in identifying studies that included all of the original proposed criteria. Of the 48 studies listed, none clearly identified answers to all of the original parameters. Whilst it is possible that these factors were recorded during the course of the study, the information was not provided in the published article. Data were also recorded (Table 2), where available, on the number and type of hospitals/units involved and the number of patients included in the study, as previous studies have suggested that the hospital classification may bias infection rates as more seriously ill patients are more likely to be referred to specialist care centres, experience longer stays in hospital and potentially be at a higher risk of contracting a health care-associated infection (HAI). However, because the number of hospitals contributing data ranged from one to 214, the number of units from one to 132, with groups of hospitals pooling data, this information merely illustrates another potentially confounding factor. Study patient numbers were similarly wide ranging: 43–236 334.

For many of the selected studies (23), the primary aim of the article was to establish the overall rates of HAI – previously described as hospital-acquired infections. SSI rates were then reported as a data subgroup of these overall reviews. In the majority of studies, HAIs were divided into four main categories: urinary tract infection (UTI), lower respiratory tract infection (LRTI), SSI and septicaemia. Table 3 presents a chronological review of selected European prevalence studies reporting overall HAI rates including the four categorisations, where available. SSIs are generally the third most frequently reported HAI although it is important to highlight that the 15–20% range indicated in Table 3 represents a percentage of all HAIs and thus of all patients, both surgical and non surgical. Only two HAI incidence studies were identified, which presented overall HAI rates of 7·8% and 7·0% (5,6).

The 14 studies listed in Table 4 have a fairly consistent SSI rate covering a range between 2% and 5%. However, as will be highlighted later in the discussion, the disparity in study protocol – and other pertinent factors – eliminates any comparability.

Six studies were identified (Table 5), which include data for multiple wound classifications to highlight the impact of this variable. An additional three studies (Table 5) were identified that provided data only on clean wound classifications (12,28,33). These studies appeared to have recorded – if not reported – more detailed information regarding the type of surgical procedure being undertaken. Notably, the infection rates reported were specified for the surgical procedure and were also found to be at the higher end of the spectrum – ranging from 7% for hernia procedures to 13% for breast surgery (28) and up to 14% for breast, varicose veins and hernia (33).

Table 6 presents nine studies that provided information regarding the patients' NNIS risk index and their associated observed infection rate. The NNIS risk index assesses three categories of variables: the ASA Physical Status Classification, duration of surgical procedure and definition of wound class. The corresponding procedures were included as detailed in the article as the weighted mean across the index. Two further studies (not listed) report that either NNIS criteria were applied in only some of the participating hospitals or that the relevant data were not used in the published article (34,35).

Presented in Table 7 are the six studies that collected data on the common pathogens associated with SSI. These data suggest that *Staphylococcus aureus* is the largest causative pathogen in SSI, accounting for some 30–40% of cases; *Escherichia coli* is responsible for approximately 15% and *Staphylococcus epidermidis* a further 10%.

Eleven studies were found that focused on the extended length of stay associated with an SSI, typically for a specific procedure (Table 8). Often the data involved comparison of two means: the length of hospital stay without an SSI and with an SSI. The calculated mean from these studies (unweighted) of the additional length of stay associated with an SSI is 9·8 days (range 6·5–14·3). Table 9 summarises the significant differences in the cost of a 'bed day' arising from anomalies in what is

Key Points

- positively few studies stated confidently the applied study definition of an SSI
- SSI are generally the third most frequently reported health care associated infection
- date suggests that *S. aureus* is the largest causative pathogen in SSI

Table 3 Health care-associated infection prevalence studies

Source	HAI (%) patient infected [range by hospital]	HAI – % infection overall [range by hospital (%)]	SSI – % total HAI [SSI rate % of all patients]	UTI – % total HAI [UTI rate % of all patients]	LRTI (pneumonia) – % total HAI [LRTI rate –% of all patients]	Septicaemia – % total HA [BSI rate % of total patients]
Klavs *et al.* (60)	4·6 ≥ 1 infection [3·1–5·4]	5·0	15 [0·7]	25 [1·2]	23 [1·0]	7 [0·3]
Lizioli *et al.* (46)	4·9 [4·1–5·7]	N/S	2·7 in surgical patients only	[1·6]	[1·1]	[0·6]
Eriksen *et al.* (62)	5·1* [3·5–9·3]	N/S	27 [1·4]	37 [1·8]	28 [1·4]	8 [0·4]
Gikas *et al.* (45)	8·6	9·3 [5–13·4]	15	23	30	16
Azzam and Dramaix (65)	6·8	8·5	28	18	30	7
Andersen *et al.* (69)	6·5 [1·4–11·7]	N/S	[4·3% of surgical patients]	[1·7]	[0·8]	[0·4]
FPSSG† (13)	6·7 ≥ 1 infection	7·6	11 [4·5% of surgical patients]	35	13¶	6
Mintjes-de Groot *et al.* (70)	4·7	4·5 per 1000 patient-days	18	42	11	10
Pavia *et al.* (71)	1·7	1·7	27 [2% of surgical patients]	27	13	13
Pittet *et al.* (73)	11·6 [9·8–13·5]	13	30	22	15	13
Scheel and Stormark (47)	N/S	6·1	29 [6·3% of surgical patients]	36	25	10
Vaqué *et al.* (12)	6·9	8·1	20 [2·8% of clean surgery patients]	25	21	14
Frankart *et al.* (74)	16·9	23	12	30	17	10
Gastmeier *et al.* (30); Ruden *et al.* (15) (NIDEP)	3·5 [0–8·9]	3·6	16	42	21	8
Emmerson *et al.* (11)	9·0 [2–29]‡	N/S	11	23	23	6·2
Kampf *et al.* (31)	3·8%§	N/S	34	35	7	4
Sartor *et al.* (78)	8·6; 7·1	N/S	21; 11	21; 27	15; 24	12; 12
Aavitsland *et al.* (82)	N/S	6·3 [0–15]	17 [3·6% of surgical patients]	33	21	6

BSI, blood stream infection; HAI, health care-associated infection; LRTI, lower respiratory tract infection; SSI, surgical site infection; UTI, urinary tract infection.
*Four most common only measured.
†French Prevalence Survey Study Group.
‡One outlier of 54%.
§HAI in surgical patients only.
¶Plus 8% URTI.

Table 4 Surgical site infection rates

Source	Procedural range (%)	Country	%	Type of study	Observation period	Surgical procedure specified
Lallemand *et al.* (63)	N/S	France	2·7	Incidence	Until discharge	General classifications only
Steinbrecher *et al.* (64)	0·26–6·5	Germany	4·0	Prevalence	N/S	13 specified surgical procedures
Thibon *et al.* (35)	0·4–5·1	France	2·2	Incidence	30 days	General classifications only
Astagneau *et al.* (7)	0·4–11·8	France	3·4	Incidence	30 days	Yes — 30 classifications given
FPSSG (13)	0·1–8·2	France	4·5	Prevalence	N/A	Recorded not detailed
Plowman *et al.* (6)	N/S	UK	1·0	Incidence	Until discharge	General classifications only — infection category of 'multiple infections' which were not counted in individual categories
Geubbels *et al.* (14)	0·0–12·9	Netherlands	3·1	Incidence	Until discharge*	Yes but of 18 063 procedures >7000 classed as 'other'
Scheel and Stormark (47)	0·0–8·3	Norway	6·3	Prevalence	N/A	Recorded not detailed
Vaqué *et al.* (12)	N/S	Spain	2·8	Prevalence	N/A	Clean surgery only — procedures not specified
Kampf *et al.* (31)	0–7·2	Germany	1·3	Prevalence	N/A	11 procedures specified
Emmerson *et al.* (11)	N/S	UK	1·1	Prevalence	N/A	General classifications only
Mertens *et al.* (79)	1·7–22·2	Belgium	1·9	Incidence	Until discharge*	Various study populations allowed — ICD-9-CM codes for 40 categories recored but not detailed
Moro *et al.* (49)	0·4–33·3	Italy	1·2/4·9	Incidence	4·9%/1·2%	Orthopaedic/general — subset of data for 10 most frequent ops
Kjaersgaard *et al.* (48)	0·0–5·8	Denmark	3·3	Prevalence	Discharge and beyond	Codes of operation — ten most frequent detailed

N/A, not applicable; N/S, not stated.
*Some post discharge surveillance.

Table 5 Surgical site infections by wound classification

Source	Country	Procedure	Clean (%)	Clean-contaminated (%)	Contaminated (%)	Dirty (%)
Lizioli *et al.* (46)	Italy	General classifications only	1·4	2·7	9·1	10·5
Geubbels *et al.* (14)	Netherlands	17 cited procedures	2·8	3·1	8·3	7·2
Cainzos *et al.* (75)	Seven-country study	Biliary tract stone	N/A	3·2	7·7	20·0
Mertens *et al.* (79)	Belgium	Abdominal, orthopaedic, gynaecological and other	1·1	1·5	5·3	19·3
Kampf *et al.* (31)	Germany	11 procedures specified	2·4	2·5	4·2	2·6
Kjaersgaard *et al.* (48)	Denmark	Codes of operations recorded — most frequent detailed	2·3	4·7	4·3	8·3
Reilly *et al.* (28)	Scotland	Breast	13	N/A	N/A	N/A
		Hernia	7			
		Vascular	10			
		Cholecystectomy	7			
Melling *et al.* (33)	UK	Breast	11·5	N/A	N/A	N/A
		Hernia	6·9			
		Varicose veins	4·9			
Vaqué *et al.* (12)	Spain	General classifications only	2·8	N/A	N/A	N/A

N/A, not applicable.

Table 6 NNIS risk assessment versus observed surgical site infection rate

Source	Country	Procedure	NNIS = 0 (%)	NNIS = 1 (%)	NNIS = 2 (%)	NNIS = 3 (%)	Overall (%)
SCIEH (61)	Scotland	Breast	1·3	4·7	14·3	0	1·9
		Abdominal hysterectomy	1·2	1·5	40·0	0	1·5
		Caesarean section	1·9	3·6	0	0	2·2
		Fractured neck of femur	0	2·6	12·5	0	2·1
		Hip replacement overall*	1·5	2·0	2·0	0	1·7
		Knee replacement overall*	0·5	1·8	1·6	0	0·9
Lallemand *et al.* (63)	France	4 + 'other'	1·5	5·4	5·9	0·0	2·74
Steinbrecher *et al.* (64)	Germany	13 different surgical procedures	0·17–3·19	0·47–5·76	0·74–9·31	4·52–12·11	0·26–6·54
Astagneau *et al.* (7)	France	27 procedures specified	1·9	5·3	11·9	23·5	3·4%
De Boer *et al.* (66)	Netherlands	Hip total replacement deep SSI	0·6	1·0	2·4	0	N/S
		Knee total replacement deep SSI	0·8	0·8	0·9	0	N/S
Golliot *et al.* (72)	France	General/visceral	2·2	5·5	12·5	26·7	3·9
Medina *et al.* (76)	Spain	Hernia – 92% elective	7·5	10·5	25	–	8·1
Ronveaux *et al.* (8)	Belgium	10 procedures detailed – ICD-9-CM codes	0·7	1·7	5·2	11·1	1·5
Mertens *et al.* (79)	Belgium	10 procedures with highest incidence of SSI detailed	1·2	1·9	4·5	12·5	1·9

NNIS, National Nosocomial Infection Surveillance; NS, not stated; SSI, surgical site infection.
*Summary of all subgroups of surgical procedure included.

included in this cost (i.e. nursing care, pharmaceuticals) as highlighted by a recent study conducted in the Netherlands (36). Additional confounding factors include the disparity in study dates and sources.

The mean additional length of stay of 9·8 days associated with an SSI (as derived from Table 8) is factored by these costs resulting in values as low as €1862 up to €4047 (at current exchange rates) for each SSI recorded.

Table 10 identifies those studies that provided some measurement of the cost associated with an SSI. These studies presented a range or a mean cost, and, where available, the detail of the procedure is provided.

Table 7 Common pathogens associated with surgical site infection

Source	Country	*Staphylococcus aureus* (%)	Coagulase negative *Staphylococcus* (epidermidis) (%)	*Escherichia coli* (%)	*Pseudomonas aeruginosa* (%)
de Boer *et al.* (66)	Netherlands	33–39	6–11	Not given	8
Geubbels *et al.* (14)	Netherlands	35	Not given	Not given	Not given
Astagneau *et al.* (7)	France	27	Not given	Not given	Not given
Geffers *et al.* (86)	Germany	30–40	Not given	15	Not given
PHLS (87)	UK	37	9	3	7
Kampf *et al.* (31)	Germany	29	10	12	10

Table 8 Extended stay associated with surgical site infection

Source	Country	Procedure	Days
Rios *et al.* (10)	Spain	Appendicectomy	7·5
Plowman *et al.* (6)	UK	General surgery	6·5
Stockley *et al.* (34)	UK	Six procedures — at various time points	7·6
Geubbels *et al.* (14)	Netherlands	17 procedures — including herniorrhaphy, caesarean section and colon resection	11·6
Schulgen *et al.* (88)	Germany	Elective and emergency	11·0
Cainzos *et al.* (75)	Seven-country survey	Biliary tract stone	8·0
Ronveaux *et al.* (8)	Belgium	10 procedures cited	8·9
Morales *et al.* (89)	Spain	General surgery	10·0
Vegas *et al.* (81)	Spain	ICD-9-CM codes for diagnosis and surgical procedure – recorded not detailed	14·3
Coello *et al.* (5)	UK	Gynaecology, general and orthopaedics	10·2
Kappstein *et al.* (83)	Germany	Cardiac	12·2

Key Points

- original objective of this review was to estimate a mean rate of SSI across Europe
- through the review it became apparent that comparison across studies is not possible due to the wide variation in data collection

DISCUSSION

The original objective of this review was to estimate a mean rate of SSI across Europe from published studies with the ultimate intention of calculating a broad pan-European perspective of the attributable economic burden.

In conducting the review, however, it became apparent that comparison across studies is not possible due to the wide variation in methodologies of data collection. Whilst it is recognised that these studies were not intended for comparison, the inconsistencies uncovered (and the absence of key data) are plainly revealed in Table 1.

Definitions and protocols

Bruce *et al.* (37) recognised that CDC (16) definitions were the most frequently referred to in the published literature. Similarly, in the 48 studies listed in Table 1, most stated that CDC definitions were used. However, in nine studies, these were described as CDC-'based', 'modified' or 'adapted' with no additional information provided. Five studies used a combination of CDC and national guidelines and three cited non CDC references. One study used the ASEPSIS wound classification system and one changed the wound definition from one study time point to the second. Any comparison across surveys requires that the classification system used should be specified. Given its already substantial influence, the CDC classification is advised for use, despite its limitations such as the difficulty of interpreting what actually constitutes an SSI.

As Barie summarised in 2002 (38), 'prospective studies must ensure that criteria for the appearance of the incision are explicit before the study starts, that all observers have been trained and that inter-rater reliability is high'. This observation is supported by Thibon *et al.* (35), who advise that if results obtained from different teams are to be comparable, then monitoring protocols must also be harmonised. Table 1 suggests that not all studies

Table 9 Costs of additional hospitalisation days associated with surgical site infection

Source	Country	Cost per day	Cost for mean of 9·8 days
Netten and Curtis (90)	UK	€409	€4008
Oostenbrink *et al.* (36)	Netherlands	€230	€2254
Geldner *et al.* (91)	Germany	€317	€3107
Pena *et al.* (92)	Spain	€170	€1666
PMSI (93)	France	€412	€4038
Orsi *et al.* (94)	Italy	€413	€4047

All general bed day costs.

Key Points

- differences in the training and validation of observers proved to be an issue
- specific definitions and processes varied
- indeed in some cases assessment was by surgeons and in others, the patients themselves

Table 10 Published data on the economic costs associated with surgical site infection

Source	Country	Procedure	Range	Mean
Riose *et al.* (10)	Spain*	Appendicectomy	€1881–2057	
Rios *et al.* (10)	Spain*	Colectomy	€6406–8141	
Plowman *et al.* (6)	UK	Inter-disciplinary		€2370
Reilly *et al.* (28)	UK†	Inter-disciplinary		€600
Geubbels *et al.* (14)	Netherlands†	Inter-disciplinary	€900–2700	
Garcia and Salto (95)	Spain*	Inter-disciplinary		€2400
Coello *et al.* (5)	UK*	Inter-disciplinary		€1900
Kappstein *et al.* (83)	Germany	Cardiac		€3010

*Surgical site infection.
†Surgical site infection, clean only.
‡Surgical site infection, 17 procedures identified.

identified who was responsible for observation. Similarly, it was difficult to determine the level of training given and whether or not the observers were independent of the institution. Whilst the 'judgement of wound status is highly subjective and at risk of intra- and inter-observer bias' (37), there are steps that can be taken to reduce this.

Trained, unbiased and validated observers

In at least six of the studies, surgeons were involved in the identification of SSIs. Taylor *et al*. (39) showed that a trained observer using a specified wound definition detected 95 SSIs from 3024 patients studied. However, in the same study, a further 18 infections were diagnosed by the surgeons alone – a criteria for diagnosis allowed by the CDC definition. Whilst the numbers were small, individual surgeons reported from 0% to 67% more infections than were identified by the standardised criteria, leading Taylor *et al*. (39) to comment that '… surgeon's diagnosis becomes a confounding variable when comparisons of rates among surgeons are made'. The sensitive issue of publication of single centre or even single surgeon SSI rates either through the medical literature or hospital league tables is also therefore likely to have some impact on the accuracy of data reported. Emmerson *et al*. (11) described one hospital that participated in studies only to withdraw once early feedback about overall infection rates had been received, and Nice *et al*. (40) report anonymised rates of SSI after caesarean section ranging from 2·5% to 17·5%. Gaynes (41) notes: 'when the added pressure of publicly available data is added to a process that already has a tendency to miss cases … the possibility of serious under-reporting of infections becomes cause for ardent concern'.

Patients are also used to identify SSIs, and whether conducted by telephone or postal questionnaire, these data undoubtedly introduce another potentially confounding source of variation. Seaman and Lammers (42) and Whitby *et al*. (43) indicate that using patients to evaluate their own surgical wounds for infection results in both under- and over-reporting. In contrast, Mitchell *et al*. (44) found that there was a close correlation between surgeons and patients when assessing the surgical site. Ideally, in order to minimise risk of bias and enhance validity and reliability of the data collected, the monitoring of SSIs should be undertaken by trained independent observers whose technique and surveillance standards have been previously validated. Of the studies listed in Table 1, only those based on the NIDEP study clearly stated that independent observers were separately trained for this surveillance. Prior to the study, the observers were validated and showed a case sensitivity of 84·3% and a specificity of 98·5%.

HAI and the calculation of SSI

In several studies, close analysis revealed that the calculation of the HAI also varied as some assessed the overall rate as including multiple infections in the same patient as a single infection (Table 3). Because a patient may have more than one infection, if the number of patients are used, this will present a lower number than if infections are accounted for individually. For example, Gikas *et al*. (45) found an 8·6% HAI patient infection rate but an overall infection rate of 9·3% when multiple occurrences in the same patient were considered. This may explain why some studies report rates that fall into the lower end of the distribution which can be misleading, as ranges are not always provided.

The four categories of infection in Table 3 are consistently mentioned in the studies and represent the majority of HAIs. The figures are consistent with the findings of Emmerson *et al*. (11), who reviewed the HAI rate from four European country studies and noted that UTI accounted for 25–35%, RTI for 20–25% and SSI for 15–20% of HAI. Table 3 suggests that septicaemia represents a further 5–15% of HAI. SSIs are the third most prevalent HAI when all patients are considered. One category of HAI that has not been accounted for is that of a patient re-admitted to hospital as a consequence of an infectious complication of a surgical procedure. Given the increasing tendency for hospitals to discharge patients as early as possible, following a surgical procedure (12,46), this is a specific area requiring further investigation.

Table 3 is useful for understanding the relative proportions of SSI versus the other infection types, but should not be used to calculate actual SSI rates. Some studies reported an SSI rate as a percentage of the overall HAI rate or as a percentage of all patients occupying surgical beds (5,47). However, without a clear distinction between pre- and postsurgical as well as non surgical patients, these methods will underestimate the true rate of SSI, which by definition, can only occur in patients following a surgical procedure. Coello *et al*. (5) found that when taken as a percentage of all patients, the SSI rate was 1·8%, but when only surgical patients were considered, this increased to 3·0%. Similarly, Scheel and Stormark (47) found that a prevalence of 1·7% of SSIs increased to 6·3% when assessing only the patients who had undergone surgery. This apparently high percentage is explained as being attributable to an ongoing national surgeons meeting resulting in the patients included in the study being only 'postoperative or emergency' patients. SSI studies must be conducted on patients who have undergone surgery, and should exclude patients occupying a surgical bed but who have yet to undergo a surgical intervention. This emphasises the importance of appropriate denominators when calculating SSI rates.

Wound classification and NNIS risk assessment

The studies in Table 5 provide data relating to infection by wound classifications. As would be expected, there is a clear relationship between infection rates within the spectrum of 'clean' to 'dirty' surgery. Clean surgery ranged from 1·1% to 2·8% and dirty surgery from 2·6% to 20%. Of the studies cited (Table 5), only Kjaersgaard *et al*. (48) state that postprocedural classification was carried out. Three others (8,28,49) made use of either postsurgical audit teams or recommended that procedures were recorded prospectively in the operating theatre by a member of the surgical team. It is important to distinguish whether the wound classification is that assigned to the procedure preoperatively (the expected) or postoperatively (the actual).

Assessment of the patient's risk of infection adds a further level of detail (Table 6). In addition to the wound classification, the US NNIS identifies two further criteria to be used in assessing the risk of SSI: the ASA score which takes into consideration the overall health of the patient and the length of procedure. These two additional variables capture information about a procedure both pre- and postoperatively: the ASA scores the patient on a scale of 1–5 prior to surgery; the length of procedure is obviously determined upon completion. Observing the range across NNIS score, it is apparent that merely reporting the overall mean rate of infection obscures enormous variance in results. Rates of infection associated with an NNIS score of 0 were invariably lower than the mean and those of higher scores. Clearly, grouping SSIs by NNIS score provides a reliable method for evaluating the rates of infection.

Surveillance period

Most, but not all, of the incidence studies revealed a defined period of observation (Table 3). Vaqué *et al*. (50) comment that the trend to earlier discharge and subsequent decrease in hospital stay leads to an increasing number of SSIs being detected in the community and that therefore 'these infections cannot

Key Points

- Table 3 presents a useful understanding the relative proportions of SSI versus other types of infections
- there is a clear relationship between infection rates within the spectrum of 'clean' to 'dirty' surgery
- clean surgery ranged from 1·1% to 2·8%
- dirty surgery ranged from 2·6% to 20%
- most, but not all, of the incidence studies revealed a defined period of observation
- earlier discharge and subsequent decrease in hospital stay lead to an increasing community incidence of SSI

Key Points

- another variance is the expected hospital stay for the same procedure conducted in different countries
- as economic pressures drive earlier discharge, post surveillance of SSI becomes more difficult
- microbiology and the causative pathogens of SSI play a pivotal role in the treatment and prevention of SSI
- the majority of the financial burden is attributable to the extended length of stay

be detected in prevalence studies'. Studies have revealed that between 12% and 84% of SSIs are detected after discharge from hospital (5,21,51–54). The difficulties in drawing comparisons are further complicated by the variations in 'expected' hospital stay for the same procedures conducted in different countries. Thus, any comparison of SSI rates must take into account the period of postsurgical hospital stay and postdischarge surveillance, and both time periods must be detailed. Geubbels *et al*. (14), for example, state that all patients were followed until discharge but do not identify the time to discharge except as an overall mean.

The NNIS recommends a period of surveillance of 30 days to ensure the accurate prospective monitoring of a patient for the development of SSI (without implant). But as economic and social pressures build to reduce the length of stay, this will correspondingly increase the importance of postdischarge infection surveillance and poses a challenge for data collection. Thirty-day follow-up is costly, time-consuming and subject to procedural problems. A study of ten participating institutions conducted by Thibon *et al*. (35) reported a mean of nearly 60% of patients lost to follow-up after discharge with individual hospital data ranging from 5·1% to 95·5%.

In Table 4, prevalence studies are generally shown to report rates of SSI at the higher end of the spectrum. This is to be expected as patient risk of infection is overestimated by a prevalence rate, as this is calculated as the number of active infections on the day of the visit divided by the number of beds visited. This is due to the influence of the duration of infections, i.e. new and existing infections are captured in a prevalence survey but only new ones in an incidence survey. It is apparent that any rational interpretation of these data would be unwise due to the number of variables associated with the gathering of SSI infection rates. For example, although most of the studies in Table 4 did not record the procedures undertaken in sufficient detail, it is also clear that they did not survey the same types of operation, nor in the same proportion. For those studies in which detail by procedure is given, large differences in the ranges of SSI by surgical procedure emerge: Geubbels *et al*. (14) reveal a range of 0–13% and Astagneau *et al*. (7) 0·4–11·8%, which are presented as means of 3·1% and 3·4%, respectively.

Pathogens

Microbiology and the causative pathogens of SSI play a pivotal role in the treatment and prevention of SSI. The NIDEP (32) study provides some interesting insights into the role of microbiology in patient management and the significance and value of monitoring and detecting SSI. This study found that microbiology samples were only taken in 67·5% of all superficial SSIs (76·9% of deep SSIs) and that the prevalence of HAIs was higher in hospitals with an in-house microbiology laboratory. Corresponding lower rates of infection were found in hospitals where the microbiology service was outsourced. The frequency of causative bacteria for SSI was found to be *S. aureus* (22·5%), *Enterococcus* spp. (12·6%), *Pseudomonas* spp. (12·6%), *E. coli* (9·9%) and *Streptococci* (7%) (32), which broadly reflects the data presented in Table 7. Causative pathogens are of specific importance when examining the rate of SSI, as Kalmeijer *et al.* (55) has already reported that nasal carriage of *S. aureus* is a major risk factor of SSI in orthopaedic surgery.

Extended length of stay

There are a large number of variables that need to be calculated to obtain a valid direct cost of an SSI, but the majority of the financial burden is attributable to the extended length of stay (5,6,28,29). Isolating the mean extended length of stay and factoring by the average daily cost of an occupied hospital bed gives a reasonable minimum indication of the cost burden of an SSI (56). It should be noted that for the purposes of this review, the extended length of stay as derived from the studies analysed was attributed only to the presence of an SSI. However, it is acknowledged that other factors may be associated with an extended length of stay, i.e. comorbidities, extremes of age, etc.

Studies selected in Table 8 reveal that the extended length of stay associated with an SSI ranges from 7 to 14 days. The mean was calculated to be 9·8 days, although this is an unweighted figure because not all the studies reported the number of cases involved.

It is acknowledged that Table 8 contains a bias: those procedures that carry a higher risk of an SSI and which therefore increase the likelihood of an extended hospital stay are more likely to be studied because the opportunity for statistically significant variance is correspondingly higher. Thus, the selection of these higher risk procedures will naturally skew the study data upward as they are not representative of all surgeries.

Costs associated with extended stay

The costs associated with the extended length of stay in Table 9, calculated from the 9·8 days derived in Table 8, results in costs of infection ranging from €1862 to €4047. Determining the daily cost of a hospital stay was difficult in some cases, and each source had a unique way to calculate the figure.

This approach cannot offer a precise indication of cost due to the large number of contributing variables that are not factored into this review, for example, regional differences, private versus public hospitals, and ward placement of the patient after surgery. However, this method does provide a reasonable mean cost of infection, particularly because it maintains local country cost differences.

The studies presented in Table 10 support the calculations made in Table 9. Costs for an SSI are generally calculated to be in the proximity of €2000 with variations attributable to procedure as well as country of origin, as would be expected from any assessment of general health care cost levels. Higher costs are associated with studies conducted on cardiac and cholecystectomy procedures due to the fact that these types of surgery are more adversely affected by any SSI that may subsequently develop.

Considering that there are an estimated 30 million surgical procedures conducted in Europe each year, the possible range for the number of cases of SSI per year falls between 450 000 and 6 000 000. At an average surgical bed day cost of €325 and an average extended hospital stay of 10 days, SSI infections could be costing European health care systems between €1·47 billion and €19·1 billion. The upper value of this range is clearly biased by the higher SSI rates associated with dirty wounds and high-risk patients (a relatively small percentage of overall procedures). It must be acknowledged, however, that any reduction in SSI rates in this group arising from improved aseptic and surgical techniques may be compromised by undertaking more and increasingly invasive and complex procedures in older and more 'at risk' patients (57).

The following minimum criteria for study protocol design are suggested: definition of infection – CDC and if modified, details should be provided; identification of surgical procedures – using ICD codes or similar system; wound classification – detail of whether this was carried out pre- and/or postoperatively; patients assessed for risk factors – systems used should be specified; trained, independent and validated observers – a short summary of this information is necessary; specified surveillance period – according to NNIS guidelines unless otherwise stated.

Clearly, these data also need to be reported in the published articles. Mayon-White *et al.* (4) in an article published in 1998 reported that 'there is an opportunity and a need for international cooperation in finding effective and applying effective means of prevention and control' of HAI. Hospitals in Europe Link for Infection Control through Surveillance (HELICS), the European-wide initiative involving 18 countries (58,59), has the opportunity to address many of these issues. However, it is a voluntary association of centres with a scarce penetration in some of those countries participating in the project. An approach encompassing surveillance, control, training and research will collate the most valuable and important data on SSI in Europe and represents a significant advance in the goal of reducing the burden of SSI.

CONCLUSION

The objective of this analysis was to provide an overview of the pan-European SSI rate and the associated cost burden. On cursory examination, the studies identified suggest that the average rate of SSI lies in the range of 2–5%. However, this percentage is likely to be misleading, as it is derived from studies that included surveys of all inpatients irrespective of whether they had undergone surgery or not. A more realistic range can be derived from Table 9 which suggests that the rate of SSI lies between 1·5% and 20% depending mainly on the type of surgical procedure and the wound classification. No mean or median value can be given as neither the denominators

Key Points

- the costs associated with the extended length of stay ranges from €1862 to €4047
- costs for an SSI are generally calculated to be in the proximity of €2000
- it is estimated that 30 million surgical procedures are conducted in Europe each year
- number of cases of SSI per year falls between 450k and 6000k
- SSI could be costing European health care systems between €1·47 billion to €19·1 billion
- encompassing surveillance, control, training and research will represent a significant advance in the goal of reducing the burden of SSI

Key Points

- the objective of this analysis was to provide an overview of the pan-European SSI rate and associated cost burden
- average rate of SSI lies in the range of 2–5%
- ultimate purpose of the tracking of SSI must be to enable the implementation of cost effective preventative measures
- a robust dataset must be established and standards of protocol and presentation agreed to allow effective tracking

nor the surgical procedures involved have been reported in the necessary detail, and consequently, grounds for comparability or aggregation of the data across the selected studies are very weak. These figures are further limited by the high level of inconsistencies in study protocol, definitions and data collection that exist in currently available studies and the wide range of rates reported by participating hospitals following identical protocols. The range of cost burdens associated with SSI was identified as €1·47–19·1 billion. Whilst it is acknowledged that the methodology for this calculation is superficial, it nevertheless provides a minimum mean from which to estimate the overall burden of SSI on European health care systems. The ultimate purpose of the tracking of SSI must be to enable the implementation of cost-effective preventative measures. To allow for the credible assessment of the effectiveness of current and future prevention methods, a robust dataset must be established and standards of protocol and presentation agreed to. It will be necessary therefore for each country to undertake prospective studies, rigorously following predetermined guidelines to enable comparison at a European or International level. As comparable data become available, there will be the tendency to cross-reference performance across countries, regions, institutions and even individuals. Whilst this may in turn lead to a reluctance to engage in data collection to avoid evaluation, it must ultimately be in the interest of patients, the medical community and society that such standardised, independent and quality monitoring take place.

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