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Surveillance of Surgical Site Infections Following Major Hip and Knee Surgery in Finland

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SURVEILLANCE OF SURGICAL SITE INFECTIONS FOLLOWING MAJOR HIP AND KNEE SURGERY IN FINLAND

A C A D E M I C D I S S E R T A T I O N

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To my family

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ABSTRACT

Background and aims. Since 1999, hospitals in the Finnish Hospital Infection Program (SIRO) have reported data on surgical site infections (SSI) following major hip and knee surgery. SSI rates have tended to be higher than in other national surveillance systems. The purpose of this study was to obtain detailed information to support prevention efforts by analyzing SIRO data on SSIs, and to evaluate possible factors affecting the surveillance results, and to assess the disease burden of postoperative prosthetic joint infections in Finland.

Methods. Procedures under surveillance included total hip (THA) and total knee arthroplasties (TKA), and the open reduction and internal fixation (ORIF) of femur fractures. Hospitals prospectively collected data using common definitions and written protocol, and also performed postdischarge surveillance. In the validation study, a blinded retrospective chart review was performed and infection control nurses were interviewed. Patient charts of deep incisional and organ/space SSIs were reviewed, and data from three sources (SIRO, the Finnish Arthroplasty Register, and the Finnish Patient Insurance Centre) were linked for capture-recapture analyses.

Results. During 1999-2002, the overall SSI rate was 3.3% after 11,812 orthopedic procedures (median length of stay, eight days). Of all SSIs, 56% were detected after discharge. The majority of deep incisional and organ/space SSIs were detected on readmission. Positive and negative predictive values, sensitivity, and specificity for SIRO surveillance were 94% (95% CI, 89-99%), 99% (99-100%), 75% (56-93%), and 100% (97-100%), respectively. In orthopedic wards, the wound culture rate ranged from 9 to 67 per 1,000 patient-days. Of the 9,831 total joint replacements performed during 2001-2004, 7.2% (THA 5.2% and TKA 9.9%) of the implants were inserted in a simultaneous bilateral operation. Patients who underwent bilateral operations were younger, healthier, and more often males than those who underwent unilateral procedures. The rates of deep SSIs or mortality did not differ between bi- and unilateral THAs or TKAs. Four deep SSIs were reported following bilateral operations (antimicrobial prophylaxis administered 48-218 minutes before incision). In the three registers, altogether 129 prosthetic joint infections were identified after 13,482 THA and TKA during 1999-2004. After correction with the positive predictive value of SIRO (91%), a log-linear model provided an estimated overall

prosthetic joint infection rate of 1.6% after THA and 1.3% after TKA. The sensitivity of the SIRO surveillance ranged from 36% to 57%. The annual disease burden estimate of prosthetic joint infections was 2.1 cases per 100,000 population after THA and 1.5 after TKA, i.e. on average nearly 200 prosthetic joint infections would have occurred in Finland annually during 1999-2004 after THA and TKA.

Conclusions. Postdischarge surveillance had a major impact on SSI rates after major hip and knee surgery. A minority of deep incisional and organ/space SSIs would be missed, however, if postdischarge surveillance by questionnaire was not performed. According to the validation study, most SSIs reported to SIRO were true infections. Some SSIs were missed, revealing some weakness in case finding. Variation in diagnostic practices may also affect SSI rates. No differences were found in deep SSI rates or mortality between bi- and unilateral THA and TKA. However, patient materials between these two groups differed. Bilateral operations require specific attention paid to their antimicrobial prophylaxis as well as to data management in the surveillance database. The true disease burden of prosthetic joint infections may be heavier than the rates from national nosocomial surveillance systems usually suggest.

CONTENTS

ABBREVIATIONS

ASA	American Society of Anesthesiologists
BMI	Body mass index
CDC	Centers for Disease Control and Prevention
CI	Confidence interval
HAI	Health care-associated infection
HELICS	Hospital in Europe Link for Infection Control through Surveillance
ICD	International Classification of Diseases
ICN	Infection control nurse
IPSE	Improving Patient Safety in Europe
KISS	Krankenhaus Infections Surveillance System
NHS	National Health Service
NHSN	National Healthcare Safety Network
NINSS	Nosocomial Infection National Surveillance Scheme
NNIS	National Nosocomial Infection Surveillance System
NPV	Negative predictive value
OR	Odds ratio
ORIF	Open reduction and internal fixation
PPV	Positive predictive value
PREZIES	Preventie van Ziekenhuisinfecties door Surveillance
SENIC	Study on the Efficacy of Nosocomial Infection Control
SIRO	Finnish Hospital Infection Program
SSI	Surgical site infection
THA	Total hip arthroplasty
TKA	Total knee arthroplasty

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on three original publications and one manuscript referred to in the text by their Roman numerals:

I Huotari K, Lyytikäinen O, the Hospital Infection Surveillance Team. Impact of Postdischarge Surveillance on the Rate of Surgical Site Infection After Orthopedic Surgery. Infect Control Hosp Epidemiol. 2006;27:1324-29

II Huotari K, Agthe N, Lyytikäinen O. Validation of surgical site infection surveillance in orthopedic procedures. Am J Infect Control. 2007;35:216-21

III Huotari K, Lyytikäinen O, Seitsalo S, the Hospital Infection Surveillance Group. Patient outcomes after simultaneous bilateral total hip and knee joint replacements. J Hosp Infect. 2007;65:219-25

IV Huotari K, Lyytikäinen O, Ollgren J, Virtanen MJ, Seitsalo S, Palonen R, Rantanen P; the Hospital Infection Surveillance Team. Disease Burden of Prosthetic Joint Infections after Hip and Knee Joint Replacement in Finland during 1999-2004: Capture-recapture Estimation. *Submitted*

1 INTRODUCTION

Joint replacement surgery is successful in restoring function and relieving pain to disabled arthritic patients. More than a million hip and knee joint replacements are performed each year worldwide (1, 2). The advantages of joint replacement surgery for a patient's quality of life are often evident (3-7). Since the introduction of joint replacement surgery (8), infective complications have declined significantly. Nowadays, a minority of joint replacement operations still leads to postoperative surgical site infections (SSI) (9). The most severe SSIs after orthopedic surgery are prosthetic joint infections: they are difficult to treat and lead to reoperations, long-term antimicrobial treatment, prolonged hospital stays, and increased health care costs (10-17). Both morbidity and mortality rates increase, and the patient's quality of life declines (18, 19).

Surveillance of health care-associated infections (HAI) is an essential part of HAI prevention. Studies have found that SSI surveillance and feedback to surgeons can reduce SSIs considerably (20). The SENIC study (the Study on the Efficacy of Nosocomial Infection Control) demonstrated that a nosocomial infection surveillance system that reports SSIs to surgeons can reduce SSIs by 32% (20). Several other studies have also shown that active surveillance, including feedback to surgeons, can reduce SSIs by up to 50% (21-26). National surveillance systems play also an important role in providing an essential benchmark for HAI rates in single hospitals (27, 28).

Measuring and improving the quality of care and patient safety in hospitals have recently caught the public's attention and interest (29, 30). In orthopedic surgery, SSI rates have been detected as a tempting quality indicator, and even mandatory reporting of these rates has been obliged in some countries (31, 32). Comparisons of SSI rates between surgeons, hospitals, or countries should, however, be made with special caution (33-36). Unless 1) the case definitions, case finding and ascertainment are standardized, 2) data are equally valid, and 3) confounding factors are detected and taken into account, there is a risk of misleading conclusions of surveillance results (37).

In Finland, more than 15,000 hip or knee arthroplasties are performed annually, and the number is increasing (38). A total of 50,000 HAIs have been estimated to occur each year in Finnish hospitals, but the total amount of orthopedic SSIs has not yet been evaluated separately (39). In a Finnish prevalence study, SSIs were the most common HAIs detected (29%) (40). Of the 88 organ/space SSIs detected, 33% were bone or joint infections. Since 1999, information on SSIs after orthopedic surgery has been

reported to the Finnish Hospital Infection Program (SIRO) at the National Public Health Institute from voluntary participating hospitals. By the end of 2005, 15 hospitals participated, and data on 28,314 hip and knee joint replacement operations and open reductions and internal fixations (ORIF) of femur fracture were recorded.

The severity of prosthetic joint infections and increasing attention paid to the quality of care and patient safety highlighted the need for an in-depth analysis of SIRO surveillance data on orthopedic SSIs. The purpose of this study was to analyze possible factors affecting the surveillance results and to obtain detailed information to support SSI prevention. SIRO data were analyzed to estimate the impact of postdischarge surveillance on the surveillance results. A validation study was performed to evaluate the sensitivity and specificity of the SIRO surveillance. Simultaneous bilateral arthroplasties and their outcomes were examined in SIRO data. Finally, the total disease burden of postoperative prosthetic joint infections in Finland was estimated by a register linkage study.

2 REVIEW OF THE LITERATURE

2.1 Surgical site infections in orthopedic surgery

2.1.1 Epidemiology and public health perspective

Morbidity

Surgical site infections are among the most common of HAIs (40, 41). In orthopedic surgery, the most severe SSIs − postoperative prosthetic joint infections − are very unwanted complications because of their severe consequences. The risk of prosthetic joint infection acquired intraoperatively is considered to be less than one percent after total hip arthroplasties (THA) and less than two percent after total knee arthroplasties (TKA) (42-45). Recent results from Dutch and German national HAI surveillance systems showed deep SSI rates of 0.9% and 0.8% during a one-year follow-up after THA, respectively (46, 47). From single hospitals, lower postoperative prosthetic joint infection rates have also been reported: for example, 0.4% after primary THA in a Swiss hospital (48).

European surveillance systems and their SSI rates and proportions of postdischarge SSIs after hip arthroplasty in the European network for HAI surveillance systems, Hospital in Europe Link for Infection Control through Surveillance (HELICS; nowadays also called IPSE, Improving Patient Safety in Europe), appear in **Table 1**. Finnish SSI rates were relatively high, but variation in postoperative length of hospital stay and postdischarge surveillance within European surveillance systems was also considerable (34, 49).

Prosthetic joint infections are difficult to treat; they often require reoperations, prolong hospital stays, and increase health care costs (10, 50, 51). The basic principle of treatment for foreign body infections is to remove, if it is possible, the infected foreign body. In joint replacement surgery, this can be performed either as a two-stage (52-54) or one-stage prosthesis exchange (55-58). In a two-stage exchange, various time intervals between removal and insertion of a new prosthesis have been recommended (2-4 weeks, if no difficult-to-treat microorganism is present, by Zimmerli et.al. (42) and 6 weeks by Brause (59)), but sufficiently powered comparative trials are lacking. In a meta-analysis, two-stage and one-stage exchanges with antibiotic-loaded cement led to cure rates of 93% and 86%, respectively (60). In carefully selected patient populations, early debridement

Table 1. Hospital in Europe Link for Infection Control through Surveillance results of surgical site infection surveillance after hip arthroplasty in 2004 by country*

Country	Number of procedures	Median postoperative length of hospital stay (days)	Surgical site infection rate (%)	Percentage of surgical site infections detected after discharge (%)	In-hospital surgical site infection rate (%)
Austria	93	12	4.3	75	1.1
Belgium	191	9	12.6	25	9.4
Finland	2,854	7	4.6	38	2.1
France	2,759	12	2.1	64	0.8
Germany	13,429	NA	1.5	NA	NA
Hungary	235	11	3.4	13	3.0
Lithuania	206	12	0.5	100	0
Netherlands	4,079	8	2.9	50	1.5
Poland	1,325	NA	3.4	NA	NA
Spain	379	8	3.7	0	3.7
UK England	18,443	9	2.1	0	2.1
UK North Ireland	2,001	6	1.6	19	1.3
UK Scotland	3,010	8	2.1	31	1.3
UK Wales	472	8	2.1	22	1.5
Total	49,476	9	2.2	20	1.4

*Modified from (34, 49)
NA, not available

(within two to three weeks postoperatively) with prosthesis retention has been quite successful (61-63). Debridement performed later results in much lower cure rates (64-68).

Alongside surgical procedures, carefully-selected antimicrobial treatment is fundamental for the successful treatment of prosthetic joint infections (42, 59, 63, 69). Comparative trials are scarce, but in staphylococcal infections, combinations containing rifampin have shown positive results (61, 63, 70, 71). In some cases, long-term suppressive antimicrobial treatment without prosthesis exchange is used (72-74).

Mortality

Prosthetic joint infections have also been associated with increased mortality. When patients with or without SSI after THA were compared, not only the patients with deep incisional or organ/space SSI, but also patients with any SSI exhibited a significantly higher mortality rate than did patients without SSI (75). Increased risk of death remained after controlling confounding factors. SSI after orthopedic surgery was also shown to be an independent risk factor for mortality among elderly people (76). In a large study comparing different surgical specialties, the case-fatality proportion related to SSI was the second highest in orthopedic surgery (after thoracic surgery) (19). The case-fatality proportion of SSI cases after THA or TKA was 17%. In a Finnish study, an excess mortality rate of 10% was related to postoperative deep infection after hip fracture operations (77).

Cost

SSIs incur considerable extra costs to health care systems all over the world (78). In Europe, the total cost of all SSIs has been estimated to range between 1.5 and 19 billion euros (79). In the United Kingdom, the burden of HAIs in orthopedics at National Health Service (NHS) hospitals was assessed at 119 million pounds (80). In US studies, each orthopedic SSI was reported to increase health care costs by 300% (50), and a single infected arthroplasty reportedly cost about 50,000 US dollars (81, 82). Based on patient insurance data in Finland in the late 1980s, an orthopedic SSI was determined to cost 30,800 euros (183,399 Finnish marks) (83).

2.1.2 Development of surgical site infection and postoperative prosthetic joint infection

Microbial contamination of the surgical site is a necessary precursor of SSI (84). The source of microorganisms is usually the patient's skin, but may also include exogenous sources (instruments, surgical personnel, operating room environment, etc.) as well as distant foci of infection in the patient (84-86).

The minimum dose of contaminating microbes is much lower, and less virulent microbes are also capable of causing infection, with the presence of foreign material. The key elements involved in the pathogenesis of foreign body infections and in biofilm formation include host proteins promoting bacterial adhesion to biomaterials and intrinsic properties of colonizing microorganisms that produce extracellular substances and show markedly-reduced susceptibility to antimicrobial killing (87-91).

The most common microbes causing surgical site infections and postoperative prosthetic joint infections after THA and TKA are *Staphylococcus aureus* and *Staphylococcus epidermidis* (34, 92-96). In prosthetic joint infections caused by hematogenous spread from distant foci, the causative microbes are slightly different (e.g. streptococci are more common) (97).

2.1.3 Prevention

Many patient and operation characteristics may influence the risk of SSI development (**Table 2**). Knowledge of these characteristics can be utilized to stratify risk of SSI (see 2.2.6.). Some of them are modifiable and may allow targeted preventive measures.

The Centers for Disease Control and Prevention (CDC) guideline provides detailed recommendations aiming to reduce SSI risk, and covers preoperative measures: preparation of the patient, hand and forearm antisepsis for surgical team members, antimicrobial prophylaxis, intraoperative measures such as ventilation, sterilization of surgical instruments, surgical attire and drapes, asepsis and surgical technique, postoperative incision care, and surveillance (84). Prevention of hyperglycemia and preoperative smoking intervention have also lowered SSI risk (98-101). Different combinations of these preventive measures have been the focus of quality improvement interventions and studies (29, 102-104).

Table 2. Patient and operation characteristics that may influence the risk of surgical site infection development according to the Centers for Disease Control and Prevention guideline*

Patient	
	Age
	Nutritional status
	Diabetes
	Smoking
	Obesity
	Coexistent infections at a remote body site
	Colonization with microorganisms
	Altered immune response
	Length of preoperative stay
Operation	
	Duration of surgical scrub
	Skin antisepsis
	Preoperative shaving
	Preoperative skin preparation
	Duration of operation
	Antimicrobial prophylaxis
	Operating room ventilation
	Inadequate sterilization of instruments
	Foreign material in the surgical site
	Surgical techniques
	Surgical drains

* Modified from (84)

Antimicrobial prophylaxis is an important method to reduce the incidence of SSI after joint replacement operations (30, 105-107). The effect of prophylaxis has also been demonstrated in ORIF of femur fracture (108, 109). One recent study (110) supported the results of previous studies (111) also stressing the timing of antimicrobial prophylaxis: infection rates after THA correlating with the time of prophylaxis administration showed a pronounced U-shaped curve with the lowest infection rates for administration between 0 and 60 minutes before incision.

According to US guidelines, 1) the recommended antimicrobial agents in joint replacement surgery are cefazolin or cefuroxime, 2) the first antimicrobial dose should begin within 60 minutes before surgical incision, and 3) the dosage should be discontinued within 24 hours after the end of surgery (112). In Scotland and in the Netherlands, guidelines recommend the administration of prophylaxis 30 minutes before incision (113, 114). US guidelines recommend that, if an operation is prolonged, a dose of cefazolin should be re-administered intra-operatively at an interval of two to five hours and cefuroxime at an interval of three to four hours to ensure adequate antimicrobial levels until wound closure (112).

In many hospitals, accurate compliance with these guidelines could be even more focused (115-117). In studies examining prophylaxis for THA, compliance with certain criteria ranged from 53% to 67% (118, 119). Improvements in antimicrobial prophylaxis performance have led to successful reductions in SSI rates (120-122). In United States, for example, a multidisciplinary computerized process for prophylactic antibiotic administration decreased the SSI rate by 48% (123).

2.2 Surveillance of surgical site infections

2.2.1 Purpose and objectives of surveillance

Surveillance is defined as “the continuous and systematic process of collection, analysis, interpretation, and dissemination of descriptive information for monitoring health problems” (124). The history of surveillance in nosocomial infection control began in 1847 when Ignaz Semmelweis, after detecting an excessively high mortality rate among mothers delivering babies in a certain division of the Vienna Lying-In Hospital, ordered all doctors and students to disinfect their hands carefully before each vaginal examination; as a result, the mortality fell from 18% to less than 3% (125, 126). Nowadays, the surveillance of HAIs is essential to any infection control program to obtain useful information for improving the quality of care (31, 127-130) and to monitor the impact of infection control interventions (131).

In many developed countries, national nosocomial infection surveillance systems have already been established. In the United States in 1970, the CDC established a voluntary, confidential reporting system to monitor HAIs: the National Nosocomial Infections Surveillance (NNIS) (132, 133). During the 1990s, several European countries such as Germany, Belgium, the Netherlands, France, and Finland began to establish national or regional networks for the surveillance of HAIs (36, 134-138). Most of these surveillance systems were based on the NNIS model, and nowadays

comprehensive surveillance methods based on the NNIS methodology are standard (127). Due to the considerable clinical relevance and high costs associated with orthopedic SSIs, SSIs after THA and TKA are under surveillance in most surveillance systems (34).

Studies have shown the importance of surveillance in the prevention of SSIs. The SENIC study demonstrated that a surveillance system reporting SSIs to surgeons can reduce SSIs (20). This landmark study pointed out that to be effective, a nosocomial infection control program must include organized control activities, an adequate number of trained infection control staff, and a system for reporting SSI rates to surgeons in addition to organized surveillance system. Many other studies have also demonstrated that active surveillance, including feedback to surgeons, can reduce SSIs by up to 50% (21, 22, 24, 25, 139-143). Such a reduction has also been demonstrated specifically in orthopedic surgery (**Table 3**). Studies have also demonstrated the cost effectiveness of SSI surveillance: after four years of surgical wound surveillance in an NHS environment in the UK with a dedicated team and postdischarge follow-up of up to three months, the proportion of infections fell significantly in orthopedic, cardiac, and thoracic surgery (130). The cost reduction due to reduced infections was calculated to exceed the cost of surveillance after two years.

2.2.2 Definitions of surgical site infections

For surveillance systems, the use of uniform definitions is critical (31, 147). The definition of an SSI for surveillance and epidemiologic purposes should be easy to use, but also unambiguous so that different observers can obtain the same results (148). Consequently, such definitions always involve some compromises. For example, the time limit for a postoperative SSI is artificial: the symptoms of postoperative joint infection may also appear more than one year after surgery. The requirements for a definition of an SSI in clinical studies differ (42, 149, 150). In several clinical studies, the definition of prosthetic joint infection has required at least one of the following criteria: purulence of synovial fluid, growth of the same microorganism in two or more deep samples, acute inflammation in histopathological examination, or the presence of a sinus tract communicating with the prosthesis (62, 67, 68, 82).

Table 3. Studies in orthopedic surgery demonstrating the effectiveness of surveillance with feedback in reducing surgical site infections

Study, publication year	Country	Surveillance system	Other preventive measures	Period	Reduction in SSI rates
Haley, 1985 (20)	USA	338 hospitals	Organized infection control activities Trained infection control physician One infection control nurse per 250 beds	5 years	35%
Borst, 1986 (144)	USA	2 hospitals	Recommendations according to intraoperative surveillance findings	3 years	66%
Douglas, 2001 (104)	Australia	1 hospital	Several interventions	1 year	100%
Schneeberger, 2002 (145)	Netherlands	1 hospital	Re-implementing a set of basic infection control measures	5 years	88%
Geubbels, 2004 (146)	Netherlands	5 hospitals	Several interventions	Various periods	36-100%
Gastmeier, 2005 (47)	Germany	21 hospitals	-	3 years	43%*
Brandt, 2006 (26)	Germany	86 hospitals	-	4 years	25%*

*Percentage presented from hip arthroplasties. Reduction smaller or no reduction in knee arthroplasties

The CDC definitions (**Table 4**) are widely used and recommended for surveillance purposes (79, 84, 151). CDC definitions in Finnish translation have been used in SIRO. The microbiological criteria (criteria b) of superficial incisional SSI have been slightly modified to require clinical signs or symptoms (pain or tenderness, localized swelling, redness, heat, or prolonged serose discharge) because the expression "aseptically-obtained culture" may not have been clear, and to avoid the acceptance of asymptomatic colonization or surveillance cultures as a case. The definitions for deep incisional and organ/space SSIs are identical to those of the CDC.

In some other national surveillance systems, minor local modifications have also been made to CDC definitions. These modifications are small but may, however, affect reported SSI rates (153). For example, within the European network for HAI surveillance systems, some countries accept wound swabs, but other countries require an organism to be cultured from fluid or tissue (153). In the English surveillance system (the Nosocomial Infection National Surveillance Scheme, NINSS), microbiological samples can be either aspirates or swabs, but the presence of pus cells is required (35, 154, 155). When the NINSS and CDC definitions were compared, the NINSS definition captured 25% less SSIs than did the CDC definition (156). In the NINSS definition, another difference is that a diagnosis of an SSI by a surgeon or attending physician is alone unaccepted (151, 153). The Dutch national surveillance system, PREZIES, uses the CDC definitions, but additionally requires that there must always be clinical symptoms and that diagnosis by only a physician is indecisive (157). Other authors have also stated that a clinician's diagnosis may impact SSI rates (147, 152, 158), and if used, a clinician's diagnosis should be categorized as either "presumptive" or "possible" SSI (147). Detailed published information of possible local variations in the CDC's SSI definition was unavailable from all national surveillance systems.

Despite the fact that in HELICS all national surveillance networks use the same definitions, with above described minor variations, major differences between countries were detected in the distribution of different types of SSIs reported after THA. The proportion of superficial SSIs was around 80% in Finland, Belgium, England, Scotland, and Wales, but around 30% in Germany, Spain, France, and Poland. The actual reason for this variation remains unknown, but further evaluation is planned (34).

Table 4. The Centers for Disease Control and Prevention definition of surgical site infections (152)

Superficial incisional SSI
A superficial SSI must meet the following criteria: Infection occurs within 30 days after the operative procedure and involves only skin and subcutaneous tissue of the incision and patient has at least one of the following: a. Purulent drainage from the superficial incision b. Organisms isolated from an aseptically-obtained culture of fluid or tissue from the superficial incision c. At least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat, and superficial incision is deliberately opened by surgeon, unless incision is culture-negative d. Diagnosis of superficial incisional SSI by the surgeon or attending physician
Deep incisional SSI
A deep incisional SSI must meet the following criteria: Infection occurs within 30 days after the operative procedure if no implant* is left in place or within one year if implant is in place and the infection appears to be related to the operative procedure and involves deep soft tissues (e.g., fascial and muscle layers) of the incision and patient has at least one of the following: a. Purulent drainage from the deep incision, but not from the organ/space component of the surgical site b. A deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever (>38^{o}C) or localized pain or tenderness, unless incision is culture-negative c. An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination d. Diagnosis of a deep incisional SSI by a surgeon or attending physician

Organ/space SSI
An organ/space SSI must meet the following criteria: Infection occurs within 30 days after the operative procedure if no implant* is left in place or within one year if implant is in place and the infection appears to be related to the operative procedure and infection involves any part of the body, excluding the skin incision, fascia, or muscle layers, that is opened or manipulated during the operative procedure and patient has at least one of the following: a. Purulent drainage from a drain that is placed through a stab wound into the organ/space b. Organisms isolated from an aseptically-obtained culture of fluid or tissue in the organ/space c. An abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination d. Diagnosis of an organ/space SSI by a surgeon or attending physician

*A nonhuman-derived implantable foreign body that is permanently placed in a patient during surgery.

2.2.3 Case finding and ascertainment

The sensitivities (**Table 5**) and specificities of different case finding methods in HAI surveillance vary (125, 159). Ideally the methods for case finding and ascertainment should be clearly defined and uniform among participating hospitals, and local surveyors should be continuously trained (35, 37, 127). If different case finding methods with varying sensitivities and specificities are used, the differences in SSI rates may not reflect real differences in SSI incidence (160).

The time used for data collection depends largely on case finding methods: time estimates for an infection control professional to perform surveillance in a 500-bed hospital varies from 8 to 54 hours per week (125, 159). Direct, prospective observation of all postoperative patients for SSIs by trained personnel is generally viewed as the gold standard to identify SSIs, but is unfeasible in everyday use (127, 171). In practice, infection control nurses (ICN) usually seek out SSIs in a hospital

by using various data sources (patient records, temperature and treatment charts, ward staff, microbiology reports) (35, 129) and decide whether an SSI fulfilling the definition criteria has occurred (31, 172). Research has shown that the ICN's experience matters: ICNs with four or more years of experience were significantly more accurate at case ascertainment than less experienced ICNs (173).

Electronic patient records are used in an increasing number of hospitals; information technology will significantly impact HAI surveillance in the future (174-176). With computerized data, ICNs can identify certain signals (antimicrobial use, microbiological culture results, etc.) that suggest the presence of an SSI (168, 170, 177, 178). The ICN can then focus on the chart review and save considerable time (178, 179). Despite the growing importance of computerized data in surveillance, frequent visits to wards remain crucial in communicating with the ward staff and providing them on-the-spot infection control training (172).

Table 5. Case finding methods and their sensitivities for health care-associated infection surveillance

Method	Sensitivity	Reference
Gold standard*	94-100%	125
Chart review	74-94%	161-163
Selective chart review		
- Selected by ward liaison surveillance	62%	164
- Selected by ward liaison and review of laboratory reports	76-89%	164
Antibiotic use	81-95%	165-167
Review of health plan administrative data	78%	168
Electronic screening of discharge diagnoses	60-65%	165, 169
Electronic analysis of microbiology reports, antibiotic administration data, and discharge diagnoses	94%	170

*The gold standard for health care-associated infection surveillance is determined by a trained physician who examines every patient, every medical record, and other relevant information available.

2.2.4 Postdischarge surveillance

Rationale for postdischarge surveillance

While the length of postoperative hospital stays decreases, the proportion of SSIs appearing after a patient's discharge from the hospital increases; this presents challenges to the accurate monitoring of SSI rates (180-184). In orthopedic surgery, postdischarge SSIs warrant special attention, because infections associated with joint replacements can occur a considerable time after surgery (42, 48, 185). Thus in joint replacement surgery, the role of postdischarge surveillance is critical. Without proper postdischarge surveillance, a surveillance system would greatly underestimate the SSI rates (186-190).

In NNIS, 54% of all SSIs after surgery were detected after the postoperative hospital stay (191). In HELICS, the proportion of SSIs following hip arthroplasties reported after discharge ranged from 0% in England to 75% in Austria (**Table 1**) (34). Within European national surveillance systems, the methods and intensity of postdischarge surveillance vary markedly (34-36, 192, 193). In the HELICS report, the variable intensity of postdischarge surveillance in different countries was noted, and certain new metrics for SSI incidence (in-hospital cumulative incidence and the incidence density of in-hospital SSI per 1,000 in-hospital postoperative patient-days at risk) were issued to somehow combat this postdischarge surveillance variability (34). The limitation of the last mentioned metric is that it may be biased because SSI risk varies over time: incidence is the highest during the first seven postoperative days and then drops.

Methods for postdischarge surveillance

Several different methods for case finding, questionnaires (194-196), telephone interviews (189, 197, 198), electronic patient charts (199), diagnostic codes, pharmacy records, and observations by health care personnel (200), have been used alone or in combination (188, 201-207). No universally agreed and accepted method, however, exists for postdischarge surveillance (208-210).

The reporter of an SSI after hospital discharge has been either a health care professional or a patient. In most studies, patients have been unable to reliably recognize postoperative infection in their own wounds: either high false positive and high false negative rates were reported (211, 212). In two studies, however, patients

were reportedly able to detect SSI with a reasonable level of accuracy, but these results cannot be generalized to all patient populations (213, 214).

As more information during routine health care activities is recorded electronically, less labor-intensive surveillance methods may also reduce the burden of postdischarge surveillance efforts (179). Comprehensive and integrated electronic health records systems, which cross primary and secondary health care, may offer a useful tool for postdischarge surveillance (210). In a US orthopedic tertiary center, for example, text-searching electronic patient records with specific search terms indicative of SSI was tested and discussed as a simple and inexpensive method to improve detection of postdischarge SSIs (215). Analysis of International Classification of Diseases (ICD) codes alone offers insufficient high-quality data for postdischarge surveillance (216), but full-text electronic medical records and other electronic databases can be utilized to enhance detection of postdischarge cases (180, 199, 201, 202, 209, 217). In the United States, health insurance administrative data was found to detect more SSIs than hospital based surveillance, although misclassifications in either system were unevaluated (168, 201, 204). Electronic data, where available, may also increase opportunities for standardization (217): access to electronic outpatient medical records allows an ICN to confirm whether a postdischarge SSI reported meets the standard criteria.

Validity of postdischarge surveillance methods

As in in-hospital surveillance, high validity of the case finding methods in postdischarge surveillance is also important in order to obtain reliable and comparable results. Ideally, the coverage, sensitivity, specificity, and positive (PPV) and negative predictive values (NPV) of the method used should be known. Reported coverages of postdischarge surveillance have often been quite low, as in a study from France which reported the loss of 59% of patients to follow-up between discharge and 30 days (218). Response rates to questionnaires mailed to patients have ranged from 15% to 33% (197, 204), and response rates to telephone interviews, from 38% to 85% (197, 198, 219). The sensitivity, specificity, and predictive values of postdischarge surveillance methods have seldom been evaluated. A systematic literature review concluded that thus far, no feasible and robust method for case finding of postdischarge SSIs has been identified; the research undertaken is either scarce or methodologically weak (210).

In the United Kingdom, a national audit of postdischarge surveillance practices was performed in 2004. Of those trusts that responded to the audit, 29% performed some form of postdischarge surveillance: the most common methods included routine

clinical follow-up (45%) and the direct observation of wounds (41%). Of the different specialties, postdischarge surveillance was most often performed after orthopedic surgery (33%) (210). In orthopedic surgery, the proportions of postdischarge SSIs to all SSIs after joint replacements in published studies have been associated with the method used: 25% with a questionnaire mailed to each patient (220), 38% by telephone screening and direct observation by health care personnel (214), 43% to 69% by combination of several methods (186), and 72% by electronic chart review (199).

2.2.5 Validation studies of surgical site infection surveillance

Because of the expanding demands for SSI rates to serve as a measure of the quality of patient care and as a tool for interhospital comparisons, data in SSI surveillance should be collected on accuracy and consistency (191, 221). In many surveillance networks, validation studies are essential to ensure the credibility and validity of data (222, 223). In the Dutch national surveillance system, PREZIES, participation in regular validation visits has been compulsory since 2002 (157).

Validation studies concerning SSI surveillance have been published in international journals from NNIS (138), PREZIES (157), Surgical Site Infection Surveillance in Scotland (224), and from KISS (223), and single hospitals (**Table 6**) (225). In the first validation study of the NNIS system, PPV, sensitivity, and specificity for SSI surveillance were 72%, 67%, and 98%, respectively (138). In this study, the gold standard was the experts' retrospective chart review.

In the Dutch national surveillance system, PREZIES, ongoing validation of SSI surveillance began in 1999 (157); regular and compulsory validation visits to hospitals are performed there. After each validation visit, a written validation report is sent to a particular hospital. As needed, the validation team can advise on improvements in surveillance, correct the data retrospectively, or even remove inferior data from the national database. As of this writing, data have been removed on only two occasions. After 859 charts reviewed during 1999-2004, PPV and NPV were 97% and 99%, respectively. In this study, sensitivity and specificity were unreported.

Table 6. Validation studies of national/regional surveillance systems for surgical site infections

Study, publication year	Country	Sampling	N	Gold standard	Positive predictive value	Sensitivity	Specificity	Comment
Emori, 1998 (138)	USA	All patients during study period	1,136	Chart review by external experts	72%	67%	98%	Results applicable to routine surveillance
Poulsen, 1996 (226)	Denmark	2 consecutive prevalence studies	455	Bedside inspection of all surgical wounds	Not reported	26%	Not reported	Results applicable to routine surveillance
Mannien, 2007 (157)	Netherlands	5 SSIs and the 20 most recent non-SSIs	859	Chart review by external experts	97%	Not reported	Not reported	
McCoubrey, 2005 (224)	Scotland	15 reported SSIs and 60 non-SSIs	602	Chart review by external experts	95%	97%*	99%*	Sensitivity and specificity applicable to sample analyzed

* Results, assuming all missing data are valid.

In Germany, two methods were compared to validate a HAI prevalence survey (SSI, urinary tract infection, lower respiratory tract infection, and sepsis) (223). In the bedside validation, sensitivity was 89% and specificity, 99.5%, and in validation by case studies, sensitivity was 96% and specificity, 93%. The authors concluded that because the bedside validation is very time-consuming, they favor validation by case studies. However, the retrospective study design always has the limitation that observers are dependent on the quality of data documented in patient records. One possible method to validate an SSI surveillance system is to perform a follow-up after conducting a prevalence study and to examine the proportion of SSIs detected in a prevalence study that are also reported via the routine surveillance system (226). In Poulsen's study, hospital staff reported to the routine surveillance system only one third of the SSIs detected by external ICPs during a prevalence study.

In a single tertiary care hospital validation study with experts' prospective daily wound examination and chart reviews, the accuracy of standard SSI surveillance was quite high: during the first study period the sensitivity and specificity of routine surveillance were 84% and 99.8%, and during the second period, sensitivity was 92% (225).

When assessing the quality indicators (sensitivity, specificity, and predictive values) of different validation studies, the study design and analyses used are important to consider (**Table 6**). When the study sample includes all operations during a certain time period and the infection prevalence in the sample and in the aggregated surveillance data are identical, the results are directly applicable to the aggregated surveillance data, (223, 225). For example, a Scottish validation study reported sensitivity, specificity, PPV and NPV for an SSI surveillance of 96.7%, 99.0%, 94.6%, and 99.4%, respectively (224). However, because the cases were selected in a ratio of 15 SSIs/60 non-SSIs, sensitivity and specificity are likely to overestimate the real quality of the routine surveillance data.

Capture-recapture method to assess sensitivity

Because in real life no surveillance system is 100% sensitive, they all, to some extent, underestimate true rates of disease. In epidemiology, capture-recapture analysis is used to adjust the degree of undercount by estimating the number of missed cases from two or more data sources. Capture-recapture methods were first developed to enumerate wild animal populations (227). More recently, these methods have been applied to epidemiology as an important tool to estimate cases missed by surveillance systems and to determine true disease burden (227-236). This method utilizes information provided by duplicate cases (cases found in more than

one source) to calculate the number of unidentified individuals (227, 235). In infectious disease epidemiology, use of the capture-recapture method is more complicated than in enumerating wild animal populations, but is often quite successful (237, 238). To use capture-recapture methods appropriately, several conditions should be met: 1) the two (or more) data sources should be independent, 2) all true matches and only matches should be identified, 3) all cases identified by the surveillance systems should be true cases that occurred in the population under investigation within a certain time period, and 4) catchability of cases in each data source should be equal (239). Even though some conditions in infectious diseases epidemiology are not always optimal for the use of the capture-recapture method (239-241), it is in many circumstances the only feasible tool to evaluate the sensitivity of a surveillance system and to estimate the true picture of the disease burden (227, 235). In infectious disease epidemiology, the capture-recapture method has been used to estimate, for example, cases of HIV, meningococcal, tuberculosis, and Legionnaires' disease (228, 229, 232, 242). Capture-recapture methods have not previously been used to estimate the sensitivity of HAI surveillance systems.

2.2.6 Stratification of risk factors and case-mix

An important complicating factor in using SSI rates as a quality indicator is the variation in patient material undergoing operations in different hospitals or by different surgeons. Unless all important determinants that affect patient infection risk are taken into account, comparisons between hospitals or surgeons can be potentially misleading (37, 172).

Risk factors for surgical site infections and prosthetic joint infections after total hip and knee arthroplasties

Patient and operation characteristics that may influence the risk of SSI development appear in **Table 2**. Several studies have identified possible risk factors for SSIs after THA or TKA. High NNIS risk index or components of NNIS risk index (82, 191, 243, 244) and revision arthroplasty (82, 245-249) have been clearly shown to increase SSI risk after THA and TKA. Some studies have also associated diabetes mellitus (250-253), advanced age (135, 155), and preoperative hospital stays of more than four days (135, 243) with higher SSI risk. In one study of the elderly, an additional risk factor for SSI after orthopedic surgery was residence in a health care facility prior to surgery (76). In a large case-control study from the Mayo Clinic as well as in some other studies, an important risk factor for prosthetic joint infection

after THA was a postoperative SSI not involving the prosthesis (74, 82, 254), (246). Increased deep infection risk has been detected in patients with rheumatoid arthritis (247, 255).

Stratification of risk factors

In the SENIC study, a risk index was developed and validated to stratify patients by their risk of developing an SSI (256). The components of the SENIC risk index were: an intra-abdominal operation, an operative procedure lasting longer than two hours, a wound classified as contaminated or dirty, and three or more discharge diagnoses. In 1991, the SENIC risk index was adapted to the NNIS risk index (160), which is nowadays a universally accepted and widely used risk index in surveillance systems (257). The NNIS risk index stratifies surgical patients according to a number of risk factors: an American Society of Anesthesiologists (ASA) score ≥3, a wound contamination classification of contaminated or dirty, and a duration of operation longer than the 75th percentile of the duration for each operative procedure (37). The basic NNIS risk index has generally performed well in predicting the risk of SSI after THA and TKA (34, 75, 191, 243, 258).

In addition to the fact that the NNIS risk index is performing well and has been validated, the NNIS risk index also has practical advantages: its components are obtainable by uploading them from operation theatre data systems (84). Other factors such as diabetes mellitus, body mass index (BMI), or immunocompromised status could be interesting factors in risk stratification, but thus far are not always possible to obtain electronically for use in routine surveillance. For research use, a random effect model, which adjusts estimates for random variation between hospitals, and procedure-specific logistic regression models have been useful in adjusting various risk factors (46, 259). For surveillance purposes, however, risk stratification by the NNIS risk index has been the best method available thus far (260).

2.2.7 Other possible factors affecting surgical site infection surveillance results

Simultaneous bilateral arthroplasties

If a patient with osteoarthritis requires joint replacement surgery for both knees or hips, these joint replacements can be performed either staged or simultaneously (261). Bilateral osteoarthritis is a common phenomenon; in a study from Scotland, for example, 30% of patients who underwent a subsequent unilateral TKA underwent a TKA of the opposite knee within five years (262). Bilateral osteoarthritis in hips has varied between 30% and 50% (263-265). Bilateral arthroplasties performed under one anaesthetic event can be done simultaneously by two operative teams or sequentially by one team.

The proportion of simultaneous bilateral TKAs in large US Health Care Financing Administration data (266) and in the Scottish Arthroplasty Project from the 1990s was around 4% (262), but in some specialized orthopedic centers, the proportion has been much higher (267): in the Mayo Clinic, 12% (268), and in St. Francis Hospital, Mooresville, 49% (269). The proportion of simultaneous bilateral THAs in a single center in Oxford was around 5% (270).

Simultaneous bilateral arthroplasties: benefits and potential risks

The reasons for the increasing number of hip and knee arthroplasties performed as simultaneous bilateral operations include patients' and health-economical benefits: the total length of hospital stay and rehabilitation is shorter (265, 266, 271-273) and total costs are lower (266, 271, 274, 275). However, concerns of possible increased peri- and postoperative morbidity (cardiac and thromboembolic events and gastrointestinal problems such as intestinal ileus and gastrointestinal bleeding) have been raised, especially among elderly patients (266, 268, 271, 276-280).

Infection control and simultaneous bilateral arthroplasties

Infection control of bilateral operations under one anaesthetic event has been discussed in orthopedic journals. Either the same instruments (276, 281) or two different sets of instruments (281, 282) have been used, and the skin preparation has

been performed simultaneously in the beginning of the anaesthesia (276) or the second side has been prepared later (283). Macaulay et al. have suggested in their article, especially for bilateral arthroplasties, that intravenous antibiotics be administered 15 minutes before each incision (so that the total dose does not, however, represent an overdose for the time period) and continued until 24 hours (284). Sufficiently-powered comparative trials or consensus on these issues are, however, lacking (281).

Theoretical issues around antimicrobial prophylaxis, skin preparation practices, and pressure directed towards the first operated hip wound also suggest the possibility of increased risk of SSI. In previous studies from single hospitals, the rates of SSIs after simultaneous bilateral TKAs and THAs were similar to those after unilateral or staged TKAs (275, 276, 285, 286) and THAs (270, 283, 287-289). In the routine data from the US Medicare system, however, Ritter el al. detected a lower SSI rate after simultaneous TKAs than after staged TKAs (266). Also, a tendency towards a lower infection rate after a bilateral TKA was found in an Australian study with 1,867 TKAs performed by its single senior author (290). At least to some extent, lower SSI rates may have been associated with a selection of healthier patients for bilateral procedures. The limitation of the US Medicare study was that the method for case ascertainment was only partially described and the follow-up period after the joint operation covered only the postoperative hospital stay (266). Thus far, national HAI surveillance systems have not published separately the SSI rates of simultaneous bilateral arthroplasties.

Hospital-related factors

In addition to the patient-related risk factors described above, hospital-related factors have also been examined. Low surgical volume in a hospital has been associated with a higher risk of death related to surgery (291) and to a higher risk of complications after THA and TKA (292-294). In the Netherlands, hospitals with a low annual volume of THAs experienced an increased risk of SSI, and no other hospital-related risk factors, like university-affiliation, were associated with the SSI risk (295). In some studies, however, the difference in SSI rates has not been statistically significant (296, 297). The limit of a low volume hospital in some of these studies has been extremely low: less than 10 to 25 THA or TKA annually.

Factors related to health care delivery

Differences in health care systems as well as legal and cultural aspects may also influence nationally reported SSI rates, but are difficult to evaluate or control scientifically (47). For example, indications for arthroplasties (298) as well as operation volumes per hospital vary from country to country. These differences have been discussed in many European studies, and researchers have noted that international comparisons should be interpreted only with these differences in mind (35, 36, 49, 153).

In many European countries, SSI surveillance is performed continuously in all hospitals, but in other countries three-month surveillance periods are common (34). However, the question remains: How can SSIs after operations with a one-year follow-up period be reliably surveyed between active three-month periods?

2.2.8 Mandatory and public reporting of health care-associated infection rates

Nowadays, more pressure exists towards the mandatory reporting of HAIs and other patient safety issues as well as towards the public disclosure of such information (133, 299). Since 2004 in the United Kingdom, it has been mandatory for NHS hospitals to publish in-hospital SSI rates after orthopedic surgery (300, 301). Since 2002 in the United States, several states have enacted legislation that requires hospitals to disclose HAI rates publicly (32). While mandatory or public reporting or both further heightens the need for comparable high-quality surveillance data on HAIs, it may also affect the HAI rates obtained (133). As validation studies have shown that low sensitivity (i.e. underreporting of infections) is more common than low specificity (138), some experts have suggested that the underreporting of HAIs becomes a cause for concern when the pressure for public disclosure is added to a process that already has a tendency to miss cases of HAI (133). In fact, the CDC recently reviewed published studies and concluded that the effectiveness of public reporting systems to improve health care performance is inconclusive (302). In the Netherlands, to avoid disproportionately compromising hospitals participating in PREZIES, the court has decided that PREZIES data need not be made public. In addition to outcome measures such as SSI rates, process measures (such as the percentage of patients with recommended antimicrobial prophylaxis given) can also be considered for public disclosure (32).

3 AIMS OF THE STUDY

The purpose of this study was to obtain detailed information to support prevention efforts by analyzing the Finnish Hospital Infection Program (SIRO) data on SSIs after major hip and knee surgery, and to evaluate possible factors affecting the surveillance results.

The specific objectives were:

1. To study the impact of postdischarge surveillance on SSI rates after hip and knee arthroplasties and ORIF of femur fracture, and to examine the distribution of SSI types detected in various locations of postdischarge surveillance (I).
2. To validate the process and the indicators of orthopedic SSI surveillance in SIRO (II).
3. To evaluate the accuracy of SIRO surveillance data on bilateral arthroplasties under one anaesthetic event and to compare the patient population undergoing bi- and unilateral THA and TKA in terms of two outcome variables: deep SSIs and mortality (III).
4. To further validate the indicators of SIRO surveillance and to assess the disease burden of prosthetic joint infections after THA and TKA (IV).

4 MATERIALS AND METHODS

4.1 Surveillance methodology in the Finnish hospital infection program (I-IV)

4.1.1 In-hospital surveillance of orthopedic surgical site infections

Information on SSIs after orthopedic surgery has been reported to SIRO from participating hospitals since 1999. Hospital participation is voluntary and confidential. Orthopedic procedures under surveillance included hip and knee arthroplasties and ORIFs of femur fracture. Hospitals prospectively collected data using common definitions and the NNIS methodology (171, 303); a written protocol with CDC definitions (208) translated into Finnish was provided. For finding cases, ICNs responsible for surveillance were recommended to visit wards once a week and to obtain additional information from microbiology laboratory reports, patient charts, and medical and nursing staff. The training on surveillance methodology organized by SIRO for local ICNs consisted of site visit at the beginning of the surveillance, meetings at least once a year, and an opportunity to consult the SIRO team by phone when needed.

For each patient under surveillance, the following data were uploaded from hospital databases and sent in electronic form to the national center: the patient's unique national identity code (which indicates age and sex), date of surgery, procedure code, uni-/bilateral operation, the consecutive number of the operative side (for bilateral operations), ASA score, wound contamination class, duration and urgency of the operation, date of admission and discharge, discharge status (discharged home, referred to another health care institution, or died), and ICD codes for diagnoses. For each infection, local ICNs collected and manually recorded the following data on a form: the patient's national identity code, date of surgery, procedure code, date and type of SSI, causative microbe, location of detection, and the consecutive number of operative side (for SSIs after bilateral operations).

4.1.2 Postdischarge surveillance of orthopedic surgical site infections

After discharge, all hospitals systematically identified SSIs on readmission and during follow-up visits. Follow-up visits usually took place two months and one year after THA and TKA. In addition, most hospitals conducted postdischarge surveillance with a questionnaire issued to each patient at discharge. If a patient showed clinical signs or symptoms in the wound area and contacted the health care system, a health care professional (nurse or physician) completed the questionnaire. If the SSI was detected after discharge, the location of detection was recorded: on readmission to the hospital, during a follow-up visit, or during outpatient follow-up upon completion of the postdischarge questionnaire.

4.1.3 Data linkage and management in the national database

In the national surveillance database, the infection reports were linked to the uploaded data by using the patient's national identity code and the date and code of the procedure. At regular intervals, the infection reports not combined in the automatic process were examined. These reports were first checked for possible errors in data entering, and the local ICNs were contacted later if needed. The errors found were manually corrected. The proportions of missing values in important fields (such as ASA score, wound contamination class, and duration of operation) were evaluated.

Table 7. Hospitals, surveillance years, operations included and other data sources used in Studies I-IV

Study	Years	Number of hospitals	Operations	Number of operations	Number of charts reviewed	Other data sources
I	1999-2002	9	Hip arthroplasties*	6,207	-	-
			Knee arthroplasties*	1,899		
			Open reductions of femur fracture	3,706		
II	1999-2003	8	Hip and knee arthroplasties*, open reductions of femur fracture	15,143	397	Interviews of infection control nurses
III	2001–2004	6	Total hip arthroplasties	5,614	**	National population registry
			Total knee arthroplasties	4,217		
IV	1999-2004	12	Total hip arthroplasties	7,561	97	Finnish Arthroplasty Register
			Total knee arthroplasties	5,921		Patient Insurance Centre

* Including partial joint replacements

** Data from the chart review of Study IV

4.2 Postdischarge surveillance after orthopedic surgery (I)

4.2.1 Data sources

During 1999-2002, 13,063 orthopedic procedures under surveillance were performed in SIRO hospitals: annual numbers per hospital varied from 142 to 559 for hip arthroplasties, 71 to 490 for knee arthroplasties, and 77 to 293 for ORIFs of femur fracture. For Study I, data on these operations were included except those with no recorded date of discharge (**Table 7**). The data were checked for data quality before analysis. No additional data sources were used.

4.2.2 Analysis and statistics

Univariate analyses were calculated with Chi-squared test or Fisher's exact test, when appropriate, for categorical variables and with the Mann-Whitney U test for continuous variables. Potential risk factors with a P value of less than 0.2 in univariate analysis and some possible confounding factors were included in multivariate analysis. Multivariate analysis was performed as a logistic regression model with a forward selection process. A P value of less than 0.05 was defined as statistically significant. Data were analyzed by SPSS for Windows, version 12.0 (Chicago, IL, USA).

4.3 Validation study (II)

4.3.1 Chart review and structured interview

Nine hospitals that had participated in orthopedic SSI surveillance for more than one year were asked to participate and eight hospitals accepted the invitation to participate in the voluntary validation study. In each hospital, the process of surveillance was validated by means of a structured interview of the ICN responsible for surveillance. The interview covered the process of data collection, interpretation of the case definition, and methods for postdischarge surveillance. A retrospective chart review was carried out for validation of the surveillance indicators. In each

hospital, a validation team reviewed a sample of patient charts, including all clinical data and laboratory and radiology reports. The sample of charts contained 10 orthopedic operations with, and 40 without, SSI. The surveyors were blinded to the patient's infection status as recorded by the hospital ICN. After the review, discrepant files were discussed with the ICN to determine sources of discordance.

4.3.2 Analysis and statistics

From the sample of charts reviewed, a PPV was determined by calculating the proportion of true infections among all infections identified by routine surveillance, and an NPV by the proportion of true negative cases among all patients identified by routine surveillance as uninfected (**Table 8**). Because the prevalence of SSI differed between the sample of reviewed charts and the aggregated SIRO surveillance data (20.7% vs 3.8%, respectively), the results of the chart review were applied to the aggregated data by multiplying the number of all SSIs detected in routine surveillance during 1999-2003 by the PPV (**Table 9**). This provided an approximation of the number of true infections in the aggregated SIRO surveillance data. The same procedure was performed for negative cases with the NPV. These procedures allowed sensitivity and specificity for the aggregated surveillance data to be determined. Confidence intervals were calculated by the asymptotic normal theory with the delta method.

Table 8. Calculation of positive and negative predictive values from the sample

	Validation group	
	Infection +	Infection -
Routine surveillance +	a (true positives)	b (false positives)
Routine surveillance –	c (false negatives)	d (true negatives)

Positive predictive value (PPV) = a / (a + b)

Negative predictive value (NPV) = d / (c + d)

Table 9. Method for applying positive and negative predictive values from the sample to aggregated surveillance data and calculating sensitivity and specificity

	Infection +	Infection -
Routine surveillance + (e)	PPV x e = a (true positives)	(1-PPV) x e = b (false positives)
Routine surveillance – (f)	(1 – NPV) x f = c (false negatives)	NPV x f = d (true negatives)

e = Number of operations with infection reported in routine surveillance

f = Number of operations without infection reported in routine surveillance

Sensitivity = a / (a + c)

Specificity = d / (b + d)

4.4 Simultaneous bilateral hip and knee arthroplasties (III)

4.4.1 Data sources

In this thesis, the term "simultaneous bilateral arthroplasty" is used for bilateral arthroplasties performed under one anaesthetic event. The reporting of variable "bilateral operations" to SIRO began in 2001. Six of twelve hospitals reported data on bilateral arthroplasties under one anaesthetic event during 2001-2004. The data on all bi- and unilateral THAs and TKAs performed in these hospitals were included. First, the data on the bilateral arthroplasties under one anaesthetic event were checked for data quality. If necessary, data were corrected so that each bilateral arthroplasty was entered as two separate operations with different operation times. The patient charts with deep incisional and organ/space SSIs were reviewed for information on antimicrobial prophylaxis (antimicrobial agent used, timing, and dose). Dates of possible deaths were obtained from the national population registry.

4.4.2 Analysis and statistics

Univariate and multivariate analyses were performed similarly as described in 4.2.2. When calculating SSI rates and analysing risk factors for SSIs, each of the operated joints was taken into account. Deaths at 7, 28, and 365 days were evaluated so that each patient was included only once, and the time to death was calculated from the last operation during the study period. To estimate the hazard ratio of progression to death, the Cox proportional hazard regression model was used. A plot of log minus log-transformation of the survival function served to assess the proportional hazards assumption. Age was evaluated as a continuous variable. The data were analyzed with SPSS version 14.0 for Windows (Chicago, IL, USA).

4.5 Register linkage study (IV)

4.5.1 Data sources

In Finland, three institutions collect information on prosthetic joint infections after THA and TKA: SIRO, the Finnish Arthroplasty Register, and the Finnish Patient Insurance Centre (**Table 10**).

Table 10. Data sources of the register linkage study and case definitions of a prosthetic joint infection following total hip and knee arthroplasties

Data source	Coverage	Case definition
Finnish Hospital Infection Program	Sentinel	CDC definitions for deep incisional and organ/space SSIs
Finnish Arthroplasty Register	Nationwide	Infection as an indication for a reoperation
Finnish Patient Insurance Centre	Nationwide	Compensated infection injuries

The Finnish Arthroplasty Register has been collecting information on joint replacements since 1980 (304-306). Health care authorities, institutions, and orthopedic units are obliged to provide information essential for maintenance of the register (307). For a primary operation, the patient's national identity code, operating hospital, date, indication for the operation, implant design, method of fixation for each component, and primary complications are recorded. For a reoperation, date of the index operation, design of the revised prosthesis, indication for revision (e.g. infection), and the new prosthesis are also recorded (308).

The Finnish Patient Insurance Centre handles the compensation procedures for patient injuries. Infection injuries are classified as infections caused by various microbes that the patient probably contracted in connection with an examination, treatment, or other similar action. In practice, ordinary, superficial, fast-healing infections fall outside the scope of compensation. Postoperative prosthetic joint infections normally merit compensation as a patient injury, if the patient claims compensation.

The chart review of prosthetic joint infections reported to SIRO was performed to confirm that the CDC definitions were met. (In this register linkage study, deep

incisional and organ/space SSIs were classified together as prosthetic joint infections.) The following data were recorded: onset, signs, and symptoms, results of laboratory tests and imaging studies, and the treatment of a prosthetic joint infection; and of the patients who had undergone a reoperation due to infection: date and type of operation and clinical findings in the operation.

4.5.2 Identification of matches

THAs and TKAs under SIRO surveillance during 1999-2004 constituted the basic dataset for register linkage. Operations with incorrect or missing patient national identity codes (n=1,827; one hospital did not send patients' national identity codes to SIRO) and those from one hospital that did not participate in the chart review (n=2,060) were excluded. The total number of study operations was 13,482: 7,561 THAs and 5,921 TKAs. Matches between the three sources were identified with the patient's national identity code, and the dates and codes of the operation.

4.5.3 Analysis and statistics

Capture-recapture analysis was used to estimate the total number of prosthetic joint infections after THA and TKA. The capture-recapture method estimates the true population size based on the number of cases captured by any combination of the three data sources. The estimates are highly sensitive to potential dependencies between the sources. For evaluation of source dependence, the Wittes method (309) and log-linear modeling in Baysian framework (310, 311) were used. With the Wittes method, the independence of sources was tested by calculating the odds ratio (OR) (and its 95% confidence interval, CI) between the cell counts of two sources within a third source. Any dependent sources were merged and the two-source estimate by Chapman's modification of the Petersen-Lincoln was used. As an alternative method, we fitted the Bayesian hierarchical log-linear model with the Gibbs variable selection using the Markov chain Monte Carlo (MCMC) method with equal prior model probabilities. This method allowed us to incorporate the uncertainty in the model selection to the estimates. The most probable model supported by the data a posteriori (as well as posterior average over models) was subsequently used to estimate both the dependencies and the total population size (number with 95% credible interval, CI). Heterogeneity in catch probabilities is also a major concern in capture-recapture analysis. To account for this, we stratified the data by operation type. Data were analyzed by SPSS for Windows version 14.0 (Chicago, IL, USA) and WinBUGS version 1.4.1 (Cambridge, UK).

4.6 Ethical aspects

The Ministry of Social Affairs and Health, the National Research and Development Center for Welfare and Health, and the Finnish Data Protection Authority have authorized the SIRO study plan and the use of data from population-based registries for research. The research plan of this thesis was also approved by the ethics group of the National Public Health Institute.

5 RESULTS

5.1 Postdischarge surveillance after orthopedic surgery (I)

5.1.1 Characteristics of study patients and operations

The 11,812 hip and knee joint replacements and ORIFs of femur fracture with the date of patient discharge available during 1999-2002 were included in Study I. The median length of hospital stay was eight days (range per hospital, 6-9 days). The patient and procedure characteristics appear in **Table 11**.

Table 11. Characteristics of patients and orthopedic procedures by procedure in nine Finnish hospitals during 1999-2002

Characteristic	Hip arthroplasty (n=6,207)	Open reduction of femur fracture (n=1,899)	Knee arthroplasty (n=3,706)
Males, %	36	35	27
Median age, years	71*	77	71
ASA 3, 4, or 5, %	53*	69	52*
Wound classification 3 or 4, %	1	1	1
Duration of operation >120 minutes, %	35	17	32
NNIS risk index ≥ 1, %	66*	75	62*
Urgent procedures, %	24	95	1
Rearthroplasty, %	22	-	12
Preoperative stay >2 days, %	8	8	3*
Median length of hospital stay, days	8*	5	8
Referred to other healthcare institution after discharge, %	55	78	40

ASA, American Society of Anesthesiologists score; NNIS, National Nosocomial Infection Surveillance System.
* Risk factor for SSI in univariate analysis ($P<0.05$).

5.1.2 Surgical site infections

A total of 384 SSIs were identified. The SSI rates for hip arthroplasty, for ORIF of femur fracture, and for knee arthroplasty were 3.9%, 2.9%, and 2.3%, respectively. Of the SSIs, 72% were superficial incisional, 18% were deep incisional, and 10% were organ/space SSIs. The median time from the operation to the date of SSI was 11 days, with intervals of 8 days for superficial incisional SSIs, 18 days for deep incisional SSIs, and 77 days for organ/space SSIs.

5.1.3 Impact of postdischarge surveillance

A total of 216 SSIs (56%) were detected after discharge. The proportion of SSIs detected after discharge by procedure type appear in **Figure 1**. Overall, 86% of organ/space SSIs, 80% of deep incisional SSIs, and 46% of superficial incisional SSIs were detected after discharge. Most of deep incisional and organ/space SSIs were identified on readmission, whereas most of the infections found during the follow-up visit or on completion of the postdischarge questionnaire were superficial incisional (**Table 12**).

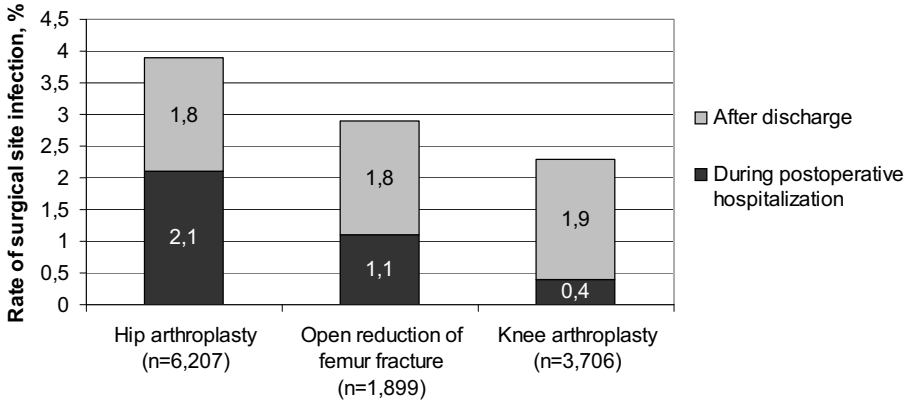

Figure 1. Rates of surgical site infections detected at nine Finnish hospitals during 1999-2002, according to type of procedure and time of detection

Table 12. Distribution of surgical site infections (SSI) among patients who underwent major hip and knee surgery at nine Finnish hospitals during 1999-2002, according to time or location of detection

Time or location of detection	Superficial incisional SSI n (%)	Deep incisional SSI n (%)	Organ/space SSI n (%)	Total n
During hospitalization	149 (89)	14 (8)	5 (3)	168
After discharge	127 (59)	57 (26)	32 (15)	216
On readmission	28 (30)	39 (42)	26 (28)	93
During follow-up visit	19 (83)	2 (9)	2 (9)	23
In outpatient follow-up by postdischarge questionnaire	64 (88)	7 (10)	2 (3)	73
Unknown	16 (59)	9 (33)	2 (7)	27
Overall	276 (72)	71 (18)	37 (10)	384

In 298 (78%) of the 384 SSIs, cultures yielded one or more microbial species. Microbial isolates were more commonly reported for SSI detected during a postoperative hospital stay than for SSIs found after discharge (93% vs 66%; P<0.001). The percentage of SSIs associated with a positive culture result differed among hospitals (range, 67-100% for in-hospital SSIs and 45-100% for postdischarge SSIs). The microbes most commonly detected were coagulase-negative staphylococci and *Staphylococcus aureus*. There was a wide variation among hospitals in the percentage of SSIs with coagulase-negative staphylococci as a causative agent (range, 30-65% for in-hospital SSI and 20-44% for postdischarge SSI).

5.1.4 Variability of SSI rates between hospitals

The overall hospital-specific rates varied from 0.8% to 6.4% among hospitals, and the rates for severe (deep incisional and organ/space SSIs) infections, from 0.4% to 2.1%. The proportion of SSIs detected after discharge in different hospitals varied from 28% to 90%, and the proportion of postdischarge SSIs detected by the postdischarge questionnaire, from 0% to 73%. In the multivariate analysis adjusted

for NNIS risk index, patient age and sex, urgency of operation, and procedure group, the hospital variable remained a significant risk factor for SSI (data not shown). When the model with the same adjustments was performed separately for SSIs detected before and after discharge, the range of hospital specific ORs was wider before than after discharge (range of OR before discharge: 0.1-5.4; range of OR after discharge: 0.4-1.8), suggesting that postdischarge surveillance alone did not explain the marked variation in SSI rates between hospitals.

5.2 Validation study (II)

5.2.1 Positive and negative predictive values

A concordance of the SSIs detected in routine SIRO surveillance and in the validation study chart review appears in **Table 13**. Routine surveillance identified 83 SSIs, 78 of which were also identified as SSIs by the validation team. Thus, the PPV was 94.0% (95% CI, 88.9-99.1%). Among the charts reviewed, no infections during routine surveillance had been reported after 314 operations, and the validation team confirmed 310 of these negative reports, yielding an NPV of 98.7% (95% CI, 97.5-100%).

Table 13. Validation results for surgical site infection surveillance after orthopedic surgery

	Chart review by validation team		
	Infection +	Infection -	Total
Routine surveillance +	78	5	83
Routine surveillance -	4	310	314
Total	82	315	397

Positive predictive value = 78 / 83 = 94.0% (95% CI, 88.9-99.1%)

Negative predictive value = 310 / 314 = 98.7% (95% CI, 97.5-100%)

5.2.2 Sensitivity and specificity

Applying the results of the validation study to the aggregated surveillance data (during 1999-2003: 592 infections and 14,551 non-infections) yielded a sensitivity of 75.0% (95% CI, 56.7-93.4%) and a specificity of 99.8% (95% CI, 99.5-100%) (**Table 14**).

One hospital was responsible for most of the infections missed (3/4) and for one false-positive infection (1/5). When the results of this hospital were excluded, the sensitivity for routine surveillance increased to 91.5% (95% CI, 76.4-100%) and the specificity, to 99.8% (95% CI, 99.6-100%).

The reasons for missing four SSIs during routine surveillance were that an ICN had received no information about the SSIs from a ward or from an outpatient department. Explanations for overreporting SSIs were related to interpretation of the case definition. Most false-positive SSIs were superficial incisional lacking appropriate clinical signs or symptoms. One organ/space SSI with clinical onset two years after the operation was reported.

Table 14. Chart review results applied to total SIRO surveillance data

	All operations under surveillance during 1999-2003		
	Infection +	Infection -	Total
Surveillance +	556*	36	592
Surveillance -	185	14,366**	14,551
Total	741	14,402	15,143

Sensitivity = 556 / 741 = 75.0%. Specificity = 14 366 / 14 402 = 99.8%.

*PPV x 592 = 556; ** NPV x 14,551 = 14,366

5.2.3 Interview results of surveillance methodology

According to the structured interviews, the following case finding methods were used: ward visits (7/8 hospitals), microbiology reports (5/8), ward notifications by link nurses (8/8) and other nursing (7/8) and medical (5/8) staff. ICN ward visits were performed mostly once a week, but extended to once a month. In all hospitals, link nurses in wards were trained for case finding. In three hospitals and selectively in five hospitals, if ward notifications of link nurses found an SSI case, an ICN reviewed the patient charts of every suspected SSI.

Most of the hospitals conducted postdischarge surveillance during follow-up visits (7/8), on readmission (8/8), and in outpatient settings with an additional questionnaire (7/8). Five hospitals used the standard questionnaire provided by SIRO. Four hospitals requested the return of all questionnaires: the response rate in these hospitals varied from 46% to 70%. Three hospitals requested the return of questionnaires only, if an SSI was identified.

The ICNs experienced difficulties in interpreting of SSI case definitions and the date of SSI (onset of signs and symptoms vs. date of wound culture). Problems mentioned involved distinguishing deep incisional SSIs from organ/space SSIs and the interpreting of prolonged serosal drainage with positive microbial culture. Six ICNs responded that they had also reported SSIs detected after the time limit imposed by the CDC definition.

The rate of wound cultures was calculable for seven hospitals. The rate in the orthopedic wards of participating hospitals varied from 9 to 67 per 1000 patient days, but failed to correlate with SSI rates by hospitals ($P = 0.38$).

5.3 Simultaneous bilateral hip and knee arthroplasties (III)

5.3.1 Characteristics of study patients and operations

Of the 9,831 joint replacements performed during 2001-2004, 7.2% of the implants were inserted in a bilateral procedure (range by hospital: 0.6–19.2%). The bilateral procedures were more common in TKA (9.9%) than in THA (5.2%).

At the time of procedure, patients who underwent bilateral THAs and TKAs were younger than those who underwent unilateral procedures, and were more often males (**Table 15**). They were also healthier: ASA scores of ≥3 or rheumatoid arthritis occurred less often. Bilateral procedures were more often primary arthroplasties. The duration of operation per operated joint did not differ between bi- and unilateral arthroplasties. The median total time from the first incision to the second closure for bilateral THA was 270 min (range: 145–462 min) and for bilateral TKA, 217 min (range: 112–450 min).

5.3.2 Deep incisional and organ/space surgical site infections

The overall rate of deep SSI after THA was 0.4% (24/5,614), and after TKA, 0.9% (37/4,217). The rates of deep SSI for bi- and unilateral arthroplasties were 0.6% (4/710) and 0.6% (57/9,121), respectively (THA 0% vs. 0.5% and TKA 1.0% vs. 0.9%). Independent risk factors for deep SSI after THA were an ASA score of ≥3 (P = 0.002; adjusted OR, 4.41; 95% CI, 1.47–12.66) and the duration of operation (P = 0.015; adjusted OR, 1.01; 95% CI, 1.00–1.01), and after TKA, an ASA score of ≥3 (P = 0.036; adjusted OR 2.20; 95% CI, 1.05–4.58) and the duration of operation (P = 0.008; adjusted OR, 1.01; 95% CI, 1.00–1.01). Simultaneous bilateral operation was not an independent risk factor for deep SSI after THA or TKA.

Table 15. Characteristics of patients and orthopedic procedures in simultaneous bilateral and unilateral total arthroplasties

Characteristic	Total hip arthroplasties (n = 5,614 joints)			Total knee arthroplasties (n = 4,217 joints)		
	Simultaneous bilateral (n = 145 patients, 290 joints)	Unilateral (n = 5,324 joints)	P value	Simultaneous bilateral (n = 210 patients, 420 joints)	Unilateral (n= 3,797 joints)	P value
Patients						
Age in years (mean±SD)	58.7±11.1	65.1±12.6	<0.001	66.6±9.8	69.3±10.1	<0.001
Males	75/145 (52)	2,126/5,324 (40)	0.004	83/210 (40)	1,023/3,797 (27)	<0.001
ASA 3, 4, or 5	26/144 (18)	2,353/5,181 (45)	<0.001	79/190 (42)	2,112/3,724 (57)	<0.001
Rheumatoid arthritis	3/145 (2)	295/5,324 (6)	0.069	10/210 (5)	339/3,797 (9)	0.037
Preoperative stay >2 days	10/145 (7)	318/5,324 (6)	0.644	11/210 (5)	136/3,797 (4)	0.214
Length of hospital stay in days (mean±SD)	10.1±2.8	7.6±4.1	<0.001	9.9±3.6	7.4±3.5	<0.001
Referred to other health care institution after discharge	32/145 (22)	2,120/5,324 (40)	<0.001	44/210 (21)	1,585/3,797 (42)	<0.001
Operations						
Primary operation	266/290 (92)	3,951/5,324 (74)	<0.001	406/420 (97)	3,264/3,797 (86)	<0.001
Wound classification 3 or 4	4/290 (1)	59/5,324 (1)	0.669	4/420 (1)	56/3,797 (2)	0.391
Duration of operation in minutes* (mean±SD)	116±28	129±55	0.381	110±31	114±41	0.710
NNIS risk index ≥1	168/290 (58)	3,574/5,324 (67)	0.001	255/420 (61)	2,607/3,797 (69)	0.001

Values in parentheses are percentages; * Per operated joint

All four deep SSIs in the bilateral group appeared after TKA: one was located on the first operative side and three others on the second operative side. The timing of antimicrobial prophylaxis (mostly cefuroxime) in the four bilateral TKA that led to deep SSI was 48 min before incision for the first operative side and 115, 155, and 218 min before incision for the second operative side, respectively. The doses (range: 1.5–3.0 g) were not repeated in the operation theatre. In unilateral operations that led to deep SSIs, antimicrobial prophylaxis was administered a median of 47 min (maximum 114 min) before incision.

5.3.3 Mortality

Mortality at 7 (0% vs. 0.1%, P = 1.00), 28 (0.3% vs. 0.2%, P = 0.55), and 365 days (0.9% vs. 1.9%, P = 0.18) after operation showed no statistical differences between bilateral and unilateral THA or TKA. Nor did mortality rates show any statistical differences, if THA and TKA were analyzed separately. None of the patients with bilateral arthroplasty died during the seven days after the operation or during postoperative hospitalization. When overall mortality served as the outcome variable in the Cox proportional hazard regression model, age, male sex, an ASA score of ≥3, rheumatoid arthritis, and revision operation were predictors for death after THA, and age, male sex, an ASA score of ≥3, and a revision operation were predictors of death after TKA; the bilateral procedure, however, was not.

5.4 Register linkage study (IV)

In Study IV, the three sources yielded 129 individual prosthetic joint infections after 13,482 total joint replacements (THA and TKA). This yields prosthetic joint infection rates of 0.9% after THA and 1.0% after TKA. Seven prosthetic joint infections were common to all three data sources, 22 were common to two sources, and 100 were unique to one source (**Figure 2**). Of the prosthetic joint infections detected in any data source, 98 (76%) were detected by SIRO. This proportion showed no difference between THA and TKA (75% vs. 77%).

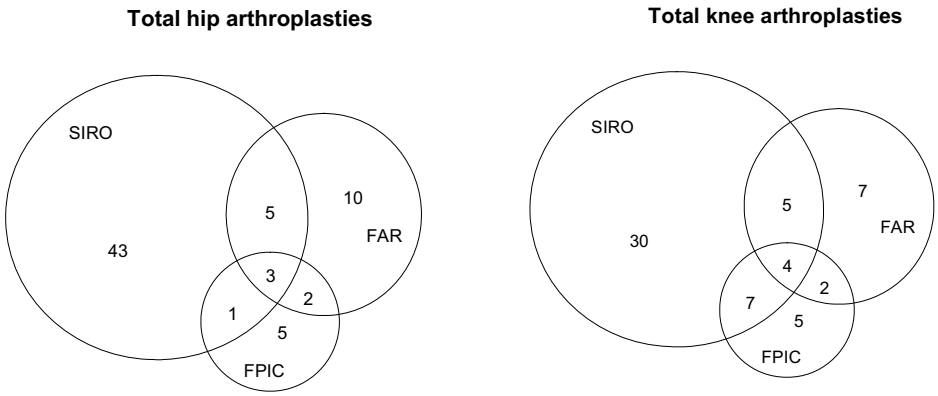

Figure 2. Number of prosthetic joint infections following 13,482 total hip and knee arthroplasties detected in different data sources in Finland during 1999-2004

SIRO, Finnish Hospital Infection Program; FAR, Finnish Arthroplasty Register; FPIC, Finnish Patient Insurance Centre

In the two-source capture-recapture analysis, the estimate of the total number of prosthetic joint infections after TKA varied from 51 to 88, and the 95% CIs for the estimates overlapped (**Table 16**). After THA for the Finnish Arthroplasty Register (FAR) and the Finnish Patient Insurance Centre (FPIC) pair, however, the estimate was three times smaller than the estimates for SIRO-FAR and SIRO-FPIC. This led to suspect and test dependence between the two sources: the Finnish Arthroplasty Register and the Finnish Patient Insurance Centre (OR, 25.8; 95% CI, 2.2-297.6). Because of this strong dependency, two alternative methods were used: the Finnish Arthroplasty Register and the Finnish Patient Insurance Centre data were merged for two-source analysis, and the log-linear model was performed. The most probable model a posteriori included the interaction term between the Finnish Arthroplasty Register and the Finnish Patient Insurance Centre. The results of these capture-recapture analyses appear in **Table 17** along with the model-averaged estimates. The estimates calculated by all three of these methods were similar: the estimated total number of prosthetic joint infections ranged from 138 to 143 after 7,561 THAs, and from 80 to 85 after 5,921 TKAs. This yielded a prosthetic joint infection rate of 1.8% after THA, and 1.4% after TKA. The sensitivity for SIRO surveillance from the estimate based on the three-source capture-recapture analysis with interaction term was 36.3% (95% CI, 20.2-54.9%) after THA, and 57.1% after TKA (95% CI, 40.9-72.4%).

Table 16. Two-source capture-recapture estimates of numbers of prosthetic joint infections after 7,561 total hip and 5,921 total knee arthroplasties, Finland, 1999-2004

Procedure group	Two-source analysis		Number of prosthetic joint infections			Capture-recapture estimate	
	Source 1	Source 2	$n_{source\ 1}$*	$n_{source\ 2}$*	$n_{source\ 1,\ source\ 2}$*	N**	95% CI
THA							
	SIRO	FAR	52	20	8	123	75-170
	SIRO	FPIC	52	11	4	126	67-181
	FAR	FPIC	20	11	5	41	27-55
TKA							
	SIRO	FAR	46	18	9	88	63-114
	SIRO	FPIC	46	18	11	73	57-95
	FAR	FPIC	18	18	6	51	39-62

*Number of prosthetic joint infections reported to source 1 or source 2 or both sources

**Estimate of the total number of prosthetic joint infections

CI, confidence interval; THA, total hip arthroplasty; TKA, total knee arthroplasty; SIRO, Finnish Hospital Infection Program; FAR, Finnish Arthroplasty Register; FPIC, Finnish Patient Insurance Centre

Table 17. Estimates of total number of prosthetic joint infections after 7,561 total hip and 5,921 total knee arthroplasties based on capture-recapture analyses, Finland, 1999-2004

Analysis method	Estimated total number of prosthetic joint infections (95% CI)	
	Total hip arthroplasty	Total knee arthroplasty
Two-source analysis by Wittes method (SIRO, FAR + FPIC combined)	142 (82-203)	85 (63-106)
Three-source analysis by log-linear model with interaction term FAR x FPIC	143 (103-224)	80 (68-100)
Three-source analysis accounting for model uncertainty: posterior average over models (SIRO, FAR, FPIC)	138 (95-339)	81 (67-109)

CI, confidence or credible interval; SIRO, Finnish Hospital Infection Program; FAR, Finnish Arthroplasty Register; FPIC, Finnish Patient Insurance Centre

Of the charts of patients of the 98 prosthetic joint infections, 97 (99%) were available for review; 89 met CDC criteria for deep incisional or organ/space SSIs. The PPV was 91% (87% for THA and 96% for TKA). Symptoms or signs were documented for most prosthetic joint infections (91%), and in more than half (56%), microorganisms were found from an aseptically-obtained culture of fluid or tissue (data incomplete). Evidence of infection was confirmed in 70 reoperations (79%), and radiologic or nuclear medicine imaging showed evidence of an infection in 30 (34%). In eight deep incisional SSIs (33%), the deep incision spontaneously dehisced or was deliberately opened by a surgeon. In five prosthetic joint infections (8%), the diagnosis was based solely on the surgeon's or attending physician's diagnosis. The nine infections that failed to meet the criteria were superficial SSIs, located on the wrong joints, or which exceeded the time limit of the CDC definition.

A total of 73 (82%) patients were reoperated at least once due to the prosthetic joint infection: 35 after THA and 38 after TKA. One-stage prosthetic joint exchange was performed on five patients, the infected prosthesis was removed from 38, and a new prosthesis was inserted into 15 (39%). For some patients, the insertion was planned, but not yet performed. The median time from removal to insertion of the new prosthesis was 169 days (range, 67-714). Seven patients had undergone plastic surgery. All patients received antimicrobial treatment.

After correction with the PPVs of SIRO and using estimates from the three-source capture-recapture analysis by the log-linear model with the interaction term FAR x FPIC, the total number of prosthetic joint infections after THA was 121 (95% CI, 88-184), and after TKA, 77 (95% CI, 66-96); the prosthetic joint infection rate was 1.6% (95% CI, 1.2-2.4%) for THA and 1.3% (95% CI, 1.1-1.6%) for TKA. During 1999-2004, an average of 7,077 THAs (i.e. 134 per 100,000 population) and 6,332 TKAs (i.e. 119 per 100,000 population) were annually performed in Finland. Based on that, it was estimated that each year (the average from 1999 to 2004), 195 postoperative prosthetic joint infections occurred after THA and TKA in Finland [after THA, 113 (95% CI, 82-172), and after TKA, 82 (95% CI, 71-102)].

6 DISCUSSION

Among European surveillance systems, Finnish SSI rates after THA and TKA have tended to be higher than those of other national surveillance systems (34, 153). Altogether, the four original studies (I-IV) provide information about the epidemiology of SSIs following major hip and knee surgery in Finland and the factors affecting the results of SIRO surveillance. First, the impact of postdischarge surveillance was evaluated (Study I). Postdischarge surveillance was found to detect a considerable number of SSIs: more than half of all SSIs and approximately 80% of deep incisional and organ/space SSIs. The SSIs detected in outpatients by a questionnaire were mostly superficial infections, whereas most deep incisional and organ/space SSIs were identified on readmission to the hospital. Thus, no need exists to strongly recommend use of an additional postdischarge surveillance questionnaire after orthopedic surgery. Study I also revealed variation in hospital-specific SSI incidences unexplained by postdischarge surveillance, and highlighted a need for a validation study. The validation study (Study II) suggested that most SSIs reported to SIRO by participating hospitals were true infections, some SSIs were missed due to weaknesses in case finding, and variation in diagnostic practices may affect SSI rates. Simultaneous bilateral THA and TKA were in the interest of surgeons in participating hospitals. Patients who underwent bilateral operations were younger, healthier, and more often males than were those who underwent unilateral procedures (Study III). The rates of deep SSIs or mortality did not differ between bi- and unilateral THAs or TKAs. Bilateral arthroplasties under one anaesthetic event require specific attention paid to their antimicrobial prophylaxis as well as to data management in the surveillance database. The possibility of register linkage with unique national identity codes was utilized to obtain more data on postoperative prosthetic joint infections (Study IV). Evidence indicated that true disease burden of prosthetic joint infections may be heavier than the rates from national nosocomial surveillance systems usually suggest. According to the estimation, nearly 200 prosthetic joint infections could occur in Finland each year (the average from 1999 to 2004) after THA and TKA.

6.1 Postdischarge surveillance after orthopedic surgery

6.1.1 Impact of postdischarge surveillance

In Study I, the median time from the operation to the date of SSI onset (11 days) was longer than the median postoperative stay (8 days). The median intervals between surgery and onset of superficial incisional, deep incisional, and organ/space SSIs were 8, 18, and 77 days, respectively. These findings suggest that effective postdischarge surveillance is essential to achieve truthful SSI rates after orthopedic surgery and especially to detect prosthetic joint infections.

In the current study, more than half of all SSIs and more than 80% of deep incisional and organ/space SSIs were detected after discharge. These figures were similar to those of a recent study from a large US integrated healthcare system using standard surveillance methodology before and after discharge (33). The study reported that 52% of all SSIs after THA and TKA were detected after discharge, and their total SSI rates exceeded the corresponding NNIS rates due to comprehensive postdischarge surveillance. In the European HAI surveillance network, HELICS, the proportion of postdischarge SSIs after hip arthroplasties varied from 0% to 75% among participating countries (34). Because of this wide variation, in-hospital incidences of SSIs were provided to permit comparisons without postdischarge surveillance. Similarly, in SIRO feedback reports, separate SSI rates − either including or excluding postdischarge SSIs − are always provided.

SIRO methods for postdischarge case finding included a special questionnaire and surveillance on readmission and during follow-up visits. In SIRO, a health care professional reported SSIs after hospital discharge, which has been considered more reliable than reporting by patients themselves (211, 212). According to the literature, a questionnaire is not the most sensitive postdischarge case finding method (186, 199, 220). However, while no universally accepted and validated method for postdischarge surveillance exists (210), the balance between cost and resources required for postdischarge surveillance and accuracy of the data obtained must be weighed individually in each surveillance system. In the future, the development of methods based on information technology, such as searching from outpatient electronic patient records and other electronic databases, will enhance the potential for effective, cost-saving and more accurate postdischarge surveillance methods as well as the opportunities for ICNs to confirm detected cases.

Limitations in Study I were that the number of patients who actually received a questionnaire and the response rate were unknown, and that postdischarge

surveillance has not been independently validated. Later, in the validation study interviews (Study II) ICNs reported postdischarge questionnaire response rates that varied from 46% to 70%. Three hospitals requested that the questionnaires be returned only if an SSI was identified. Response rates of 46% to 70% are higher than those reported in other studies (15-33%) (197, 204).

6.1.2 Surgical site infection rate and distribution of infection types

In Study I, the SSI rates − including postdischarge SSIs − were 3.9% for hip arthroplasty (including hemiarthroplasties), 2.9% for ORIF of femur fracture, and 2.3% for knee arthroplasty. Of all SSIs, more than 70% were superficial incisional. The SSIs detected with a postdischarge questionnaire were mostly superficial incisional, whereas most deep incisional and organ/space SSIs were identified on readmission to the hospital. So in SIRO, one potential weakness in case finding with a postdischarge questionnaire mostly affects the detection of superficial incisional SSIs, whereas the detection of SSIs during readmission is crucial to recognizing most severe SSIs. However, it seems that no need exists to strongly recommend surveillance with a postdischarge questionnaire after orthopedic surgery. Only a few other studies have reported the proportions of SSI types detected in different postdischarge locations. In the NNIS, the percentage of deep incisional and organ/space SSIs among SSIs detected on readmission was similar to that reported in Study I (70% vs. 60%) (191). A smaller percentage of SSIs detected in outpatients in Study I were more severe than those detected in outpatients in NNIS (12% vs. 22%). The studies are, however, not entirely comparable, because NNIS data included all surgical procedures, and the length of hospital stay likely varied considerably between procedures.

6.1.3 Variability of surgical site infection rates between hospitals

In Study I, as in previous reports from other national surveillance systems (155, 295) hospital-specific SSI rates in SIRO varied widely. Most of the rates were near the mean value, but some outliers were also detected. This variation may indicate real differences in SSI incidence, although other reasons are also possible (37, 221). The case mix, reflected by NNIS risk index, and the proportion of urgent surgical procedures, failed to explain the differences. Variation in some unmeasured intrinsic risks, such as immunocompromised status or obesity (221), cannot be ruled out. In SIRO material, extremely low-volume hospitals did not participate: in all

participating hospitals, hip joint replacements were performed more than 140 times per year and knee joint replacements more than 70 times per year.

Postdischarge surveillance results showed some variation: the proportion of SSIs detected after discharge varied from 28% to 90%, and the proportion of postdischarge SSIs detected with a questionnaire, from 0% to 73%. The hospitals with the highest SSI rates did not, however, perform the most active surveillance by means of the postdischarge questionnaire. Also, multivariate analyses suggested that postdischarge surveillance alone failed to explain the marked variation in SSI rates between hospitals. Thus, the variation in hospital-specific SSI rates may partly reflect differences in other factors, such as diagnostic practices. For example, differences in the frequency of culturing wound specimens can be suspect, because the proportion of SSIs with positive microbial culture results, and especially with coagulase-negative staphylococci differed, widely among hospitals. Thus, Study II examined the wound-culturing activity. In addition, variation in physicians' diagnostic practices has been suggested to impact SSI rates (156, 158). This variation may also exist in SIRO hospitals, but could not be evaluated in this study.

As one can already suppose from the issues described above, hospital-specific low or high SSI rates are not always easy to interpret. Low rates may reflect either an effective infection control program or poor identification of SSIs, and similarly, moderately high rates may indicate either a real infection control problem or effective case finding (35). However, the wide range in Study I in the hospital-specific SSI rates did emphasize the need for a validation study.

6.2 Validation study

6.2.1 Indicators of surveillance

The positive and negative predictive values of SIRO orthopedic SSI surveillance (PPV, 94%; 95% CI, 89-99%; NPV, 99%; 95% CI, 98-100%), were much higher than the results reported from the first NNIS validation study (138) and only slightly lower than PREZIES (157) or Scottish validation results (224). SIRO sensitivity (75%; 95% CI, 57-93%) and specificity (99.8%; 95% CI, 99.6-100%) were favourable compared to those reported from NNIS, but better indicators have been published (225). Other surveillance systems have not published sensitivities and specificities calculated by the same method used in this current study, even though this method has been discussed and accepted in international meetings of HAI surveillance experts.

In the validation sample, some underreporting of SSIs was detected. Patients with missed SSIs had passed through SIRO hospitals, such that an ICN failed to receive information about their SSIs. Thus, as in the NNIS validation study, insufficient case finding in SIRO also explained the underreporting of SSIs (138). On the whole, the overreporting of infections seemed not to be a major problem. When detected, overreporting stemmed from slight variations in ways of interpretating the case definitions; most false positive infections were superficial incisional SSIs without lacking clinical signs or symptoms, at least as documented in patient charts.

One limitation of this study was the small number of charts reviewed: an optimal sample size would have been two to three times larger. The current sample, however, was estimated in advance to be the largest that could realistically in each hospital be reviewed by two persons in one day. If the SIRO validation study will be repeated in a few years, the target number of patient charts per hospital could be slightly higher (for example in a ratio of 12 SSIs: 48 non-SSIs). This sample size per hospital multiplied by the current number of participating hospitals (15) would extend the total sample size to include 900 to 1,100 cases. Consequently, confidence intervals for predictive values, sensitivities, and specificities would be narrower. Even this larger study material would be insufficient to validate surveillance for organ/space SSIs or to evaluate hospital-specific surveillance quality indicators. Another limitation was the retrospective study design, although retrospective chart review is most often the only possible method for validation of a national surveillance system in several hospitals (138, 223).

6.2.2 Process of surveillance

In the ICN review, the most common case finding methods were ward notifications by link nurses and ICNs' ward visits. Microbiology reports were screened by ICNs in five out of eight hospitals. According to the literature, the sensitivity for ward-liaison alone was 62% (164), and for ward-liaison combined with the screening of microbiology laboratory reports, 76-89% (164). Because combining the screening of microbiology laboratory reports with ward-liaison improves sensitivity, it would be recommendable also in SIRO for ICNs in all hospitals to routinely screen microbiology reports from orthopedic wards.

Even though some variation in patient materials in this present study may exist (not all hospitals do have separate orthopedic wards), a 7-fold variability in wound culturing activity in wards treating THA and TKA patients is considerable. Although a positive culture is only one of the CDC criteria, SSIs without positive culture are often more difficult to find. This supports the opinion that even though the CDC

definition offers a reasonable standard for hospitals to follow (312), it still leaves too much potential for subjective decisions (152, 156, 158, 223). Subjective decisions (whether a physician makes an SSI diagnosis or whether a wound culture is taken) are likely to affect SSI rates. Moreover, the assessments made by the validation team are not entirely independent of these previous decisions either. Thus, differences in diagnostic practices between hospitals and surgeons may influence SSI rates even after validation.

Because the continuous training of surveyors is important to ensure the quality of surveillance (35, 37, 127), the results of both the chart review − especially the misclassified cases − and the interview have already been utilized in ICN training. For example, some clarifications of the SSI definition have been discussed and recommended: serose discharge is considered prolonged only after seven days, and no SSIs appearing after CDC definition time limits need to be reported.

6.3 Simultaneous bilateral hip and knee arthroplasties

6.3.1 Frequency of simultaneous bilateral arthroplasties

In SIRO hospitals during 2001-2004, the proportion of simultaneous bilateral THA and TKA were about 5% and 10%, respectively. These operations require specific attention to data management, because if they are not entered into the surveillance database as two separate operations, the denominator for calculating SSI rates will be insufficient, and the SSI rate will therefore be too high. Recently, the National Healthcare Safety Network (NHSN) in the United States started to require in their surveillance protocol, two separate procedure records, if a bilateral procedure is performed, and for each procedure, a unique duration of operation.

In Study III, the proportion of simultaneous TKA was higher than in large US Health Care Financing Administration data (4%) (266), but lower than in certain specialized orthopedic centers (66%) (269).The proportion of simultaneous bilateral THA was similar to that of other reports (5.1% vs 4.7%) (270). Data in this present study may, however, include a higher proportion of simultaneous bilateral THAs and TKAs than is generally performed in Finnish hospitals due to the interest of the hospitals that report data on the ‘bilateral’ variable. Before this present study no national HAI surveillance system has published results on SSIs after simultaneous bilateral arthroplasties. However, these national systems have the great advantage of receiving data from large numbers of arthroplasties: if these data were recorded and

correctly analyzed, national surveillance systems could play an important role in providing information on simultaneous bilateral arthroplasties in the future.

6.3.2 Deep incisional and organ/space surgical site infections and mortality

In Study III, an increased risk of deep incisional and organ/space SSI after simultaneous bilateral THA and TKA was not detected. The rates of deep SSI after TKA were similar to those of previous studies, although different rates have also been reported (266, 269, 275, 276, 285, 286). One strength of this present study compared to other studies was that the SIRO surveillance system used the CDC definition of SSIs with a follow-up period of one year. As discussed previously in this thesis, the importance of postdischarge surveillance was highlighted: the median time from an arthroplasty to the onset of deep incisional and organ/space SSIs was 39 days, which was clearly longer than the median hospital stay after hip or knee arthroplasties (7–10 days). Mortality at 7, 28, and 365 days showed no difference between simultaneous bilateral and unilateral THA and TKA, nor was the bilateral operation a predictor for death in the Cox model.

However, one limitation of this study was its limited power to prove non-difference between the two tested groups, when the outcome variables were quite rare. This limitation may be outweighed in the SIRO database after additional surveillance years, when these analyses could be repeated. Another limitation in interpreting the study results was the patient selection, as significantly younger and healthier patients were selected for simultaneous bilateral groups. This means that even with multivariate analyses, the number of elderly patients in the bilateral group was insufficient to conclude that the bilateral procedure is safe for elderly patients. The US Medicare study had the opposite limitation: the mean age of patients was 73 years, and they could not assess the risks for adults below 65 years (266). However, as bilateral simultaneous arthroplasties have suggested, to pose a greater risk of death among elderly patients, the patient selection for these procedures in SIRO hospitals seemed to be successful (286, 288, 313).

6.3.3 Antimicrobial prophylaxis

The number of deep SSIs was very low in the bilateral group; however, it may be indicative that antimicrobial prophylaxis was administered up to 3.5 hours before incision in the bilateral operations that led to deep SSI. In unilateral operations that led to deep SSIs, antimicrobial prophylaxis was administered more often in the recommended

time frame before incision (a median of 47 minutes), but in unilateral operations, the maximum interval detected (114 minutes) was also too long before incision. According to the prevailing US consensus in unilateral operations, the infusion of the first antimicrobial prophylaxis dose should begin within 60 minutes before surgical incision and, if operation prolongs, cefuroxime should be re-administered intra-operatively at an interval of 3–4 hours and cefazolin at an interval of 2-5 hours to ensure adequate antimicrobial levels until wound closure (112). For simultaneous bilateral arthroplasties, specific guidelines and sufficiently powered comparative studies targeting antimicrobial prophylaxis are still lacking and needed. However, because interventions focusing on antimicrobial prophylaxis have been demonstrated to decrease SSI rates (120-122) and this present study found potential for improvement, creation of specific guidelines and performance improvement interventions to achieve the best possible dosage of antimicrobial prophylaxis, both in bi- and unilateral arthroplasties, is recommended and could lead to a reduction in SSI rates.

6.4 Register linkage study

6.4.1 Disease burden of prosthetic joint infections

According to the three-source capture-recapture analysis, the total number of prosthetic joint infections estimated to occur after THA and TKA in Finland annually was around 200. The rate of prosthetic joint infections was 1.6% after THA and 1.3% after TKA. The combination of active postdischarge surveillance and the possibility to perform accurate register linkage studies by means of unique national identity codes contributed to this rather high, but possibly realistic, estimate of the prosthetic joint infection burden in Finland. The estimates were higher than the rates usually suggested by national nosocomial surveillance systems. The rates, including deep incisional and organ/space SSIs, reported from the Dutch nosocomial infection surveillance system were 0.9% after THA (46) and, from the German system, 0.8% and 0.6% after THA and TKA, respectively (47). A few studies from single specialized centers have shown even lower prosthetic joint infection rates (0.4%) (48).

Prosthetic joint infections cause significant morbidity and increase health care costs (10-13). In the chart review, all patients with prosthetic joint infections received antimicrobials, and 82% of them were known to have undergone additional surgery. Data on some reoperations (i.e. performed in other hospitals) may have been unavailable in patient charts.

6.4.2 Sensitivity

In this study, the sensitivity achieved for SIRO surveillance, 36% (95% CI, 20-55%) after THA and 57% after TKA (95% CI, 41-72%), was lower than the sensitivity detected in the validation study (75%; 95% CI, 56-93%) and the sensitivity reported from the US NNIS system (67%) (138). The sensitivity in TKAs achieved by the capture-recapture method was closer to that of the validation study, and the confidence intervals overlapped, but the sensitivity related to THA was clearly lower. The methodology in this present study, however, differed from that of previous studies. Without the capture-recapture technique, if the prosthetic joint infections found in SIRO were simply divided by the total number of prosthetic joint infections found in any study register, the sensitivity would have been 76%, which is close to that found in the validation study.

Several studies have demonstrated the efficacy of surveillance with feedback to surgeons in preventing SSIs (20-24). However, some experts have suggested that the intensity of surveillance may decrease over time, in which case the reduced SSI rate would reflect a reduction in sensitivity rather than a real reduction in the SSI rate (47). Because the capture-recapture method can be used repeatedly to evaluate changes in disease incidence and surveillance sensitivity (229), repeated capture-recapture analyses, despite their known limitations, could provide a tool to evaluate the time trends in the sensitivity of a surveillance system.

6.4.3 Conditions and limitations of capture-recapture analysis

The strengths and weaknesses of the estimates found in Study IV are related to the conditions that should be met in order to use capture-recapture methods appropriately: 1) two (or more) data sources should be independent, 2) all true matches − and only matches − should be identified, 3) all cases identified by the surveillance systems should be true cases that occurred in the population under investigation within a certain time period, and 4) the catchability of cases in each data source should be equal (239).

Independency of data sources

Using three data sources enabled the appropriate investigation of source dependencies. A strong dependence was found between two registers (the Finnish Arthroplasty Register and the Finnish Patient Insurance Centre), which was taken

into account in the analyses by combining the two dependent sources and performing the log-linear model.

Reliable matching of cases

Unique personal identifiers enabled the accurate identification of all duplicate cases both within and between sources. The situation is much more complicated in environments in which unique personal identifiers do not exist (314).

Including only true cases

Although the definitions of the prosthetic joint infection in the three sources differed, they were not inconsistent. The experience from the previous validation study and the chart review in this present study was that deep incisional and organ/space SSIs are sometimes difficult to distinguish. Therefore, both deep incisional and organ/space SSIs were considered prosthetic joint infections, which may lead to some overestimation of the total number of prosthetic joint infections and to some underestimation of the sensitivities. The PPV detected in SIRO was slightly lower than that found in the validation study for all SSIs (94%). For the two other registers, we assumed that their PPVs were 100%. In the Finnish Arthroplasty Register, only patients having undergone a reoperation due to infection were recorded. The patients in the Finnish Patient Insurance Centre definitely had true prosthetic joint infections, because claims of infection injury are individually evaluated and only true infection injuries are eligible for compensation.

Equal catchability

Because of type of operation introduced variable catchability within the Finnish Arthroplasty Register and the Finnish Patient Insurance Centre, data were stratified and estimates were obtained separately for THA and TKA. Reoperations seemed better reported to the Finnish Arthroplasty Register, and claims were more common in the Finnish Patient Insurance Centre after TKA than after THA. The reasons for this remain unclear. Some treatment strategies, clinical consequences, or patient characteristics which differed between these two operations may have influenced catchability. Analysis of variable catchability by age, gender, patient's risk index,

hospital or region would be of interest; this was impossible in this study, however, due to the small numbers.

As an additional data source, data (ICD codes) from the National Research and Development Center for Welfare and Health could be also used in the future in capture-recapture analyses.

6.5 Unanswered questions and future considerations

Surveillance of SSIs after orthopedic surgery is important but to perform appropriately is challenging. A lot of effort in many countries has been made to develop well-functioning surveillance systems to promote prevention. Thus far, the surveillance systems and health care environments differ so much that even after this in-depth analysis of Finnish orthopedic surveillance data, to assess whether the incidence of SSIs after THA and TKA is truly higher in Finland than in, for example, the Netherlands remains difficult. Many possible influential factors from other countries remain either unstudied or unpublished, and the actual scientific evaluation of all possible confounding factors between countries is nearly impossible. Nevertheless, international comparisons can be useful in stimulating the development of national surveillance systems and the prevention of infective complications. Challenges faced by national surveillance systems are often similar, and international cooperation and discussions among HAI experts are fruitful and can lead to improvements.

Within SIRO, differences in hospital-specific SSI rates after THA and TKA were detected. While these differences may be real, other underlying reasons for these differences may exist. Some space for interpretation of CDC definition exists (315), but further training seeks to promote their uniform interpretation. Repeated training utilizing case studies is also important during forthcoming years (316). The responsibility of ICNs to train the link nurses in their hospitals could be helped by offering ready training material for their use. It could also be useful to repeat the validation study in some years with a higher number of charts reviewed.

In the future, cooperation is essential to develop information technology systems that could detect certain signals such as infection-associated operation codes and ICD codes, antimicrobial drug use, and specific words in full-text electronic medical records, in order to assure as systematic case finding as possible. With such a system, achieving a sensitivity of higher than 90% could be possible (170). After receiving the signal of a possible SSI, an ICN could ascertain the SSI diagnosis by reviewing the patient's electronic records and, if needed, visit the ward. Some

researchers have suggested that, with a reduced burden of manual data collection, ICNs devote to use more time for other prevention activities (217).

Information technology may also help in assessing the reasons for variation in SSI rates by increasing opportunities for risk stratification. Then data on BMI, diabetes mellitus, or perioperative blood glucose could be available for risk stratification. Blood glucose also provides important data, such as whether glucose optimizing for operation has been successful or could be improved.

Reporting SSIs from hospitals to SIRO is based on confidentiality. At least until variation in case finding methods and CDC definition interpretation is minimized, the public reporting of SSI rates in Finland would provide misleading information on SSI rates in different hospitals. However, the hospitals themselves (their management, surgeons, and ICNs) could benefit even more from using their own results as well as the benchmark SIRO results in their SSI prevention. In many hospitals, special interventions to improve infection control performance (including antimicrobial prophylaxis) related to joint replacement operations could be useful to prevent further SSIs (317). The achievements of these interventions could be monitored with continuous surveillance. Despite the challenges, surveillance and infection control activities together can lead to reduced incidence of SSIs.

7 CONCLUSIONS

1. For hip and knee arthroplasties and open reductions of femur fracture, postdischarge surveillance detected more than half of all SSIs and approximately 80% of severe SSIs. The SSIs detected in outpatients by a questionnaire were mostly superficial infections, whereas most deep incisional and organ/space SSIs were identified on readmission to the hospital.

2. According to the validation study, most SSIs reported to SIRO by participating hospitals were true infections. Thus, when an SSI case was reported, the criteria of the case definition were usually correctly interpreted. Some SSIs were missed, which may be due to weaknesses in case finding. Variation in diagnostic practices may also affect SSI rates.

3. Patients who underwent bilateral operations were younger, healthier, and more often males than were those who underwent unilateral procedures. In this patient material, no differences were found in deep SSI rates or mortality between bi- and unilateral THA and TKA. Bilateral operations do, however, require specific attention in the timing of antimicrobial prophylaxis as well as in the data management of the surveillance database, if one seeks to provide surgeons with specific feedback on this issue,

4. The capture-recapture analysis can be used to analyze the sensitivity of a national surveillance system. This method, combined with postdischarge surveillance, provided a rather high, but probably realistic, prosthetic joint infection rate estimate. The true disease burden of prosthetic joint infections could be heavier than the rates from national nosocomial surveillance systems usually indicate.

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