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Trends in surgical site infection and periprosthetic joint infection after primary total hip arthroplasty in two national health registers 2013–2022

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SUMMARY

Background: This study aimed to assess trends in surgical site infection (SSI), re-operations for SSI, and re-operations for periprosthetic joint infection (PJI) following primary total hip arthroplasty (THA) in Norway from 2013 to 2022. Two national health registers were used to compare their abilities as surveillance tools for PJI after primary THA.

Methods: The Norwegian Surveillance System for Healthcare-Associated Infections (NOIS) was evaluated for 30-day incidence and risk of SSI and reoperations for SSI after THA. Reporting to NOIS is mandatory. The Norwegian Arthroplasty Register (NAR) was assessed for 30-day and 1-year incidence and risk of re-operation due to PJI after THA. Reporting to NAR is based on patient consent. Descriptive statistics and adjusted Cox regression analyses, accounting for sex, age and American Society of Anesthesiology class, were performed.

Results: A total of 87,923 primary THAs were included in NOIS, with 1393 (1.6%) reported as 30-day SSIs. The 30-day re-operation rate for SSI in NOIS was 0.9% ($N = 765$), with 96% completeness of 30-day follow-up. In NAR, out of 91,194 THAs, the 30-day re-operation rate for PJI was 0.8% ($N = 725$) and the 1-year rate was 1.2% ($N = 1019$). The completeness of 30-day re-operation for PJI in NAR compared with re-operation for SSI in NOIS was 95%. Annual risk factors were similar across registers. There was a corresponding decline in SSI [adjusted hazard rate ratio (aHRR) 0.92, 95% confidence interval (CI) 0.90–0.93] and reoperations for SSI (aHRR 0.95, 95% CI 0.92–0.97) in NOIS, and reoperations for PJI (30 days: aHRR 0.96, 95% CI 0.94–0.99; 1 year: aHRR 0.95, 95% CI 0.95–0.99) in NAR.

Conclusion: There has been a corresponding decline in SSI and re-operation for PJI between 2013 and 2022. The 95% completeness of 30-day re-operation for PJI in the patient-consent-based NAR, compared with the mandatory NOIS, is considered excellent. The findings indicate a genuine reduction in the incidence of SSI and PJI after primary THA.

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Introduction

Postoperative infection is a significant concern in orthopaedic surgery, and such infections are surveilled for patient safety and as a measure of quality of care. Primary total hip arthroplasty (THA) is an indicator procedure for the surveillance of infection in orthopaedic surgery in Norway, as in several other countries (USA, UK, Netherlands, etc.). In Norway, two definitions of postoperative infections are surveilled: surgical site infection (SSI) and re-operation for periprosthetic joint infection (PJI). The national surveillance systems surveil SSI, as defined by the surveillance protocol of the European Centre for Disease Prevention and Control (ECDC) [1]. The arthroplasty registers surveil re-operations and/or revisions for PJI, as defined by the European Bone and Joint Infection Society [2]. Both endpoints are indicators of PJI.

Trends in PJI may be associated with factors such as changes in surgical technique and strategy, infection control measures, and patient risk factors [3]. In the last decades, studies on SSI after THA have reported a reduction in incidence [4–7]. In contrast, several register studies on the risk of re-operation or revision for PJI after THA have reported an increasing risk [3,8,9]. However, recent studies have reported that the risk of re-operation for PJI has plateaued over the last decade [10,11].

In Norway, there are two independent national health registers that surveil PJI after primary THA. The Norwegian Surveillance System for Healthcare-associated Infections (NOIS) surveils all primary THAs 30 days postoperatively for SSI. The Norwegian Arthroplasty Register (NAR) follows all THAs until re-operation or death of the patient. The same primary THAs are reported to the NOIS and NAR independently. Therefore, correspondence between the reported THAs in the NOIS and NAR can be assessed. It is also possible to assess changes in incidence of SSI and re-operation for PJI over time. This study aimed to assess trends in SSI, re-operation for SSI, and re-operation for PJI following primary THA in Norway from 2013 to 2022. In addition, this study reports the concordance and differences between the two registers as surveillance instruments for PJI in a national THA cohort.

Norwegian Surveillance System for Healthcare-associated Infections

The NOIS monitors the incidence of SSI after six surgical procedures, as indicator procedures for different surgical specialties. THA is one of them. Reporting is mandatory by law. The NOIS is facilitated by the National Institute of Public Health in Norway. The aim is to surveil SSIs for unwanted variation and changes in incidence at hospital level. The NOIS has full-year reporting of primary THAs since 2013; the last year of available data at the time of this study was 2022.

Data are reported tertiarily to the NOIS from the individual hospitals with a standardized electronic form by dedicated infection prevention staff who are not involved in treatment of the patients. The information collected includes hospital affiliation, patient characteristics, duration of surgery, American Society of Anesthesiology (ASA) score, antibiotic prophylaxis, date of admission, surgery, discharge, first SSI, last follow-up, type of arthroplasty, type of SSI (superficial, deep, organ/space), re-operation for SSI, and who reported the SSI diagnosis. All THA patients are followed up 30 days postoperatively. SSI assessment is performed at discharge and within 30 days postoperatively. Patients receive a questionnaire post discharge, asking if there are any signs of SSI. If no SSI occurred, the patient is censored at death or 30 days postoperatively. Hence, SSI or re-operation for SSI beyond 30 days is not reported. All SSIs reported are verified by the patient's general physician or an orthopaedic surgeon. The completeness of reporting of 30-day follow-up of THA in the NOIS is 96%. From the NOIS, all 87,923 primary THAs reported from the period 2013–2022 were included in the analyses.

Norwegian Arthroplasty Register

Since its establishment in 1987, the NAR has collected data on primary and revision THAs with all subsequent re-operations. The data registered include detailed information on patient and procedure characteristics, indication for THA, type of implant, method of fixation, and duration of surgery. If a subsequent re-operation is performed, a new registration is created and linked to the primary THA using the unique identification number of each Norwegian inhabitant [12]. Reporting is done on a form (electronic or paper) by the surgeon immediately after surgery. Data from the NAR are validated against the Norwegian Patient Register at individual level, and the completeness of reporting is 97% for primary THA, 93% for re-operation, 100% for coverage of Norwegian hospitals, and 100% for deaths [13].

Reported re-operation for PJI is based on the surgeon's pre- and intraoperative assessment. Subsequent corrections of the diagnosis based on the results on bacterial findings are not reported. The cause of the re-operation, if misdiagnosed, is therefore not subsequently corrected. In addition, PJIs that do not require re-operation are not reported. Hence, the risk of re-operation for PJI will not capture all PJIs, and some may be misdiagnosed.

In the NAR, THAs were followed until any revision, until the date of death or emigration, or until 31st December 2022. All 91,194 primary THAs reported to the NAR in the period 2013–2022 were included in the analyses.

Methods

Statistics

The number of primary THAs in the NOIS and NAR were compared at group level according to sex, age group (<45, 45–54, 55–64, 65–74, 75–84 and >85 years) and ASA score (1, 2, 3, 4 and missing) for estimation of concordance. The NOIS endpoints were 30-day SSI and 30-day re-operation for SSI. The NAR endpoints were 30-day and 1-year re-operation for PJI. Annual incidence rates of the four endpoints were presented with absolute numbers and graphically.

Cox regression analyses were performed with adjustment for sex, age group and ASA score to estimate adjusted hazard rate ratios (aHRR) as an expression of relative risk. The mean annual risk was estimated, with 95% confidence intervals (CI), for each of the four endpoints. Non-overlapping CIs were considered to be significant.

In addition, changes in the relative risk of SSI and re-operation for SSI or PJI were assessed as a function of year of

operation. These analyses gave a graphical display of the relationship based on a generalized additive model for survival data [14]. The curves are presented with 95% CI. SPSS 29.0 (IBM Corp., Armonk, NY, USA) and R (R Foundation, Vienna, Austria) were used for statistical analyses, and the study was performed in accordance with the RECORD statement for observational studies [15].

Ethics and disclosures

The registration of data and the study was performed confidentially on patient consent (NAR) or legislated by law (NOIS), and according to Norwegian and European Union data protection rules. The authors had no conflicts of interest.

Results

In total, 87,923 THAs from the NOIS and 91,194 THAs from the NAR were assessed; 96.4% of the THAs in the NAR were also in the NOIS. The annual distribution of patient-related risk factors such as sex, age and ASA score were nearly identical in the NOIS and NAR, and stable throughout the study period (Table I). The distribution of risk factors, and completeness and coverage of the registers, indicated that the two national registers were representative of each other, but not identical (Table II). Therefore, the NOIS and NAR may be considered representative for the same national THA population.

In the NOIS, 1393 (1.6%) cases of SSI after THA were reported, of which 765 (0.9%) underwent re-operation for SSI within 30 days (Table III). In other words, only 55% of SSIs required re-operation within the 30-day follow-up period.

In the NAR, 725 (0.8%) patients were re-operated for PJI within 30 days, and 1019 (1.2%) were re-operated within 1 year after THA (Table III). Hence, 71% of PJIs occurring within the first postoperative year were re-operated during the first 30 days.

The completeness of reporting of 30-day re-operation for PJI in the NAR compared with re-operation for SSI in the NOIS was 95%. The annual number of THAs with subsequent SSI or re-operation for SSI in the NOIS, and subsequent 30-day and 1-year re-operation for PJI in the NAR are presented in Table III and Figure 1.

Table I
Annual distribution of patient-specific factors in primary total hip arthroplasty in the Norwegian Surveillance System for Healthcare-associated Infections (NOIS) and the Norwegian Arthroplasty Register (NAR) for the period 2013—2022

		2013 (%)	2014 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)
Norwegian Surgical Site Infection Surveilance System (NOIS)											
Sex	Female	65	65	65	64	64	63	64	63	63	63
	Male	35	35	35	36	36	37	36	37	37	37
Age group	<45years	3	3	3	3	3	3	3	3	2	2
	45-54years	8	9	8	8	9	9	9	9	9	8
	55-64years	22	22	22	22	23	23	22	21	22	22
	65-74years	37	38	39	37	37	37	37	37	36	35
	75-84years	25	23	24	24	23	23	24	25	25	28
	>85years	5	5	5	5	4	5	5	5	5	5
ASA class	1	14	15	14	15	15	14	13	13	14	11
	2	66	65	66	66	66	65	64	64	63	62
	3	18	18	18	18	19	21	21	21	21	21
	4+	0	0	0	0	0	1	1	1	0	1
	Missing	2	2	2	1	0	0	1	1	2	5
	Total	7720	7807	8222	8657	9050	9422	9761	8250	8947	10,087
Norwegian Arthroplasty Register (NAR)											
Sex	Female	65	66	65	64	64	63	64	63	63	63
	Male	35	34	35	36	36	37	36	37	37	37
Age group	<45years	3	3	3	3	3	3	3	3	3	3
	45-54years	8	9	8	8	10	9	9	10	9	8
	55-64years	23	22	22	22	23	23	22	22	23	22
	65-74years	37	38	39	37	37	37	37	37	35	35
	75-84years	24	23	23	24	23	23	24	25	25	27
	>85years	5	5	5	5	4	5	5	4	5	5
ASA class	1	15	14	14	15	15	14	13	13	13	12
	2	65	65	65	65	64	64	63	63	63	64
	3	19	20	20	19	20	21	22	22	22	23
	4+	0	0	0	0	0	0	1	1	1	1
	Missing	1	1	1	1	1	1	1	1	1	0
	Total	8103	8137	8448	8954	9176	9610	10,044	8726	9514	10,482

ASA, American Society of Anesthesiology.

Table II
A summary of patient-specific factors in primary total hip arthroplasty (THA), and coverage and completeness of reporting in the Norwegian Surveillance System for Healthcare-associated Infections (NOIS) and the Norwegian Arthroplasty Register (NAR) for the period 2013—2022

		NOIS		NAR	
		Number of THAs (%)		Number of THAs (%)	
Sex	**Female**	56,337	(64)	58,306	(64)
	Male	31,586	(36)	31,888	(36)
Age group	**<45 years**	2514	(3)	2700	(3)
	45-54 years	7581	(9)	7981	(9)
	55-64 years	19,541	(22)	20,419	(22)
	65-74 years	32,560	(37)	33,705	(37)
	75-84 years	21,575	(24)	22,110	(24)
	>85 years	4152	(5)	4279	(5)
ASA class	**1**	12,185	(14)	12,609	(14)
	2	56,559	(64)	58,395	(64)
	3	17,367	(20)	19,038	(21)
	4+	416	(0.5)	483	(0.5)
	Missing	1396	(2)	669	(1)
	Total	87,923		91,194	
Complete 30-day follow-up		96 %			
Completeness, primary				97 %	
Completeness, revision				92 %	

ASA, American Society of Anesthesiology.

In the NOIS, there was a mean annual reduction in risk of both SSI (RR 0.92, 95% CI 0.90—0.93, per year) and re-operation for SSI [risk reduction (RR) 0.95, 95% CI 0.92—0.97, per year] (Figure 2). In the NAR, there was a corresponding, but less pronounced, mean annual reduction in risk of re-operation for PJI (30 days: RR 0.96, 95% CI 0.94—0.99, per year; 1 year: 0.97, 95% CI 0.95—0.99, per year) over the period 2013—2022 (Figure 2).

Discussion

Main findings

The study investigated the temporal trends in SSI and PJI after THA from 2013 to 2022 in Norway using two separate national health registers. The main finding was that both 30-day incidence and risk of SSI and re-operation for SSI after THA, as well as 30-day and 1-year risk of re-operation for PJI decreased over the last decade. The findings were similar in the two national health registers, including nearly all the primary THAs performed in Norway. The findings are considered robust. These findings are in line with other publications on SSI, but in contrast to studies on re-operation for PJI [3—10].

Several infection surveillance systems have reported a trend of decreasing rates of SSI after THA, including both superficial and deep infections [4—7]. ECDC reports a stable in-hospital incidence of SSI after THA since 2011, in slight contrast to the results of the present study for the same period [16,17]. A review from 2015 reports found increasing risk of SSI in several countries [18].

The NOIS and NAR surveil infection after primary THA with

Table III
Annual number of primary total hip arthroplasties (THAs), 30-day incidence of surgical site infection (SSI) and re-operation for SSI in the Norwegian Surveillance System for Healthcare-associated Infections (NOIS), in addition to number of primary THAs, and 30-day and 1-year incidence of re-operation for periprosthetic joint infection in the Norwegian Arthroplasty Register (NAR) for the period 2013—2022

	NOIS			NAR		
Year of primary THA	**Number of THAs reported**	**30-Days Surgical Site Infection (%)**	**30-Days Reoperation for Surgical Site Infection (%)**	**Number of THAs reported**	**30-Days Reoperation for Deep Infection (%)**	**1-Year Reoperation for Deep Infection (%)**
2013	7720	178 (2.31)	87 (1.13)	8103	75 (0.93)	102 (1,26)
2014	7807	142 (1.82)	61 (0.78)	8137	62 (0.76)	90 (1,11)
2015	8222	169 (2.01)	92 (1.12)	8448	71 (0.84)	107 (1.27)
2016	8657	155 (1.79)	82 (0.95)	8954	81 (0.90)	122 (1,36)
2017	9050	155 (1.71)	86 (0.95)	9176	76 (0.83)	125 (1.36)
2018	9422	148 (1.57)	82 (0.87)	9610	86 (0.89)	125 (1.30)
2019	9761	139 (1.42)	78 (0.80)	10,044	81 (0.81)	117 (1.16)
2020	8250	89 (1.08)	58 (0.70)	8726	67 (0.67)	102 (1.17)
2021	8947	89 (0.99)	59 (0.66)	9514	52 (0.55)	93 (0.98)
2022	10,087	129 (1.28)	80 (0.79)	10,482	74 (0.71)	116 (1.11)
Total	**87,923**	**1393 (1.58)**	**765 (0.87)**	**91,194**	**725 (0.80)**	**1019 (1.21)**

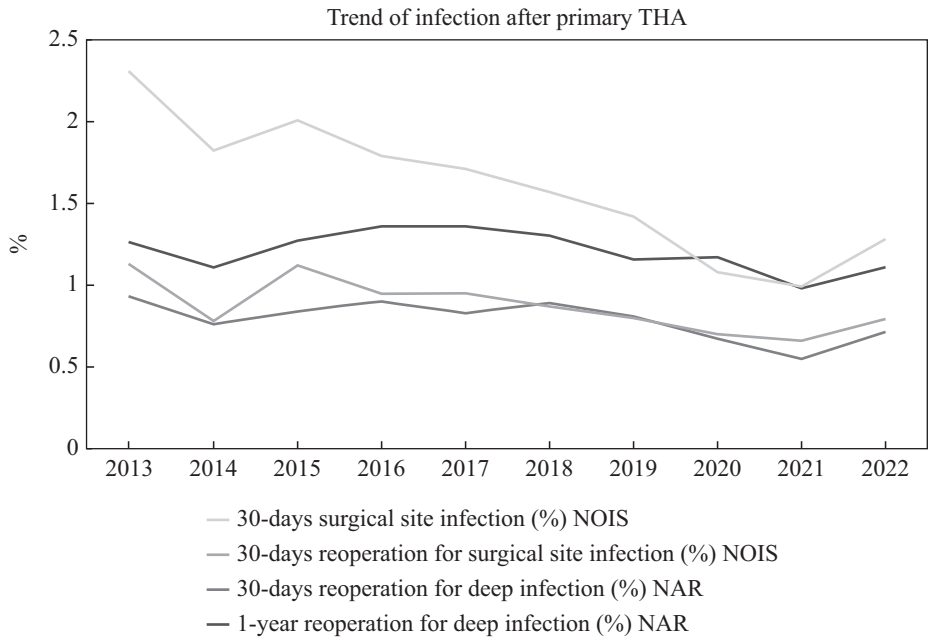

Figure 1. Annual 30-day incidence of surgical site infection (SSI) and re-operation for SSI in the Norwegian Surveillance System for Healthcare-associated Infections (NOIS), in addition to 30-day and 1-year incidence of re-operation for periprosthetic joint infection in the Norwegian Arthroplasty Register (NAR) for the period 2013—2022. THA, total hip arthroplasty.

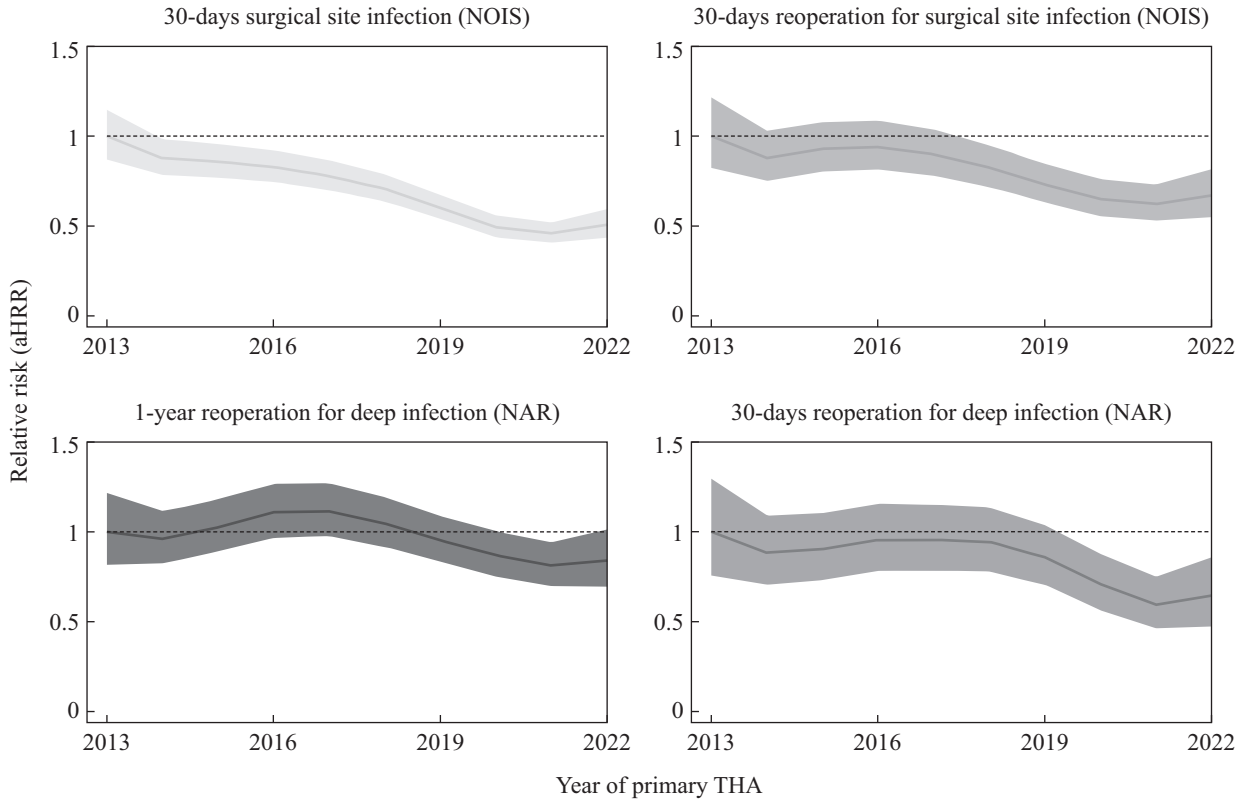

Figure 2. Annual risk [adjusted hazard rate ratio (aHRR)] of surgical site infection (SSI) within 30 days, and re-operation for SSI within 30 days, in the Norwegian Surveillance System for Healthcare-associated Infections (NOIS), and re-operation for periprosthetic joint infection within 30 days and 1 year in the Norwegian Arthroplasty Register (NAR), adjusted for sex, age and American Society of Anesthesiology score. The dotted lines represent the reference risk in 2013 (aHRR=1). THA, total hip arthroplasty.

different definitions (SSI and re-operation for PJI) and duration of observation. In addition, data capture, methodology and coverage differ. Similar differences in other studies may explain, in part, the variety of trends found in publications.

SSI is observed at discharge from hospital or at post-discharge surveillance, by self-reporting and confirmed by a general physician or surgeon 30 days postoperatively, in concordance with a specific set of diagnostic criteria and strict definition [1,19]. The NOIS only includes 30 days of surveillance of SSI after THA. SSI or re-operation for SSI >30 days after the index surgery are not reported to the NOIS and will be missed in the surveillance [20].

In the NAR, the surgeon reports re-operation for PJI at any time after THA. PJI as the cause of the re-operation is disclosed and reported by the surgeon immediately after surgery, based on pre- and intraoperative assessment, without later correction based on confirmed bacterial findings [21]. Most 1-year re-operations for PJI (71%) were performed within 30 days following primary THA. Twenty-nine percent of SSIs were re-operated >30 days after primary THA; this percentage was a little higher than reported in a previous study from the NOIS, which found that 14% missed deep SSIs occurred >30 days after the index surgery [20]. Superficial SSIs which are not re-operated are not reported to the NAR, only NOIS. Re-operations for SSI >30 days after THA are reported as re-operations for PJI to the NAR but not the NOIS. This demonstrates that the two registers contain complementary data.

It is debated whether superficial SSIs exist or not in the immediate postoperative phase of THA. It is claimed that if the superficial wound is infected, the whole wound, including the implant, is infected, and that the distinction between superficial and deep is arbitrary. An odds ratio of 5.6 (95% CI 1.2—27.4) for superficial SSI after THA relative to PJI, as reported by Peel et *al.*, indicates that patients may have a superficial SSI without a subsequent PJI, but SSI acts as a potent risk factor [22,23]. As a result, there has been a trend towards considering the risk of PJI too high in cases of wound problems and superficial SSIs, so early re-operation including thorough debridement, tissue sampling and wound closure has been advocated [21,24,25].

This study found the most pronounced reduction in incidence and risk of SSI and re-operation for PJI in 2020 and 2021, which were the peak years of the coronavirus disease 2019 pandemic. In this period, elective surgical capacity was reduced [26]. This reduction was caused by resource reallocation, prioritization of urgent cases, and concerns about patient safety. One could argue that, due to the shortage of intensive care capacity, healthier patients were prioritized for elective primary THA unless urgent, with fewer SSIs and PJIs as a result. Fewer THAs were reported in the years of the pandemic, but trends of fewer comorbidities (ASA score) or lower age in patients undergoing primary THA in Norway in 2020—2021 were not found in this study. Other studies have reported no change in the rates of PJI and SSI during the pandemic [27,28]. On the other hand, the increased awareness of hygiene and infection control measures during the pandemic may have contributed to improved compliance with guidelines for SSI protection protocols in healthcare settings, including operating theatres, and possibly fewer SSIs with subsequent PJI and re-operation [29]. In addition, healthcare providers may have been more diligent in following protocols to prevent infections [29]. However, the findings of the influence of the pandemic on SSI are conflicting [28,30—32].

Register studies can provide a useful source of information on incidence rates and trends of both SSI and re-operation for PJI, due to large numbers and continuous observation. In the NOIS, this study found 96% completeness of reporting of 30-day follow-up of the primary THAs, and only 2% missing variables (ASA score), which is considered excellent completeness for national level. However, the registrations were at hospital level, and primary THAs re-operated for SSI in a different hospital may have been missed in the NOIS if the patients' self-reporting form was not returned or validated by a doctor. Both infection protection staff and orthopaedic surgeons validate the individual registrations of SSI in the NOIS, but they normally only have access to the primary hospital. In contrast, if reported as a re-operation for PJI to the NAR, reports from any hospital are linked to the primary THA. However, considering the 96% completeness of reporting of follow-up, this reporting bias is probably minor. The NAR had completeness of reporting of 97% for primary THA, 92% completeness of reporting for any re-operation, and 100% coverage of Norwegian hospitals compared with the Norwegian Patient Register [13]. This is considered good, but the NAR did not have the exact coverage estimation of re-operations for PJI alone. The finding of 95% incidence for 30-day re-operation for PJI in the NAR compared with re-operation for SSI in the NOIS indicates that there is no major reporting bias for re-operation for PJI in the NAR. This is in contrast to a recent Dutch study which found that only one-third of the revisions for PJI were reported to the Dutch Arthroplasty Register compared with re-operations for SSI reported to the Dutch National Nosocomial Surveillance Network [33].

Neither SSI surveillance systems nor arthroplasty registers fully encompass and register PJIs as defined by the European Bone and Joint Infection Society [2]. As mentioned, 1-year follow-up, as recommended for implants in the ECDC manual, is not recorded in the NOIS, but the influence of this is considered minor [1,20]. The NOIS is therefore limited by the short period of observation, whereas the NAR is susceptible to under-reporting or misdiagnosis by the surgeon, or PJIs treated with re-operation not being reported [21]. However, a recent validation study has shown accuracy of 87% when PJI is reported to the NAR as the cause of the re-operation [21].

In this way, the two registers are complementary in capturing different infections and aspects of PJI. This is considered to be a strength of this study, but limitations for the individual registers. However, the present study had the advantage of numbers for direct comparison, and despite differences in definitions and observation, a corresponding decreasing incidence and risk of infection of all endpoints was found in both registers.

However, register studies have inherent limitations [34]. Even after adjustment for sex, age and ASA score in the survival analyses — important factors associated with SSI and re-operation — there may be residual confounding. Such confounding factors may be changes over time in evaluation of SSI or PJI, reporting, re-operation threshold, diagnostics, surgeon awareness, prophylactic measures for infection, and virulence and resistance of the bacteria causing infection. These factors are not accounted for in the present study, but the finding of

similar time trends for incidence and risk of both SSI and PJI indicate that unknown confounding was minor.

Of the THAs reported to the NAR over the study period, 96% were also reported to the NOIS. Not all private and public hospitals reported throughout the study period. Re-operation after failed hip fracture surgery, where osteosynthesis is converted to THA, may be reported as a revision THA, whereas it is really a primary THA. This may be due to misconception or may be economically motivated. Such bias is automatically corrected in the NAR by synchronization with the Norwegian Hip Fracture Register, but not in the NOIS. Moreover, since a near-complete number of primary THAs from two entirely separate nationwide registers demonstrated similar trends, external validity is expected to be good and the findings robust.

So how have we become better at avoiding PJI? Orthopaedic surgeons and infection protection staff have worked meticulously with prophylactic measures over the last decades, and new knowledge has been acquired and evidence-based guidelines for prophylactic measures have been established [35,36]. Improved understanding of how patients get infected, improved timing and change in antibiotic prophylaxis, advances in surgical techniques, shorter surgical duration, and shorter length of hospital stay have likely all contributed to reducing the risk of SSI and PJI.

Continuous education and training of healthcare professionals may also have played a crucial role in ensuring that infection protection practices are up to date and implemented effectively. However, educational infection protection programmes vary significantly from country to country, and a long-term effect on the incidence of SSI has not been found [37—39]. In Norway, systematic review and development of prophylactic measures against SSI has been a strong focus over the study period, guidelines for antibiotic prophylaxis in arthroplasty and prevention of postoperative infections have been established, and compliance has been surveilled [13,40].

In conclusion, the incidence and risk of SSI (NOIS) and re-operation for PJI (NAR) have had a corresponding decline over the period 2013—2022. Ninety-five percent completeness of reporting of 30-day re-operation for PJI to the patient-consent-based NAR compared with the mandatory NOIS is considered good. As unoperated SSIs are not reported to the NAR, the registers are complementary. These findings may reflect a true reduction in the incidence of SSI and PJI after primary THA.

Conflict of interest statement
None declared.

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