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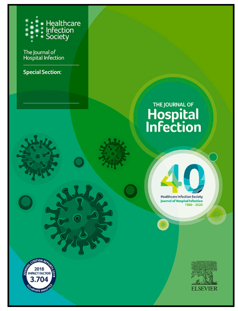

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Trends of Surgical Site Infection and Periprosthetic Joint Infection after Primary Total Hip Arthroplasty in Two National Health Registers 2013 - 2022

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Summary

This study aimed to assess trends in surgical site infection (SSI), reoperations for SSI, and reoperations 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. There has been a corresponding decline in SSI and reoperation for PJI between 2013 and 2022. A 95% completeness of 30-days reoperation for PJI in the patient-consent based Norwegian Arthroplasty Register, compared to the mandatory Norwegian Surveillance System for Healthcare Associated Infections is considered excellent. The findings indicate a genuine reduction in SSI and PJI incidence after primary THA.

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) has been an indicator procedure for 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 reoperations for periprosthetic joint infection (PJI). The national surveillance systems surveil SSI, as defined by European Centre for Disease Prevention and Control's (ECDC) surveillance protocol (1). The arthroplasty registers surveil reoperations and/or revisions for PJI, as defined by the European Bone and Joint Infection Society (EBJIS)(2). Both endpoints are indicators of PJI.

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

In Norway we have two independent national health registers that surveil PJI after primary total hip arthroplasty (THA). The Norwegian Surveillance System for Healthcare Associated Infections (NOIS) surveil all primary THAs 30 days postoperatively for SSI. The Norwegian Arthroplasty Register (NAR) follow all THAs until any reoperation or death of the patient. The same primary THAs are reported to NOIS and NAR independently. Therefore, we may assess the correspondence between the reported THAs in NOIS and NAR. We may also assess changes in incidences of SSI and reoperations for PJI over time. This study aimed to assess trends in surgical site infection (SSI), reoperations for SSI, and reoperations for periprosthetic joint infection (PJI) following primary total hip arthroplasty (THA) in Norway from 2013 to 2022. In addition, we report on concordance and differences between the two registers, as surveillance instruments for PJI in a national THA cohort.

The Norwegian Surveillance System for Healthcare Associated Infections (NOIS)

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

The data is tertiarily reported to the NOIS from the individual hospitals in a standardized electronic form, by dedicated infection prevention staff not involved in treatment of the patients. The information collected includes hospital affiliation, patient characteristics, duration of surgery, ASA-score, antibiotic prophylaxis, date of admission, surgery, discharge, first SSI, and last follow up, type of arthroplasty, type of SSI (superficial, deep, organ/space), reoperation for SSI and who reported the SSI diagnosis. All THA-patients are followed up 30 days postoperatively. The assessment of SSI was done at discharge and within 30 days postoperatively. Patients received a questionnaire post discharge that they returned, where it was stated if there were any sign of SSI. If no SSI occurred, the patient was censored at death or 30 days postoperatively. Hence SSI or reoperations for SSI beyond 30 days were not reported. All SSI reported were to be verified by the patient's general physician or an orthopaedic surgeon. The 30-days completeness of follow-up of THA in NOIS is 96%. From NOIS, all 87,923 primary THAs reported from the period 2013 to 2022 were included in the analyses.

The Norwegian Arthroplasty Register (NAR)

The NAR has since its establishment in 1987 collected data on primary and revision THAs with all subsequent reoperations. The data registered includes detailed information on patient and procedure characteristics, indication for THA, type of implant, method of fixation, and duration of surgery. If a subsequent reoperation is performed, a new registration will be created and linked to the primary THA by a unique identification number of each Norwegian inhabitant (12). Reporting is done on a form (electronically or on paper) by the surgeon immediately after surgery. The data from NAR is validated against the Norwegian Patient Register on an individual level, and the completeness of reporting was 97% for primary THAs, 93% for reoperations, 100% coverage of Norwegian hospitals, and 100% reporting of deaths (13).

Reported reoperation for PJI is based on the surgeon's pre- and intraoperative assessment. Later corrections of the diagnosis based on results on bacterial findings were not to be reported. The cause of the reoperation, if misdiagnosed, is therefore not later corrected. In addition, PJIs not reoperated are not to be reported. Hence, the risk of reoperation for PJI will not capture all PJIs, and some may be misdiagnosed.

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

Material and methods

Statistics

Number of primary THAs in NOIS and NAR were compared on a group level according to sex, age group (<45, 45-54, 55-64, 65-74, 75-84, >85 years) and ASA-class (1, 2, 3, 4 and missing) for estimation of concordance. The NOIS endpoints were 30-Days SSI and 30-Days reoperation for SSI. The NAR endpoints were 30-Days and 1-Year reoperation for PJI. Annual incidences of the four endpoints were presented with absolute numbers and graphically.

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

In addition, we investigated changes in the relative risk of SSI and reoperation for SSI or PJI 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 were presented with 95%CI. We used IBM SPSS 29.0 and R statistical software packages for analyses, and the study was performed in accordance with the RECORD statements 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 EU data protection rules. No conflict of interest is declared.

Results

In total, 87,923 THAs from NOIS and 91,194 THAs from NAR were assessed. 96.4% of the THAs in NAR were also in NOIS. The annual distribution of patient related risk factors such as sex, age and ASA-class were nearly identical in the NOIS and the NAR and stable throughout the study period (Table 1). 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 2). Therefore, NOIS and NAR may be considered representative for the same national THA population.

In NOIS, 1,393 (1.6 %) were reported with an SSI after THA, of which 765 (0.9 %) were reoperated for the SSI within 30 days (Table 3). In other words, only 55 % of SSI were reoperated within the 30-days follow-up.

In NAR, 725 (0.8 %) patients were reoperated for PJI within 30 days, and 1,019 (1.2 %) within one year after THA (Table 3). Hence, 71 % of PJIs occurring within the first postoperative year were reoperated during the first 30 days.

The completeness of 30-days reoperation for PJI in NAR compared to reoperation for SSI in NOIS was 95%. The annual number of THAs with subsequent SSI or reoperation for SSI in the NOIS, and subsequent 30-Day and 1-Year reoperation for PJI in NAR are presented in Table 3 and Figure 1.

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

Discussion

Main findings

We studied the temporal trends in SSI and PJI after THA from 2013 to 2022 in Norway by using two separate national health registers. The main finding was that both the 30-days incidence and risk of SSI and reoperation for SSI after THA, as well as the 30-days and 1-year risk of reoperation for PJI, have 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. Our findings are in line with other publications on SSI, but in contrast to studies on reoperations for PJI (3-10).

Several infection surveillance systems report a trend of decreasing rates of SSI after THA, including both superficial and deep infections (4-7). The ECDC reports a stable in-hospital incidence of SSI after THA since 2011, in slight contrast to what we found for the same period (16, 17). A review from 2015 reports increasing risk of SSI in several countries (18).

The SSI surveillance systems (NOIS) and the arthroplasty register (NAR) surveil infection after primary THA with different definitions (SSI and reoperation for PJI) and duration of observation. In addition, data capture, methodology and coverage differ. Similar differences in other studies, may partly explain 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 the specific set of diagnostic criteria and strict definition (1, 19). NOIS, only have 30 days surveillance of SSI after THA. SSI, or reoperation for SSI later than 30 days following index surgery, are not reported to NOIS and will be missed in the surveillance (20).

In NAR, the surgeon reports reoperation for PJI at any time after THA. PJI as cause of the reoperation 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 reoperations for PJI (71 %) were performed within 30 days following primary THA. The 29% of SSI reoperated later than 30 days after primary THA was a little higher than reported in a previous study from NOIS, reporting 14 % missed deep SSIs occurring later than 30 days (20). Superficial SSIs not reoperated are not reported to the NAR, and reoperations for SSI later than 30 days after THA are reported as reoperations for PJI to NAR but not NOIS. This demonstrates that the two registers contain complementary data.

It is debated whether superficial SSI exist or not in the immediate postoperative phase of a 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 (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). Because of this, there has been a trend towards considering the risk of PJI too high in cases of wound problems and superficial SSIs, so an early reoperation including thorough debridement, tissue sampling, and wound closure, has been advocated (21, 24, 25).

We found the most pronounced reduction in incidence and risk of SSI and reoperation for PJI in 2020 and 2021, which was the peak years of the Covid-19 pandemic. In this period the elective surgery 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 shortage of intensive care capacity, healthier patients were prioritized for elective primary THA unless urgent, with less SSIs and PJIs as a result. Fewer THAs were reported in the years of the pandemic, but we did not find a trend of less comorbidity (ASA-class) or lower age in patients undergoing primary THA in Norway in 2020-2021 in our study. Others report no change in rate 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 to guidelines of SSI protection protocols in healthcare settings, including surgical theaters, and possibly less SSIs with subsequent PJI and reoperations (29). In addition, healthcare providers may have been more diligent in following protocols to prevent infections (29). However, the findings of the pandemic's influence on SSI are conflicting (28, 30-32).

Register studies can provide a useful source of information on incidences and trends of both SSI and reoperations for PJI, due to large numbers and continuous observation. In NOIS we found a 96 % complete 30-days follow-up of the primary THAs reported, and only 2 % missing variables (ASA-class), which is considered an excellent completeness on a national level. However, the registrations were at hospital level, and primary THAs reoperated for SSI in a different hospital may have been missed in NOIS, if the patients' self-reporting form was not returned or validated by a doctor. Both infection protection staff and orthopedic surgeons validate the individual registrations of SSI in NOIS, but they normally only have access to the primary hospital. In contrast, if reported as reoperation for PJI to the NAR, reports from any hospital is linked to the primary THA. However, considering the 96 % completeness of follow up, this reporting bias is probably minor. The NAR had completeness of 97 % for primary THA, 92 % completeness for any reoperation, and 100 % coverage of Norwegian hospitals, compared to the Norwegian Patient Register (13). This is considered good, but NAR did not have the exact coverage estimation of reoperations for PJI only. The finding of 95% incidence of 30-days reoperation for PJI in NAR compared to reoperation for SSI in NOIS indicate that there is no major reporting bias for reoperation for PJI to NAR. This is in contrast to a recent Dutch study that only found 1/3 of the revisions for PJI reported to the Dutch Arthroplasty Register (LROI) compared to reoperations for SSI reported to the Dutch National Nosocomial Surveillance Network (PREZIES)(33).

Neither the SSI surveillance systems nor the arthroplasty registers fully encompass and register PJIs as defined by European Bone and Joint Infection Society (2). As mentioned, 1-year follow up, as recommended for implants in the ECDC manual, is not performed in NOIS, but the influence of this is considered minor(1, 20). NOIS is therefore limited by short period of observation, whereas NAR is susceptible to under-reporting or misdiagnosis by the surgeon or PJIs treated without reoperation not being reported (21). However, a recent validation study has shown an accuracy of 87% when PJI is reported to NAR as cause of the reoperation (21).

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

Register studies have, however, inherent limitations (34). Even if we adjusted for sex, age and ASA-class in the survival analyses, important factors associated with SSI and reoperation, there may be residual confounding. Such confounding factors may be changes over time in evaluation of SSI or PJI, reporting, reoperation threshold, diagnostics, surgeon awareness, prophylactic measures for infection, and the virulence and resistance of bacteria causing infection. These factors are not accounted for in the present study, but the finding of similar time trend for incidence and risk of both SSI and PJI, indicate that unknown confounding was minor.

Of the THAs reported to NAR during the study period, 96 % were also reported to NOIS. Not all private and public hospitals reported throughout the study period. In addition, one reason may be that reoperation after failed hip fracture surgery, where an osteosynthesis is converted to THA, may be reported as a revision THA, whereas it really is a primary THA. This may be due to misconception or be economically motivated. Such bias is automatically corrected in 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 why have we become better in avoiding PJI? Orthopedic surgeons and infection protection staff have worked meticulously with prophylactic measures the last decades, and new knowledge is acquired and evidence-based guidelines for prophylactic measures are established (35, 36). Improved understanding of how patients get infected, improved timing and change in antibiotic prophylaxis, advancements in surgical techniques, shorter surgical duration, as well as shorter length of hospital stay have probably 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 effectively implemented. However, educational infection protection programs 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 at strong focus in the study period and guidelines for antibiotic prophylaxis in arthroplasty and prevention of postoperative infections are established and compliance is surveilled (13, 40).

Conclusion

The incidence and risk of SSI (NOIS) and reoperation for PJI (NAR) has had a corresponding decline during the period 2013-2022. A 95% completeness of 30-days reoperation for PJI to the patient-consent based NAR, compared to the mandatory NOIS is considered good. Since unoperated SSIs are not to be reported to NAR, the registers are complementary. Our findings may reflect a true reduction in incidence of SSI and PJI after primary THA.

Conflict of interest statement

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Table 1. The annual distribution of patient specific factors in primary THA, in the NOIS and the NAR 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	<45yrs	3	3	3	3	3	3	3	3	2	2
	45-54	8	9	8	8	9	9	9	9	9	8
	55-64	22	22	22	22	23	23	22	21	22	22
	65-74	37	38	39	37	37	37	37	37	36	35
	75-84	25	23	24	24	23	23	24	25	25	28
	>85yrs	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	7,720	7,807	8,222	8,657	9,050	9,422	9,761	8,250	8,947	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	<45yrs	3	3	3	3	3	3	3	3	3	3
	45-54yrs	8	9	8	8	10	9	9	10	9	8
	55-64yrs	23	22	22	22	23	23	22	22	23	22
	65-74yrs	37	38	39	37	37	37	37	37	35	35
	75-84yrs	24	23	23	24	23	23	24	25	25	27
	>85yrs	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	8,103	8,137	8,448	8,954	9,176	9,610	10,044	8,726	9,514	10,482

Table 2. A summary of patient specific factors in primary THA, and coverage and completeness of reporting, in the NOIS and the NAR 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)
Agegroup	**<45 Years**	2,514	(3)	2,700	(3)
	45-54 Years	7,581	(9)	7,981	(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	4,152	(5)	4,279	(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	1,396	(2)	669	(1)
	Total	87,923		91,194	
Complete 30-day follow-up		96 %			
Completeness, primary				97 %	
Completeness, revision				92 %	

Table 3. Annual number of primary THAs, 30-days incidence of SSI and reoperation for SSI in NOIS, in addition to number of primary THAs, 30-days and 1-year incidence of reoperation for PJI in 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	7,720	178 (2.31)	87 (1.13)	8,103	75 (0.93)	102 (1,26)
2014	7,807	142 (1.82)	61 (0.78)	8,137	62 (0.76)	90 (1,11)
2015	8,222	169 (2.01)	92 (1.12)	8,448	71 (0.84)	107 (1.27)
2016	8,657	155 (1.79)	82 (0.95)	8,954	81 (0.90)	122 (1,36)
2017	9,050	155 (1.71)	86 (0.95)	9,176	76 (0.83)	125 (1.36)
2018	9,422	148 (1.57)	82 (0.87)	9,610	86 (0.89)	125 (1.30)
2019	9,761	139 (1.42)	78 (0.80)	10,044	81 (0.81)	117 (1.16)
2020	8,250	89 (1.08)	58 (0.70)	8,726	67 (0.67)	102 (1.17)
2021	8,947	89 (0.99)	59 (0.66)	9,514	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**	**1,393 (1.58)**	**765 (0.87)**	**91,194**	**725 (0.80)**	**1,019 (1.21)**

Figure 1. Annual 30-days incidence of SSI and reoperation for SSI in NOIS, in addition to 30-days and 1-year incidence of reoperation for PJI in NAR, for the period 2013-2022.

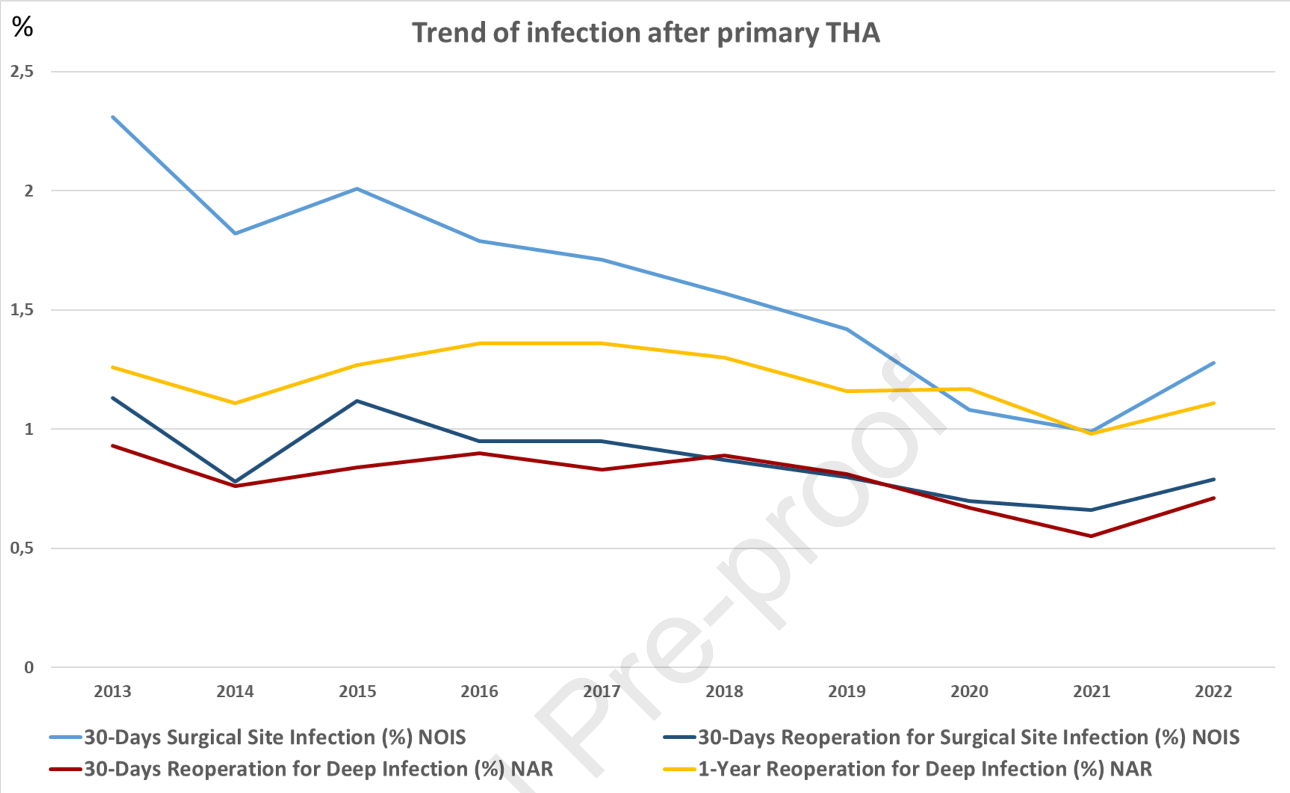
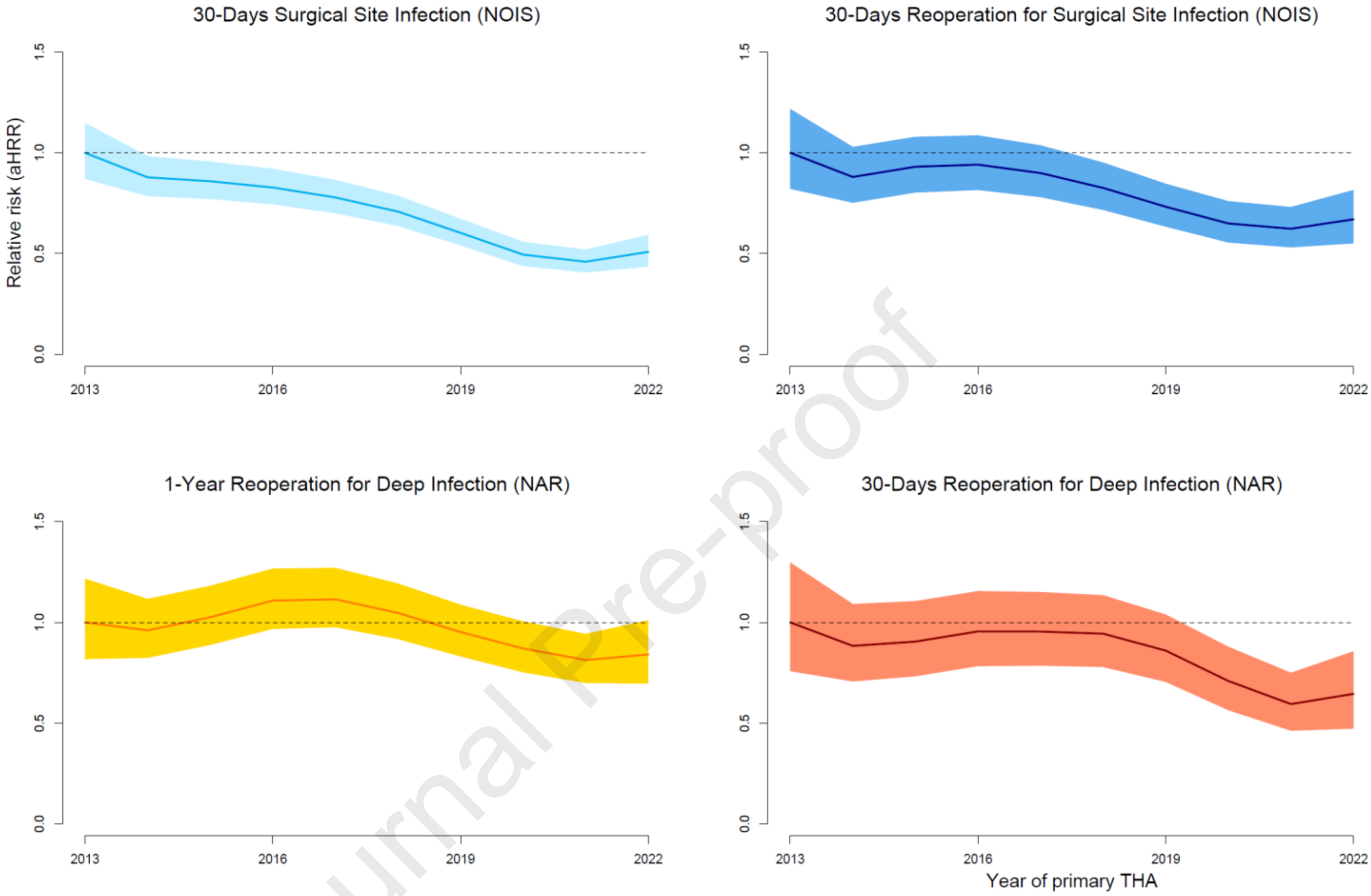


Figure 2. Annual risk (aHRR) of SSI within 30 days, reoperation for SSI within 30 days, in NOIS, and reoperation for PJI within 30 days one year in NAR, adjusted for sex, age, and ASA-class. The dotted lines represent the reference risk in 2013 (aHRR = 1)



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Norwegian Surgical Site Infection Surveilance System (NOIS)

		2013 (%)	2014 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)
Sex	Female	65	65	65	64	64	63	64	63	63	63
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Age group	<45yrs	3	3	3	3	3	3	3	3	2	2
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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	7,720	7,807	8,222	8,657	9,050	9,422	9,761	8,250	8,947	10,087

Norwegian Arthroplasty Register (NAR)

		2013 (%)	2014 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)
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	<45yrs	3	3	3	3	3	3	3	3	3	3
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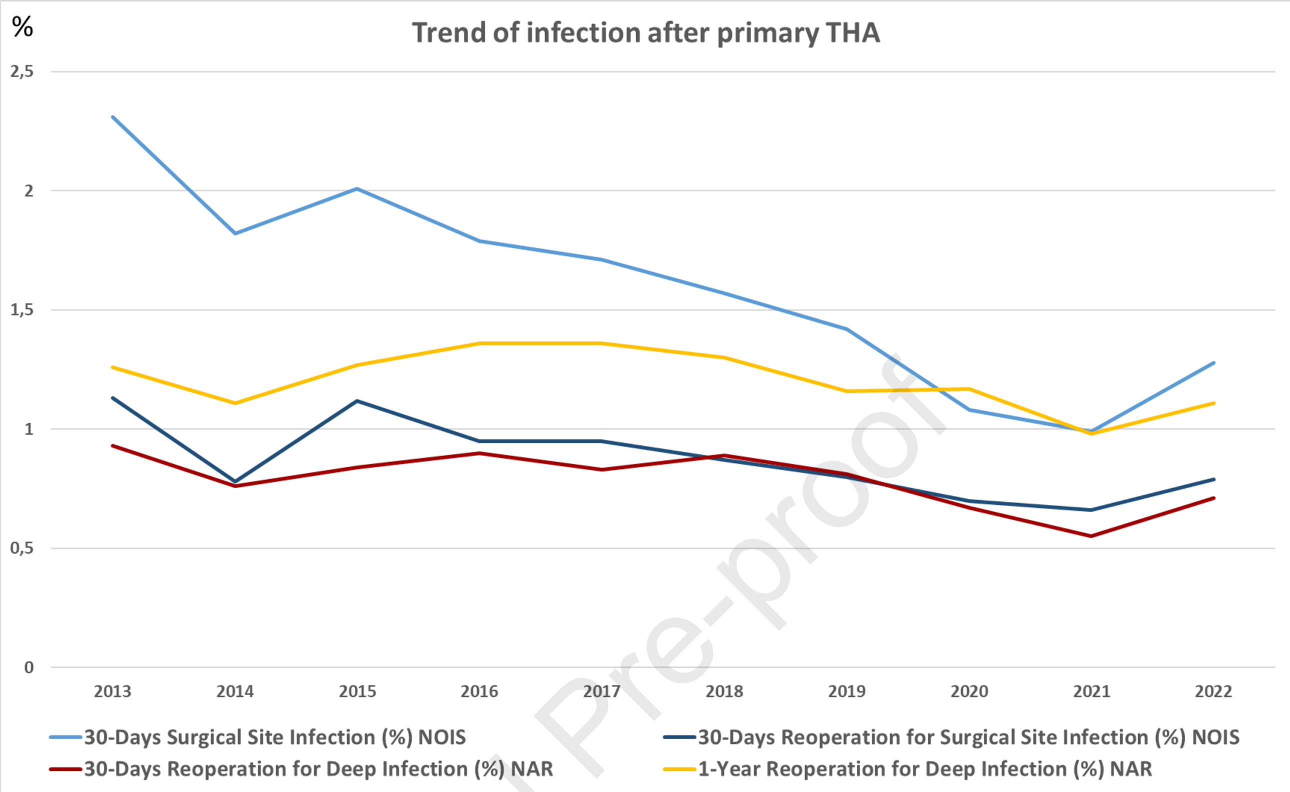

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