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Concise Communication

Surgical site infections following hip and knee arthroplastic surgery: Trends and risk factors of *Staphylococcus aureus* infections

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Abstract

We investigated surgical site infections (SSIs) following hip and knee arthroplasties to evaluate predictors of SSI. We found a significant increase in deep *Staphylococcus aureus* (SA) SSIs despite the decreasing overall SSI rate. The risk of deep SA-SSI differed between genders and among age groups and was affected by timing of surgery.

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Surveillance of surgical site infections (SSIs) has been conducted in the Finnish Hospital Infection Program (SIRO) since 1999. The long-term trend of SSI rates after hip arthroplasty (HPRO) and knee arthroplasty (KPRO) has been decreasing, but very recently, a slight increase has been observed in deep SSIs. In the national laboratory-based surveillance, the increase in invasive infections caused by methicillin-sensitive *Staphylococcus aureus* (MSSA) continues. To find targets for SSI prevention, we sought to determine whether *Staphylococcus aureus* (SA) is responsible for the recent increased rates of SSI, and we investigated patient, operation, and hospital predictors of SA-SSI.

Methods

Participation in SIRO surveillance is voluntary, and these results are handled confidentially.[1] Inpatient and postdischarge surveillance were performed by trained infection control nurses using the Center for Disease Control and Prevention definitions established in 1992.[2] We analyzed data on 157,082 HPROs and KPROs from 19 hospitals participating in prospective SIRO surveillance during 1999–2016. Participation increased from 3 hospitals in 1999 and 2000 to an average of 11 hospitals during 2001–2016. All 5 university hospitals participated, and 12 of 20 healthcare districts were represented. HPROs and KPROs included total or partial, primary or revision, and elective or fracture-related operations. We defined deep SSIs as either deep incisional or organ-space SSIs, and we defined deep SA-SSI as deep SSI when SA was the only causative agent.

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We used marginal logistic regression to model trends to identify independent predictors of deep SA-SSI. For adjustments, we chose subsets of patient, operation and hospital-related factors previously shown to be important risks for SSI: age, gender, American Society of Anesthesiologists (ASA) score, wound class, duration of operation, elective/emergency, time of operation, hospital-specific operation volume. We also used proportion of SSIs detected by postdischarge surveillance and those confirmed by culture.[3] Clustering of unknown hospital-specific factors was taken into account by using a robust standard error estimator. The Nordic Medico-Statistical Committee Classification of Surgical Procedures codes were used to group operation types: knee, hip total or partial, and primary or revision. For each analysis, a P-value $\leq .05$ was considered statistically significant. All analyses were performed using STATA version 15 statistical software (StataCorp, College Station, TX).

Results

Among all 87,261 HPROs, 14,515 (17%) were revisions, and 6,772 of 69,821 KPROs (10%) were revisions. Overall, 146,754 (93%) were elective operations. The average age of patients was 69.6 years (standard deviation, 11.4 years), and 100,245 (64%) were female. We identified 3,618 SSIs. Among them, 2,004 were superficial SSIs and 1,614 were deep SSIs. Also, 223 deep incisional SSIs occurred after HPROs and 149 deep incisional SSIs occurred after KPROs, whereas 744 organ-space SSIs occurred after HPROs and 498 organ-space SSIs occurred after KPROs. Of the 3,618 SSIs, 2,874 (79%) of the superficial SSIs and 1,424 (88%) of the deep SSIs were microbiologically confirmed. *Staphylococcus aureus* was the causative agent in 39% of deep SSIs (range by year, 12%–50%); 25 deep SSIs were methicillin-resistant SA (MRSA).

The annual SSI rate decreased significantly during 1999–2016 ($P < .001$ for adjusted trend), and the crude rate varied between

1.64% and 4.02% (Fig. 1). However, we detected a significant increasing trend in deep SSI rate ($P < .001$ for trend). The proportion of deep SA-SSIs increased annually by 9% (95% confidence interval [CI], 1.03–1.14). The trends were similar for both HPRO and KPRO, but the increase in the proportion of deep SA-SSIs was greater for HPRO (12% vs 5%).

In the multivariable analysis, independent factors significantly associated with increased risk of deep SA-SSIs included male gender, hip revision, operation during summer, ASA classification > 1 , and duration of operation > 120 minutes (Table 1). The effect of age differed between genders. The risk decreased with age among males, but no such effect was found among females. The risk factors were the same for HPRO and KPRO, except during the summer months (adjusted odds ratio [OR], 1.40; 95% CI, 1.05–1.87). Surgeries after 11 a.m. (adjusted OR, 1.39; 95% CI, 1.08–1.79) were associated with increased the risk in the HPRO group only, and the duration of operation (adjusted OR, 1.77; 95% CI, 1.39–2.26) was associated with increased the risk in the KPRO group only.

Discussion

Our study based on 17-year surveillance data of 157,082 orthopedic procedures showed that despite the decreasing trend of overall SSI rate, there were significant increases in the deep SSI rate and in deep infections caused by SA following HPRO and KPRO.

Our overall annual SSI rate decreased from 4.0% to 1.6%, and the trend was significant after adjustment by various patient, operation, and hospital-related factors. The similar decreasing trends of crude overall SSI rates in orthopedic surgery have also been observed in other national surveillance systems[4,5] and European surveillance.[6] In the ECDC 2016 annual report, the SSI rate after HPRO varied in different countries between 0.1% and 4.0% and after KPRO this rate varied between 0.1% and 1.4%. Deep SSI rates are rarely reported separately; the European figures are available in the ECDC Surveillance Atlas.[7]

We found a significant increase in deep SSI rates and deep SSIs caused by SA. Unlike us, our Swiss colleagues showed a decreasing incidence of SSIs due to SA during 2004–2014 despite the increase in invasive MSSA infections, which might have been related to their national prevention activities.[8] They did not differentiate deep and organ-space infections, and they included all types of surgery. *Staphylococcus aureus* was responsible for 39% of microbiologically confirmed deep SSIs. This finding is in line with that of a Spanish study in which SA accounted for 36% of deep SSIs, and 22% were MRSA.[9] We detected only 25 infections (0.7%) caused by MRSA.

The risk factors for SA-SSI we identified are mainly well known: male gender, high ASA score, long duration of operation, revision arthroplasties.[3] However, the risk of deep SA-SSI was higher among young males than older, and in HPROs performed after 11 a.m. Notably, emergency operation was not a risk factor, neither were partial HPROs, all of which are presumably fracture related. This finding suggests that all emergency operations might not be correctly coded and/or that there may be some patient-related risk factors or gaps in pre- or perioperative practices in certain patient groups, such as young men. Among factors not frequently studied, we found seasonality: summer months were a risk factor for deep SA-SSI in HPRO. Similar findings have been reported by Kane et al,[10] who speculated that the optimal condition during hot summer months might lead to increased bacterial population in the environment and on human skin.

Our study has several limitations. First, we did not have complete data on the use of perioperative antimicrobial prophylaxis, and we do not know whether nasal decolonization and/or preoperative bathing was in use or when it was implemented. Neither did we have data on body mass index, smoking, alcohol abuse, or underlying conditions (eg, fractures or diabetes mellitus). Second, the study period was long, and it is very likely that other changes occurred, for example in diagnostics of joint infections and postdischarge surveillance, which influenced our results. Realizing these possible biases, the proportion of culture confirmed SSIs and SSIs detected by postdischarge surveillance were included in our model.

In summary, our study demonstrates that the increased rates of deep SSIs could be hidden behind the overall SSI rates. HPRO and KPRO are rather heterogeneous procedure groups in terms of operation types (ie, elective or emergency, total or partial, and primary or revision), which should be considered when giving feedback to surgeons and ranking hospitals by SSI rates. These results suggest that pre- and perioperative practices of certain patient groups need further evaluation and that some groups may benefit from these efforts, such as those colonized with SA.

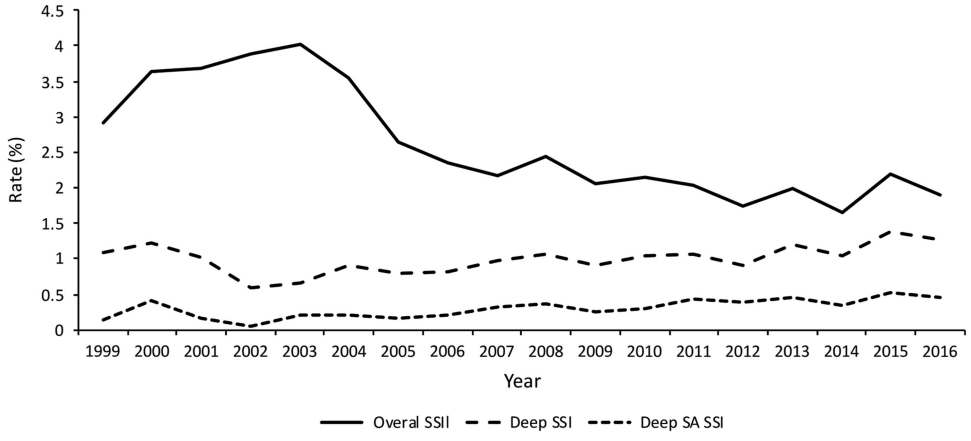

Fig. 1. Overall, deep and deep *Staphylococcus aureus* (SA) rate of surgical site infections (SSIs) following hip and knee arthroplasties, 19 Finnish hospitals during 1999–2016.

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Table 1. Multivariate Logistic Regression Model for Risk and Protective Factors of Deep *Staphylococcus aureus* Surgical Site Infections Following Hip and Knee Arthroplasties, 19 Hospitals in Finland During 1999–2016

Risk/Protective Factor Variable	Effect	Adjusted OR	95% CI		*P* Value
Gender	Male vs female	9.31	3.34	25.96	.000
Age in males	Increase of risk by 10 y	0.80	0.75	0.85	.000
Age in females	Increase of risk by 10 y	1.00	0.87	1.16	.900
ASA score	> 1 vs 1	2.59	1.56	4.30	.000
Type of operation	Emergency vs elective	1.15	0.64	2.06	.634
	Primary total hip vs primary partial hip	1.18	0.60	2.32	.634
	Revision hip vs primary partial hip	1.63	1.14	2.34	.008
	Primary knee vs primary partial hip	1.06	0.78	1.45	.703
	Revision knee vs primary partial hip	1.63	0.82	3.25	.161
Wound class	> 1 vs 1	0.82	0.44	1.54	.543
Duration of operation	> 120 min vs <120 min	1.43	1.14	1.79	.002
Time of operation	Operation before 11 a.m. vs after 11 a.m.	0.80	0.63	1.01	.061
Month of operation	Summer months (May, June, July, August) vs other months	1.32	1.04	1.69	.023

Note: OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists.

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