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Impact of the COVID-19 pandemic on the incidence of surgical site infection after orthopaedic surgery: an interrupted time series analysis of the nationwide surveillance database in Japan

T. Mimura [a,*], G. Matsumoto [b], T. Natori [b,c], S. Ikegami [a], M. Uehara [a], H. Oba [a], T. Hatakenaka [a], T. Kamanaka [a], Y. Miyaoka [a], D. Kurogochi [a], T. Fukuzawa [a], M. Koseki [d], S. Kanai [c], J. Takahashi [a]

[a] *Department of Orthopaedic Surgery, Shinshu University School of Medicine, Matsumoto, Japan*
[b] *Department of Laboratory Medicine, Shinshu University School of Medicine, Matsumoto, Japan*
[c] *Division of Infection Control, Shinshu University Hospital, Matsumoto, Japan*
[d] *Faculty of Textile Science and Technology, Shinshu University, Nagano, Japan*

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SUMMARY

Background: During the COVID-19 pandemic, hygiene awareness was increased in communities and hospitals. However, there is controversy regarding whether such circumstances affected the incidence of surgical site infections (SSIs) in the orthopaedic surgical field.
Aim: To examine the impact of the COVID-19 pandemic on the incidence of SSIs after orthopaedic surgery.
Methods: The medical records of patients having undergone orthopaedic surgery were extracted from the nationwide surveillance database in Japan. The primary outcomes were the monthly incidences of total SSIs, deep or organ/space SSIs, and SSIs due to meticillin-resistant *Staphylococcus aureus* (MRSA). Interrupted time series analysis was conducted between pre-pandemic (January 2017 to March 2020) and pandemic (April 2020 to June 2021) periods.
Results: A total of 309,341 operations were included. Interrupted time series analysis adjusted for seasonality showed no significant changes in the incidence of total SSIs (rate ratio 0.94 and 95% confidence interval 0.98–1.02), deep or organ/space SSIs (0.91, 0.72–1.15), or SSIs due to MRSA (1.07, 0.68–1.68) along with no remarkable slope changes in any parameter (1.00, 0.98–1.02; 1.00, 0.97–1.02; and 0.98, 0.93–1.03, respectively).
Conclusions: Awareness and measures against the COVID-19 pandemic did not markedly influence the incidence of total SSIs, deep or organ/space SSIs, or SSIs due to MRSA following orthopaedic surgery in Japan.

* Corresponding author. Address: Department of Orthopaedic Surgery, Shinshu University School of Medicine, Asahi 3-1-1, Matsumoto, Nagano, 390-8621, Japan. Tel.: +81 263 37 2659; fax: +81 263 35 8844.
E-mail address: tettim3@yahoo.co.jp (T. Mimura).

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Introduction

Postoperative surgical site infections (SSIs) are among the most common complications of surgery and can lead to increased medical costs, prolonged hospital stay, and even mortality [1]. There are numerous ways to reduce the rate of SSIs both peri- and intra-operatively, one of them being improved hand hygiene [2]. Widespread institutional guidelines promoting hand hygiene by hand washing or alcohol-based hand scrubs have been shown to decrease SSI rates in several surgical sub-specialties [3–5].

Other reports have described a reduction in meticillin-resistant *Staphylococcus aureus* (MRSA) infections through hand hygiene. MacDonald *et al.* found that institutional guidelines mandating the widespread use of alcohol hand scrubbing prior to any patient contact in a surgical ward were associated with a substantially lower incidence of SSIs due to MRSA versus previous years [6]. In South Korea, a three-year hand hygiene programme remarkably decreased MRSA bloodstream infections in a high-MRSA institute [7]. An alcohol/chlorhexidine hand hygiene programme in another hospital was effective in improving hand hygiene compliance and reducing nosocomial MRSA infections despite high MRSA endemicity as well [8].

During the recent COVID-19 pandemic, many health authorities introduced a nationwide total lockdown together with a bundle of hygienic measures. The Japanese version of the COVID-19 lockdown was less strict than those enforced elsewhere in that the stay-at-home mandate was voluntary. The Japanese government also asked people to avoid crowded areas, wear masks, and wash their hands, which was met with high compliance [9]. In hospitals, the COVID-19 pandemic led to intensified hygiene awareness and measures, with increased hand-scrubbing and the constant use of surgical masks and gloves.

With such an increased awareness of viral infections in communities and hospitals, we hypothesized a corresponding positive impact on the incidence of SSIs. Accordingly, this study aimed to identify how the situation of intensified hygiene awareness and precautions during the COVID-19 pandemic affected the rate of SSIs and SSIs due to MRSA.

Methods and patients

This study was approved by the institutional ethics review board of Shinshu University Hospital (No. 5363) and conducted in accordance with the ethical standards of the Declaration of Helsinki. This study followed Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Data source

Data on SSIs in patients who underwent orthopaedic surgery between 1st January 2017, and 30th June 2021, were extracted from the Japan Nosocomial Infection Surveillance (JANIS) database. JANIS recruits hospitals on a voluntary basis each year, whereby participating institutions are required to report SSI surveillance data for selected operative procedures electronically on a biannual basis [10]. As of January 2021, JANIS collects the SSI surveillance data from more than 600 institutions and is the largest SSI database in Japan. Recorded variables include age, American Society of Anaesthesiologists score, operation time, emergency, sex, use of implants, and wound class. Total SSIs detected during hospitalization, readmission, and post-discharge outpatient visits are also collected. For all SSI cases, the causative pathogen and specific site of infection are also recorded.

The Japanese government announced a state of emergency on 7th April 2020 to counter the COVID-19 pandemic. Accordingly, April 2020 was judged as the cut-off for the commencement of the pandemic, with operations divided into pre-pandemic (January 2017 to March 2020) and pandemic (April 2020 to June 2021) periods.

Outcome measures

The primary outcomes were the monthly incidences of total SSIs, deep or organ/space SSIs, and SSIs due to MRSA. According to internationally accepted conventions [11,12], SSIs were defined as infection within 30 days after the operative procedure for superficial incisional SSI, infection within 30 days after the operative procedure if no implant was left in place, and infection within one year if an implant was left in place for deep incisional or organ/space SSI. SSI due to MRSA was confirmed if MRSA was isolated as the causal SSI pathogen.

Statistical analysis

We first conducted a descriptive analysis of demographic and surgical data for the pre-pandemic and pandemic periods. Values are expressed as the median and interquartile range for continuous variables and the number and proportion for dichotomous variables.

Next, interrupted time series analysis using a segmented Poisson regression model was performed to identify the level and trend changes in the monthly rates of SSIs due to the pandemic, with consideration given to time dependence. We added the log-transformed total number of operations as an offset variable in analyses to convert SSI counts into rates and adjust for the total number of operation changes over time. As seasonal variation has been reported in SSI rates after orthopaedic surgery [13–15], this factor was taken into account by including harmonic terms (sines and cosines). Both the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) were calculated to compare the models. The validity of the models was assessed with correlograms (autocorrelation and partial autocorrelation functions) and residual plots. For all analyses, a P-value of <0.05 was considered significant. Statistical testing was performed using the statistical package R, version 4.2.1 (available at http://www.r-project.org).

Patient and public involvement

This research was performed without patient involvement. No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for recruitment, design, or implementation of the study. No patients were asked to advise on interpretation or writing up of results. There are no plans to disseminate the results of the research to study participants or the relevant patient community.

Results

A total of 309,341 operations were collected and divided into the pre-pandemic (226,166 operations) and pandemic (83,175 operations) groups (Table I). The demographic and surgical data were similar between groups. The all-time incidences of SSIs were 0.92% for total SSIs, 0.53% for deep or organ/space SSIs, and 0.15% for SSIs due to MRSA. These incidences were 0.96%, 0.55%, and 0.17% in the pre-pandemic group and 0.82%, 0.48%, and 0.12% in the pandemic group, respectively.

Figure 1 shows the observed monthly incidences of SSIs in the interrupted time series analysis. Table II presents the estimated level and trend changes for the monthly incidences of total SSIs, deep or organ/space SSIs, and SSIs due to MRSA. For total SSIs and deep or organ/space SSIs, the models adjusted for seasonality revealed AIC and BIC values less than the unadjusted models; thus, the adjusted models were considered optimal. For SSIs due to MRSA, however, there was a discrepancy between the AIC and BIC values regarding the superiority of model selection. Seasonality was observed as a peak in the summer season. The Poisson regression model adjusted for seasonality showed a significant monthly decrease independent from the pandemic for total SSIs (rate ratio (RR) 0.996 and 95% confidence interval (CI) 0.992–0.999) and SSIs due to MRSA (RR 0.989 and 95% CI 0.980–0.998, with no change for deep or organ/space SSIs (RR 0.999 and 95% CI 0.994–1.004). Both unadjusted and seasonally adjusted models indicated no significant level or trend changes in SSI incidence due to the pandemic.

Discussion

The main findings of this study using a nationwide surveillance database in Japan were as follows: (1) for the incidences of total SSIs and deep or organ/space SSIs, the analysis model adjusted for seasonality was more appropriate than the unadjusted model, with seasonality peaking in summer; (2) in Japan, the incidences of total SSIs and SSIs due to MRSA showed a decreasing trend regardless of the COVID-19 pandemic; and (3) interrupted time series analysis revealed that the COVID-19 pandemic had no demonstrable immediate impact on the

Table I
Patient characteristics

	Total (*N* = 309341)	Pre-pandemic (*N* = 226166)	Pandemic (*N* = 83175)
Age, years[a]	73.0 [63.0, 82.0]	74.0 [63.0, 82.0]	73.0 [63.0, 82.0]
Sex, *N* (%)			
Female	196,549 (63.5)	143,948 (63.6)	52,601 (63.2)
Male	112,792 (36.5)	82,218 (36.4)	30,574 (36.8)
Operation time, min[a]	93.0 [64.0, 137.0]	93.0 [64.0, 137.0]	94.0 [64.0, 137.0]
Operation, *N* (%)			
Fracture fixation	100,721 (32.6)	74,637 (33.0)	26,084 (31.4)
Hip prosthesis	68,191 (22.0)	49,159 (21.7)	19,032 (22.9)
Knee prosthesis	52,646 (17.0)	38,913 (17.0)	13,733 (16.5)
Laminectomy	38,718 (12.5)	27,910 (12.5)	10,808 (13.0)
Spinal fusion	46,333 (15.0)	33,469 (15.0)	12,864 (15.5)
Revision spinal fusion	647 (0.2)	491 (0.2)	156 (0.2)
Amputation	2085 (0.7)	1587 (0.7)	498 (0.6)
Wound class, *N* (%)			
I	300,817 (97.2)	220,231 (97.4)	80,586 (96.9)
II	4949 (1.6)	3125 (1.4)	1824 (2.2)
III	1952 (0.6)	1566 (0.7)	386 (0.5)
IV	1623 (0.5)	1244 (0.6)	379 (0.5)
ASA score, *N* (%)			
1	60,007 (19.4)	44,326 (19.6)	15,681 (18.9)
2	201,159 (65.0)	147,031 (65.0)	54,128 (65.1)
3	47,222 (15.3)	34,106 (15.1)	13,116 (15.8)
4	928 (0.3)	689 (0.3)	239 (0.3)
5	25 (0.0)	14 (0.0)	11 (0.0)
Emergency operation, *N* (%)			
Yes	27,016 (8.7)	19,446 (8.6)	7570 (9.1)
No	282,325 (91.3)	206,720 (91.4)	75,605 (90.9)
Implant use, *N* (%)			
Yes	262,420 (84.8)	192,400 (85.1)	70,020 (84.2)
No	46,921 (15.2)	33,766 (14.9)	13,155 (15.8)
Endoscopic surgery, *N* (%)			
Yes	5714 (1.8)	3969 (1.8)	1745 (2.1)
No	303,627 (98.2)	222,197 (98.2)	81,430 (97.9)

ASA, American Society of Anaesthesiologists.
[a] Values that are the median [first quartile, third quartile].

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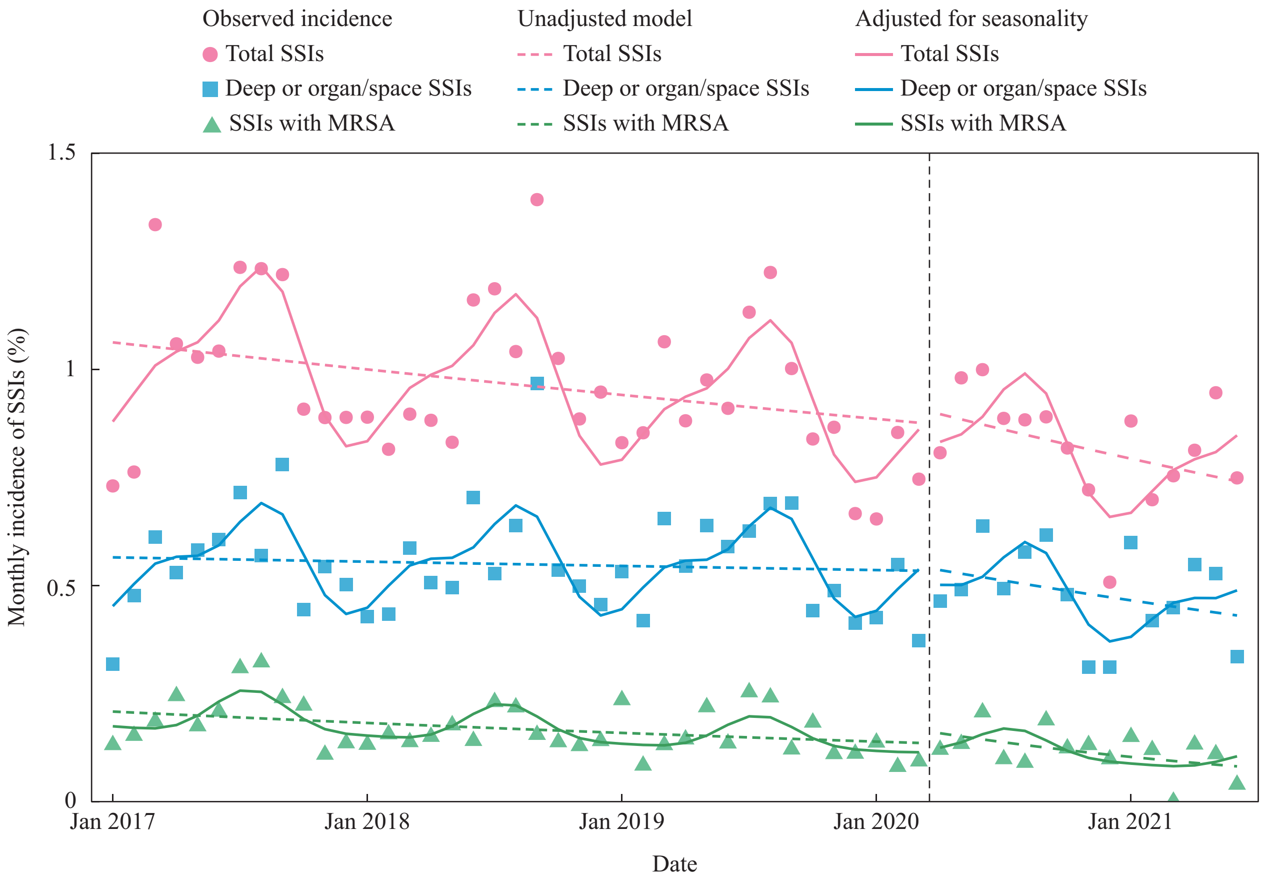

Figure 1. Trends in the monthly incidences of surgical site infections (SSIs). The vertical dotted line indicates the identified commencement of the COVID-19 pandemic (April 2020). MRSA, meticillin-resistant *Staphylococcus aureus*.

monthly incidences of total SSIs, deep or organ/space SSIs, or SSIs due to MRSA following orthopaedic surgery.

Several single-centre studies have reported reductions in SSIs during the pandemic. Losurdo *et al.* found in a general surgery cohort that SSI risk was significantly lower during the lockdown [16]. Similarly, an investigation in the field of cardiac surgery showed significantly lower rates of sternal wound infections in 493 patients receiving an operation during lockdown compared with patients with surgical intervention in the preceding 12 months [17]. A cohort analysis in India also revealed that the COVID-19 pandemic led to a 23% decreased risk for SSIs in major oncologic resections [18]. The above reports attributed the positive effects to such improved hygiene measures as hand washing, mask wearing and decreased physical patient contact. In contrast, other research groups found comparable SSI risk levels before and during the COVID-19 pandemic, which was similar to our findings. In a single-centre study in Switzerland, the risk of SSIs in orthopaedic surgery was not influenced by the extended public health measures in the total COVID-19 lockdown [19]. In an

Table II
Results of interrupted time series analysis of the impact of COVID-19 on the incidence of surgical site infections (SSIs)

	Level change		Slope change		AIC	BIC
	Rate ratio (95% CI)	*P*	Rate ratio (95% CI)	*P*		
Total SSIs						
Unadjusted Poisson regression	1.04 (0.87–1.24)	0.68	0.99 (0.97–1.01)	0.36	399.6	407.6
Poisson regression adjusted for seasonality	0.94 (0.98–1.02)	0.47	1.00 (0.98–1.02)	0.97	366.3	382.2
Deep or organ/space SSIs						
Unadjusted Poisson regression	1.02 (0.81–1.28)	0.87	0.99 (0.96–1.01)	0.24	364.1	372.1
Poisson regression adjusted for seasonality	0.91 (0.72–1.15)	0.42	1.00 (0.97–1.02)	0.71	341.6	357.5
SSIs with MRSA						
Unadjusted Poisson regression	1.22 (0.79–1.90)	0.37	0.97 (0.92–1.01)	0.14	276.1	284.0
Poisson regression adjusted for seasonality	1.07 (0.68–1.68)	0.77	0.98 (0.93–1.03)	0.38	269.6	285.5

AIC, Akaike information criterion; BIC, Bayesian information criterion; CI, confidence interval; MRSA, meticillin-resistant *Staphylococcus aureus*.

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American multi-centre retrospective cohort of 14,844 patients, there were no remarkable changes in the rates of periprosthetic joint infections or superficial SSIs in patients undergoing primary total joint arthroplasty between pre-COVID-19 pandemic and COVID-19 pandemic cases [20].

The increased global awareness of hygiene during the COVID-19 pandemic may have theoretically led to a decrease in SSIs. The surveillance for healthcare epidemiology in Japan showed that the use of hand sanitizer at medical institutions increased by approximately 50% in 2020 compared with 2019 [21]. However, we observed no decreases in SSI rates in our cohort. This might be explained by several reasons. First, general peri-operative hygiene protocols for orthopaedic surgery in Japan have already been established, with the risk of SSIs reportedly 1–3% for elective clean surgery [22]. Bebko *et al.* witnessed that, in 709 patients undergoing elective orthopaedic surgery with hardware implantation, 17 patients (2.4%) developed an SSI [23]. Our cohort of a nationwide surveillance database in Japan revealed an all-time incidence of 0.92% for total SSIs. Although data are scarce [21], it is possible that perioperative hygiene awareness is already high in Japan, regardless of the pandemic. Therefore, the increases in hygiene awareness among the hospitals during the pandemic may not have translated to a significant impact on SSIs. Second, most SSIs are believed to be acquired during the surgery itself [24]; even if the pandemic improved awareness of hygiene in communities, its immediate effect on SSIs might have been limited.

There are conflicting reports on the impact of the pandemic on MRSA infections. A recent study of National Healthcare Safety Network data by Weiner-Lastinger *et al*. revealed that in the third and fourth quarters of 2020, there were increases in the infection rates of MRSA bacteraemia in American acute-care hospitals of 22.5% and 33.8%, respectively, compared with the same quarters in 2019 [25]. In an earlier report, increases in MRSA acquisition rates were detected during the Severe Acute Respiratory Syndrome outbreak in 2003 [26], which implicated the increased use of antimicrobials for pneumonia cases during the outbreak. In contrast, a report from Singapore indicated that MRSA acquisition rates in hospitals and central-line-associated-bloodstream infections declined significantly owing to aggressive infection prevention control measures to prevent healthcare-associated transmission of COVID-19 [27]. In the surveillance database of Japan, the number of patients and isolation rate for *Staphylococcus aureus* and MRSA in hospitals have both been trending downwards [28]. This drop possibly represented the results of more thorough infection control measures for hand hygiene and other contact prevention steps in hospitals because the number of patients with COVID-19 was increasing. Although it is presumed that decreases in the carriage rate of MRSA will lower SSIs due to MRSA, minor changes in MRSA detection rates may not have reflected an immediate significant impact on SSIs. Further study is needed to examine the long-term effects on SSIs due to MRSA.

The strengths of this study included a high number (309,341) of operations and prospective registry nationwide surveillance design. Although our results may not be directly comparable to those in other countries having different social conditions for pandemics, their generalizability is strengthened by the nationwide setting. This investigation also had several limitations, including the lack of continuous monitoring for other countermeasures, such as wearing a mask and restrictions of hospital visitations. Therefore, it was not possible to quantitatively assess the detailed changes in hygiene awareness. As we did not monitor antibiotic administration, there was a risk that changes in antimicrobial use due to the pandemic confounded the incidence of SSIs due to MRSA.

In conclusion, the COVID-19 pandemic did not influence the incidence of total SSIs, deep or organ/space SSIs, or SSIs due to MRSA following orthopaedic surgery in Japan. It appears that, at least in the field of orthopaedic surgery, the immediate effect of increased hygiene awareness and promotion in communities and hospitals on SSIs may have been limited.

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Conflict of interest statement

The authors declare no conflicts of interest associated with this manuscript.

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