



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: [www.ajicjournal.org](http://www.ajicjournal.org)

## Major Article

## Surgical site infections during the COVID-19 era: A retrospective, multicenter analysis

Bradford B. Smith MD<sup>a,\*</sup>, Wendelyn Bosch MD<sup>b</sup>, John C. O'Horo MD, MPH<sup>c,d</sup>, Marlene E. Girardo MS<sup>e</sup>, Patrick B. Bolton MD<sup>a</sup>, Andrew W. Murray MD<sup>a</sup>, Ingrid L. Hirte BS<sup>f</sup>, Kai Singbartl MD, MPH<sup>g</sup>, David P. Martin MD, PhD<sup>h</sup><sup>a</sup> Department of Anesthesiology and Perioperative Medicine, Mayo Clinic, Phoenix, AZ<sup>b</sup> Division of Infectious Diseases, Mayo Clinic, Jacksonville, FL<sup>c</sup> Division of Public Health, Infectious Diseases and Occupational Medicine, Mayo Clinic, MN<sup>d</sup> Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, MN<sup>e</sup> Department of Quantitative Health Sciences, Mayo Clinic, Phoenix, AZ<sup>f</sup> Mayo Clinic Alix School of Medicine, Scottsdale, AZ<sup>g</sup> Division of Critical Care Medicine, Mayo Clinic, Phoenix, AZ<sup>h</sup> Department of Anesthesiology and Perioperative Medicine, Mayo Clinic, Rochester, MN

## Key Words:

SARS-CoV-2

Healthcare-associated infections

National healthcare safety network

Perioperative

**Background:** Surgical site infections (SSIs) are an undesired perioperative outcome. Recent studies have shown increases in hospital acquired infections during the coronavirus disease 2019 (COVID-19) pandemic. The objective of this study was to evaluate postoperative SSIs in the COVID-19-era compared to a historical cohort at a large, multicenter, academic institution.

**Methods:** A retrospective review of all patients who underwent National Health and Safety Network (NHSN) inpatient surgical procedures between January 1, 2018 and December 31, 2020. Patients from the COVID-19-era (March–December 2020) were compared and matched 1:1 with historical controls (2018/2019) utilizing the standardized infection ratio (SIR) to detect difference.

**Results/Discussion:** During the study period, 29,904 patients underwent NHSN procedures at our institution. When patients from the matched cohort (2018/2019) were compared to the COVID-19-era cohort (2020), a decreased risk of SSI was observed following colorectal surgery (RR = 0.94, 95% CI [0.65, 1.37],  $P = .76$ ), hysterectomy (RR = 0.88, 95% CI [0.39, 1.99],  $P = .75$ ), and knee prosthesis surgery (RR = 0.95, 95% CI [0.52, 1.74],  $P = .88$ ), though not statistically significant. An increased risk of SSI was observed following hip prosthesis surgery (RR 1.09, 95% CI [0.68, 1.75],  $P = .72$ ), though not statistically significant.

**Conclusions:** The risk of SSI in patients who underwent NHSN inpatient surgical procedures in 2020 with perioperative COVID-19 precautions was not significantly different when compared to matched controls at our large, multicenter, academic institution.

© 2022 Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.

Health care associated infections (HAIs) are one of the most undesired adverse outcomes associated with perioperative surgical care. Surgical site infections (SSIs), the most frequent form of HAIs, are associated with significant morbidity, mortality, and patient dissatisfaction.<sup>1</sup> Largely considered preventable, SSIs pose significant financial burden on the health care system with an annual estimated cost

of \$3.5–10 billion in the United States alone.<sup>2</sup> Multiple risk factors have been identified for the development of SSIs following surgical procedures including facility related risk factors (inadequate operating room (OR) ventilation, increased OR traffic, insufficient sterilization of equipment) and intraoperative risk factors (improper aseptic technique, hand hygiene, and gloving).<sup>1</sup> Improved basic preventative measures by all perioperative providers, such as proper hand hygiene and improved environmental cleaning, have been suggested to reduce HAIs and SSIs.<sup>3,4</sup>

The coronavirus disease 2019 (COVID-19) pandemic has significantly altered the delivery of health care across the world. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus of

\* Address correspondence to Bradford B Smith, MD, Department of Anesthesiology and Perioperative Medicine, MAYO CLINIC ARIZONA, 5777 E Mayo Blvd, Phoenix, AZ 85054, United States.

E-mail address: [smith.bradford@mayo.edu](mailto:smith.bradford@mayo.edu) (B.B. Smith).

Conflicts of interest: None to report.

COVID-19 is transmissible by respiratory droplets, contaminated hands, and environmental surfaces.<sup>5-7</sup> In response, health care facilities worldwide implemented additional preventative hygiene measures to limit possible transmission to patients and providers. Initiatives at our institution, similar to other facilities, included continuous perioperative surgical mask wearing, emphasized hand hygiene, use of personal protective equipment (PPE: fitted N95 masks and/or respirators, face shields, gowns, gloves), social distancing, and enhanced environmental disinfection of perioperative areas to protect providers, patients, and employees.<sup>5,6,8</sup> These initiatives, often labeled as Perioperative COVID-19 Precautions, have resulted in a heightened awareness regarding perioperative infection prevention and basic hygienic behaviors.

The anesthesia provider is essential in the fight to reduce perioperative HAIs due to their frequent contact with the patient's airway, mucosa, skin, and bloodstream. Prior studies have shown that interventions such as hand hygiene monitoring, improved environmental cleaning, patient decontamination, and vascular care all reduce the risk of HAIs.<sup>3,8</sup> Preliminary, small, single-center studies have shown mixed results regarding the impact of COVID-19 infection protocols on the rate of SSIs compared to historical cohorts.<sup>9-13</sup> The objective of this study was to evaluate the risk of postoperative SSIs in the COVID-19-era compared to a historical cohort at a large, multicenter, academic institution for inpatient colorectal, hysterectomy, hip prosthesis, and knee prosthesis surgeries.

## METHODS

This study was approved by the institutional review board (IRB) at the Mayo Clinic and the requirement for written informed consent was waived for all patients who had previously granted permission to use their medical records for observational research (consistent with Minnesota Statute 144.295). This manuscript adheres to the applicable STROBE guidelines. The study cohort was identified through the Mayo Clinic Infection Prevention and Control (IPAC) database, an institutional database that records and reports SSI rates quarterly. The IPAC database contains a current list of SSIs for National Health and Safety Network (NHSN) inpatient procedures including colorectal surgery, abdominal hysterectomy, knee prosthesis, and hip prosthesis procedures. Patients who underwent the above NHSN surgical procedures and developed SSIs at reporting Mayo Clinic centers between January 1, 2018 and December 31, 2020 were identified and included in the study cohort. Reporting centers where SSI data for NHSN procedures was analyzed included Mayo Clinic sites in Phoenix, Arizona; Jacksonville, Florida; Rochester, Minnesota and Mayo Clinic Health Systems sites in Eau Claire, Wisconsin; La Crosse, Wisconsin; Mankato, Minnesota and Red Wing, Minnesota.

Universal perioperative COVID-19-precautions were implemented at our multicenter institution in March 2020 and included enhanced hand hygiene efforts, limiting operating room and general hospital traffic, health care provider and patient masking including the use of appropriate personal protective equipment (PPE) during aerosol generating procedures, and social distancing. All patients presenting for perioperative care were required to have a COVID-19 polymerase chain reaction (PCR) test within 48 hours of scheduled surgery. If positive for COVID-19 infection and the surgery was an elective procedure, the procedure was delayed at least 20 days. If a patient tested positive for COVID-19 infection or COVID-19 testing was unknown but the case was considered urgent/emergent, then appropriate COVID-19 operating room precautions were instituted. These included "modified droplet precautions" (masks, eye protection, gowns, and gloves) for routine care with the addition of a respirator (N95 or equivalent, for example, powered air-purifying respirator) for aerosol-generating procedures (AGPs) throughout the perioperative period; procedures were performed in a negative

pressure operating room with only required personnel present, a high efficiency particulate air (HEPA) viral filter was placed on the breathing circuit, a plastic drape covered the patient during emergence, and the patient was transported with a facemask to recover in a negative pressure isolation room. Only patients who underwent surgical procedures between March 1 and December 31, 2020 were included in the year 2020 or COVID-19-era patient cohort.

Demographic and perioperative data including age, American society of Anesthesiologists (ASA) physical status classification, body mass index, history of diabetes, wound classification, surgery type, risk adjustment,<sup>14</sup> procedure duration, description of SSI, surgical closure technique, time from procedure to SSI, signs and symptoms of infection, laboratory evidence of infection, radiographic evidence of infection, presence of abscess, presence of sinus tract, and mortality were collected and reviewed.

Mayo Clinic uses the NHSN surveillance definition for SSIs, which includes a 30-day surveillance period for hysterectomy and colorectal surgery and a 90-day surveillance period for hip prosthesis and knee prosthesis surgery. Health care acquired infections, including SSIs, are reported quarterly to NHSN, providing us with the risk adjusted standardized infection ratio (SIR) for each surgical procedure. The SIR is calculated by dividing the number of observed infections by the number of predicted infections. The SIR is calculated by NHSN only if the number of predicted HAIs is  $\geq 1$ . An SIR  $>1.0$  reveals more HAIs were observed than predicted, while an SIR  $<1.0$  indicates fewer HAIs were observed than predicted. A ratio of 0 signifies that no SSIs were reported during the respective study period.<sup>15</sup> We elected to use the 2015 baseline all SSI SIR model based on inpatient procedures, categorized as superficial, deep, and organ space SSIs identified on admission, readmission, and post-discharge surveillance. Superficial and deep incisional SSIs are limited to primary incisional SSIs only. Cases that meet the NHSN criteria for "Present At Time of Surgery" (PATOS), are excluded from both the numerator and denominator for SSI SIR calculation.

## Statistical analysis

Demographic and perioperative data were descriptively summarized using mean  $\pm$  SD or median for continuous variables and frequency percentages for categorical variables. Patient and procedural characteristics were compared by procedure year for all surgeries and within each surgery type. Kruskal-Wallis testing was used for continuous variables and  $\chi^2$  testing for categorical variables. Patients with surgeries completed in the year 2020 were then matched 1:1 based on age ( $\pm 6$  years), gender, and procedure type with patients who underwent similar surgical procedures in the year 2018 or 2019, to eliminate bias. A greedy algorithm was used to produce the most optimal matches. The NHSN provided SIR data was generated for each group (year 2020 and matched years 2018/2019). The SIR was also produced for each of the three years studied: 2018, 2019 and 2020. SIRs for year 2020 were compared against year 2018, 2019 and the matched groups (years 2018/2019). The SIRs were compared using the NHSN SAS macro %binom presented as relative ratios. Two-tailed tests were utilized with statistical significance inferred with a  $P$ -value  $\leq .05$ . All statistical analysis were performed using SAS version 9.4 (SAS Institute Inc.).

## RESULTS

During the study period, 29,904 patients underwent colorectal, hysterectomy, hip, and knee prosthesis procedures at our multicenter institution. Patient demographic and perioperative data are displayed in Table 1. Surgical site infections (SSIs) were identified in 258 patients following 2,231 colorectal surgeries, 46 patients following 1,192 hysterectomies, 132 patients following 3,414 hip prosthesis

**Table 1**  
Demographic and perioperative data

	Procedure year			Total (N = 29904)	P-value
	2018 (N = 10873)	2019 (N = 11494)	2020 (N = 7537)		
Age					.8648*
Mean (SD)	64.7 (13.52)	64.6 (13.32)	64.6 (13.69)	64.6 (13.49)	
Median	66.0	66.0	66.0	66.0	
Range	18.0, 103.0	18.0, 103.0	18.0, 103.0	18.0, 103.0	
ASA Classification, n (%)					<.0001 <sup>†</sup>
1	292 (2.7%)	351 (3.1%)	167 (2.2%)	810 (2.7%)	
2	5314 (48.9%)	5693 (49.5%)	3555 (47.2%)	14562 (48.7%)	
3	4927 (45.3%)	5035 (43.8%)	3520 (46.7%)	13482 (45.1%)	
4	320 (2.9%)	396 (3.4%)	278 (3.7%)	994 (3.3%)	
5	20 (0.2%)	19 (0.2%)	17 (0.2%)	56 (0.2%)	
Emergency Procedure, n (%)					<.0001 <sup>†</sup>
No	10651 (98.0%)	11160 (97.1%)	7256 (96.3%)	29067 (97.2%)	
Yes	222 (2.0%)	334 (2.9%)	281 (3.7%)	837 (2.8%)	
BMI (kg/m <sup>2</sup> )					<.0001*
Mean (SD)	30.5 (6.88)	30.8 (6.92)	30.1 (6.93)	30.5 (6.91)	
Median	29.8	30.0	29.4	29.8	
Range	12.6, 59.3	13.0, 59.5	14.4, 59.8	12.6, 59.8	
Diabetes Mellitus, n (%)					<.0001 <sup>†</sup>
No	10112 (93.0%)	11205 (97.5%)	7255 (96.3%)	28572 (95.5%)	
Yes	761 (7.0%)	289 (2.5%)	282 (3.7%)	1332 (4.5%)	
Wound Class, n (%)					<.0001 <sup>†</sup>
Clean	7341 (67.5%)	7882 (68.6%)	4929 (65.4%)	20152 (67.4%)	
Clean-contaminated	2801 (25.8%)	2684 (23.4%)	1732 (23.0%)	7217 (24.1%)	
Contaminated	316 (2.9%)	480 (4.2%)	485 (6.4%)	1281 (4.3%)	
Dirty	415 (3.8%)	448 (3.9%)	391 (5.2%)	1254 (4.2%)	
Risk Adjustment Factors, n (%)					<.0001 <sup>†</sup>
0	3449 (32.1%)	3778 (33.3%)	2236 (30.1%)	9463 (32.1%)	
1	4855 (45.2%)	5021 (44.3%)	3256 (43.8%)	13132 (44.5%)	
2	2231 (20.8%)	2245 (19.8%)	1655 (22.3%)	6131 (20.8%)	
3	198 (1.8%)	297 (2.6%)	286 (3.8%)	781 (2.6%)	
Missing	140	153	104	397	
Type of HPRO/KPRO procedure, n (%)					<.0001 <sup>†</sup>
Hemi	790 (10.6%)	851 (10.6%)	673 (13.4%)	2314 (11.3%)	
Total	6660 (89.4%)	7158 (89.4%)	4364 (86.6%)	18182 (88.7%)	
Missing	3423	3485	2500	9408	
Type of Hemi HPRO/KPRO, n (%)					.9595 <sup>†</sup>
Partial Primary	412 (52.2%)	442 (51.9%)	353 (52.5%)	1207 (52.2%)	
Partial Revision	376 (47.6%)	406 (47.7%)	319 (47.4%)	1101 (47.6%)	
Total Revision	2 (0.3%)	3 (0.4%)	1 (0.1%)	6 (0.3%)	
Missing	10083	10643	6864	27590	
Type of Total HPRO/KPRO, n (%)					<.0001 <sup>†</sup>
Partial Revision	36 (0.5%)	11 (0.2%)	0 (0.0%)	47 (0.3%)	
Total Primary	6097 (91.5%)	6490 (90.7%)	3963 (90.8%)	16550 (91.0%)	
Total Revision	527 (7.9%)	657 (9.2%)	401 (9.2%)	1585 (8.7%)	
Missing	4213	4336	3173	11722	
Surgical Site Infections					
Colorectal	107	94	57	258	
Hysterectomy	14	20	12	46	
HPRO	39	57	36	132	
KPRO	39	42	22	103	

\*Chi-Square P-value

<sup>†</sup>Kruskal-Wallis P-value. Am J Infect Control. 2009 Dec;37(10):783-805. Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; HPRO, hip prosthesis and related operations; KPRO, knee prosthesis and related operations, N/n, number; SD, standard deviation

procedures, and in 103 patients following 4,036 knee prosthesis procedures (Table 1). Demographic and perioperative data for patients who developed SSIs following colorectal surgery, hysterectomy, hip prosthesis surgery, and knee prosthesis surgery are displayed in Supplemental Table 1. A significant difference in the rate of emergency procedures by year was observed amongst the entire patient cohort (2.0% in 2018, 2.9% in 2019, and 3.7% in 2020,  $P < .0001$ ) (Table 1) but no difference was observed when comparing the rate of emergency procedures by specific procedure type (Supplemental Table 1). A significant difference in the type of SSI (deep incisional primary vs organ-space infection vs superficial incisional) was observed in patients who underwent hip prosthesis surgery ( $P = .04$ ), but no difference was observed for the remaining surgical procedures (Supplemental Table 1). Following 1:1 patient matching, demographic and

perioperative data were compared amongst 112 colorectal surgery patients, 24 hysterectomy patients, 70 hip prosthesis surgery patients, and 44 knee prosthesis surgery patients (Supplemental Table 2). In hip prosthesis surgery patients, a significant difference in the type of SSI (deep incisional primary vs. organ-space infection vs. superficial incisional;  $P = .03$ ) was observed between matched groups but no other significant differences were observed between groups (Supplemental Table 2).

A relative ratio (RR) comparing the SIR from the years 2018 of 2020 and 2019 of 2020 is outlined in Table 2. In patients that underwent colorectal surgery, a significant decrease in the risk of SSI was observed when comparing 2018 vs. 2020 (RR = 0.58, 95% CI [0.42, 0.79],  $P < .001$ ) and 2019 vs 2020 (RR 0.71, 95% CI [0.50, 0.98],  $P = .04$ ) (Table 2). A non-significant, decreased risk of SSI was also observed

**Table 2**  
Standardized infection ratio comparison of 2018, 2019, and COVID-era group (2020) by procedure type

Surgery	2018 vs 2020		
	Ratio*	95% CI	P-value
Colorectal Surgery	0.576	(0.415, 0.794)	.0007
Hysterectomy	1.302	(0.588, 2.846)	.5055
Hip Prosthesis and Related Operations	1.297	(0.818, 2.052)	.2660
Knee Prosthesis and Related Operations	0.824	(0.481, 1.382)	.4719
Surgery	2019 vs 2020		
	Ratio*	95% CI	P-value
Colorectal Surgery	0.706	(0.504, 0.980)	.0375
Hysterectomy	0.910	(0.431, 1.855)	.8081
Hip Prosthesis and Related Operations	0.959	(0.624, 1.456)	.8504
Knee Prosthesis and Related Operations	0.844	(0.496, 1.406)	.5270

\*Relative ratio comparing the Standardized Infection Ratio (SIR) between the control groups (2018 or 2019) and COVID-era group (2020).

following hysterectomy in 2019 vs 2020 (RR = 0.91, 95% CI [0.43, 1.86],  $P = .81$ ), hip prosthesis surgery in 2019 vs 2020 (RR 0.96, 95% CI [0.62, 1.46],  $P = .85$ ), knee prosthesis surgery in 2018 vs 2020 (RR = 0.82, 95% CI [0.48, 1.38],  $P = .47$ ), and knee prosthesis surgery in 2019 vs 2020 (RR = 0.84, 95% CI [0.50, 1.41],  $P = .53$ ) (Table 2). A non-significant increase in the risk of SSI was observed when comparing 2018 vs 2020 following hysterectomy (RR = 1.30, 95% CI [0.59, 2.85],  $P = .51$ ) and hip prosthesis surgery (RR = 1.30, 95% CI [0.82, 2.05],  $P = .27$ ) (Table 2).

When patients from the matched cohort (2018/2019) were compared to the COVID-19-era cohort (2020), a decreased risk of SSI was observed following colorectal surgery (RR = 0.94, 95% CI [0.65, 1.37],  $P = .76$ ), hysterectomy (RR=0.88, 95% CI [0.39, 1.99],  $P = .75$ ), and knee prosthesis surgery (RR = 0.95, 95% CI [0.52, 1.74],  $P = .88$ ) but failed to meet statistical significance (Table 3). An increased risk of SSI was observed following hip prosthesis surgery (RR 1.09, 95% CI [0.68, 1.75],  $P = .72$ ) (Table 3).

## DISCUSSION

The COVID-19 pandemic has significantly altered the delivery of health care across the world including implementation of infection prevention protocols in the perioperative environment. Surgical site infections, one of the most common complications following surgical procedures, result in increased morbidity and mortality, sepsis, readmission, and extended postoperative hospital stay with negative economic impact on the health care system.<sup>16,17</sup> The main findings of this study show that the risk of SSI in patients who underwent NHSN inpatient surgical procedures in 2020 with perioperative COVID-19 precautions was not significantly different when compared to matched controls from 2018 and 2019 at our large, multicenter, academic institution.

**Table 3**  
Standardized infection ratio comparison of matched group (2018/2019) vs COVID-era group (2020) by procedure type

Surgery	Matched 2018/2019 vs 2020		
	Ratio*	95% CI	P-value
Colorectal Surgery	0.943	(0.650, 1.369)	.7579
Hysterectomy	0.875	(0.386, 1.986)	.7465
Hip Prosthesis and Related Operations	1.090	(0.680, 1.748)	.7189
Knee Prosthesis and Related Operations	0.954	(0.524, 1.736)	.8771

\*Relative ratio comparing the Standardized Infection Ratio (SIR) between the control group (2018/2019) and COVID-era group (2020).

Since the onset of the pandemic in March 2020, implementation of Perioperative COVID-19 Precautions, including strict hand hygiene, gloving, use of PPE, distancing, and environmental disinfection have become standard practice.<sup>6,8</sup> Heightened awareness of perioperative viral transmission and increased adherence to Perioperative COVID-19 Precautions carried optimism that perioperative SSIs would be further reduced as a result. Retrospective, single-centered studies from Italy, the United Kingdom, Germany, and Greece reported statistically significant reductions in SSIs following general surgery, cardiac surgery, neurosurgery, and colorectal surgery, respectively.<sup>9-11,18</sup> These findings are significant given that many of the surgical procedures performed following the COVID-19 shutdown were urgent/emergent in nature, conferring higher risk, while minor, elective procedures at low-risk of SSI were less commonly performed. A retrospective, propensity score matched study from India evaluated the risk of SSI following elective major oncologic surgery and reported that “increased compliance with hand hygiene, near-universal mask usage, and social distancing during the COVID-19 pandemic possibly led to 23% decreased odds of SSI in major oncologic resections.” Subsequent retrospective studies from Switzerland, China, and the United States failed to show significant reductions in SSIs in the COVID-19-era following orthopedic and oculo-facial plastic surgery.<sup>12,13,19</sup>

In the current study, a significant decrease in the risk of SSI was observed following colorectal surgery when comparing 2018 vs 2020 and 2019 vs 2020 (Table 2). When COVID-19-era patients who underwent colorectal surgery were compared to matched controls, a decreased risk of SSI was observed, but failed to meet statistical significance (RR = 0.94, 95% CI [0.65, 1.37],  $P = .76$ ) (Table 3). No statistically significant difference in the risk of SSI was identified in patients who underwent hysterectomy, hip prosthesis, and knee prosthesis surgery in the COVID-19-era cohort when compared to matched controls who underwent similar procedures prior to the pandemic (Table 3). Important to the analysis of the findings herein and a major strength of the current study is an understanding of institutional surveillance and reporting of SSIs. We elected to review surgical procedures that Mayo Clinic IPAC performs routine SSI surveillance, defined by NHSN, across our multicenter institution. This database contains a current list of SSIs, including the SIR, provided to us by NHSN, which is an ideal risk adjusted and standardized SSI metric. To reduce the risk of confounding variables, we performed matching with a historical patient cohort which underwent similar procedures at our institution (Supplemental Table 2, Tables 2 and 3). We think this approach, utilizing SIR to define SSI and matched analysis, offers the most comprehensive review of SSIs during the COVID-19-era available in the literature.

Our results may be congruent with the findings of Unterfrauer et al, that medical centers and surgical procedures with low rates of SSIs pre-COVID-19 may not benefit from additional infection prevention measures of perioperative COVID-19 precautions to the extent seen in centers and surgical procedures with historically higher rates of SSIs.<sup>13</sup> While the aforementioned small, retrospective, single-centered studies provided hope that SSIs may be reduced early in the pandemic,<sup>9-11,18</sup> larger subsequent studies, including the findings herein, fail to demonstrate significant differences. Although counter-intuitive, we observed no robust or statistically significant changes in SSI despite unprecedented changes in surgical workflow and PPE use. We speculate that in centers with low rates of SSIs, modifiable environmental factors may offer minimal potential to further reduce SSI in the future. The data presented here may yield more subtle conclusions when combined in future meta-analysis with other large observational reports.

The findings of the current study come at a time of unparalleled challenges and strain to individual providers and the entire health care system imposed by the pandemic. Concern for a decline in health



care safety has been raised<sup>20</sup> given recent studies that show increases in HAIs during the pandemic, including: catheter-associated urinary tract infections, central-line associated blood stream infections, and methicillin-resistant *Staphylococcus aureus* bacteremia.<sup>21,22</sup> The authors agree with Fleisher et al.<sup>20</sup> that a renewed emphasis on rewarding a culture of safety that actively strives to support providers and promote resiliency and quality is necessary to achieve the level of care our patients deserve.

To evaluate compliance and promote a culture of infection prevention, perioperative hand hygiene compliance has been monitored for many years at our institution. A trained observer assesses the operating room environment and records compliance with hand hygiene performance. The rate of hand hygiene compliance is reported monthly, with results communicated to providers. The frequency and documentation of hand hygiene compliance has not been standardized at all centers in our institution. Furthermore, compliance with additional COVID-19 precautions at our institution was expected but not strictly monitored during the study period.

### Limitations

This study has limitations inherent to a large, retrospective cohort analysis including the potential for missing patient data and charting inaccuracies. Given that many centers within our institution are tertiary referral centers, patients often receive perioperative care at our institution and may receive postoperative follow-up elsewhere. Despite 29,904 patients included in the study cohort, the low incidence of SSIs made statistical analysis of the outcome of interest difficult due to limited statistical power. Furthermore, the results of this study should be interpreted in the context of the pre-described NHSN surgical procedures, the postoperative surveillance routinely performed by the Mayo Clinic IPAC to detect SSIs, and how the SSIs are reported. Thus, these findings may not be reproducible across other surgical procedures or other medical centers. Differences in the incidence of SSIs may be observed when alternative definitions, surveillance, and reporting of SSIs exist. Moreover, perioperative “COVID precautions” intended to protect health care workers from infection, were not specifically designed to reduce SSI. Furthermore, differences in relative risk of SSI observed in the data may reflect limited statistical power secondary to the low incidence of SSI in the study population.

### CONCLUSIONS

Surgical site infections pose significant burden to patients, perioperative providers, and the entire health care system. The main findings of this study show that the risk of SSI in patients who underwent NHSN inpatient surgical procedures in 2020 with perioperative COVID-19 precautions was not significantly different when compared to matched controls from 2018 and 2019 at our large, multicenter, academic institution.

### Acknowledgments

The authors acknowledge Vickie Miller M.S.N., R.N., CIC for her contributions in collecting data.

### SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.ajic.2022.09.022>.

### References

- Ban KA, Minei JP, Laronga C, et al. American college of surgeons and surgical infection society: surgical site infection guidelines, 2016 update. *J Am Coll Surg*. 2017;224:59–74.
- Anderson DJ, Podgorny K, Berrios-Torres SI, et al. Strategies to prevent surgical site infections in acute care hospitals: 2014 update. *Infect Control Hosp Epidemiol*. 2014;35:605–627.
- Loftus RW, Campos JH. The anaesthetists' role in perioperative infection control: what is the action plan? *Br J Anaesth*. 2019;123:531–534.
- Schweizer ML, Chiang HY, Septimus E, et al. Association of a bundled intervention with surgical site infections among patients undergoing cardiac, hip, or knee surgery. *JAMA*. 2015;313:2162–2171.
- Sampathkumar P, Beam E, Breeher LE, O'Horo JC. Precautions, utilization of personal protective equipment, and conservation strategies during the COVID-19 pandemic. *Mayo Clin Proc*. 2020;95(9S):S11–S13.
- Bowdle A, Munoz-Price LS. Preventing infection of patients and health care workers should be the new normal in the era of novel coronavirus epidemics. *Anesthesiology*. 2020;132:1292–1295.
- Ludwig S, Zarbock A. Coronaviruses and SARS-CoV-2: a brief overview. *Anesth Analg*. 2020;131:93–96.
- Dexter F, Parra MC, Brown JR, Loftus RW. Perioperative COVID-19 defense: an evidence-based approach for optimization of infection control and operating room management. *Anesth Analg*. 2020;131:37–42.
- Chacon-Quesada T, Rohde V, von der Brölie C. Less surgical site infections in neurosurgery during COVID-19 times-one potential benefit of the pandemic? *Neurosurg Rev*. 2021;44:3421–3425.
- Losurdo P, Paiano L, Samardzic N, et al. Impact of lockdown for SARS-CoV-2 (COVID-19) on surgical site infection rates: a monocentric observational cohort study. *Updates Surg*. 2020;72:1263–1271.
- Hussain A, Ike DI, Durand-Hill M, Ibrahim S, Roberts N. Sternal wound infections during the COVID-19 pandemic: an unexpected benefit. *Asian Cardiovasc Thorac Ann*. 2020;29:376–380.
- Liou V, Yoon M. Comparative incidence of periocular surgical site infections with increased surgical mask use during the COVID-19 pandemic. *Ocul Immunol Inflamm*. 2021;1–6.
- Unterfrauner I, Hruby LA, Jans P, Steinwender L, Farshad M, Uckay I. Impact of a total lockdown for pandemic SARS-CoV-2 (Covid-19) on deep surgical site infections and other complications after orthopedic surgery: a retrospective analysis. *Antimicrob Resist Infect Control*. 2021;10:112.
- Edwards JR, Peterson KD, Mu Y, et al. National Health care Safety Network (NHSN) report: data summary for 2006 through 2008, issued December 2009. *Am J Infect Control*. 2009;37:783–805.
- The NHSN Standardized Infection Ratio (SIR). Center for disease control and prevention. Accessed December 22, 2021. <https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/nhsn-sir-guide.pdf>.
- Panos G, Mulita F, Akinosoglou K, et al. Risk of surgical site infections after colorectal surgery and the most frequent pathogens isolated: a prospective single-centre observational study. *Med Glas (Zenica)*. 2021;18:438–443.
- Mulita F, Liolis E, Akinosoglou K, et al. Postoperative sepsis after colorectal surgery: a prospective single-center observational study and review of the literature. *Prz Gastroenterol*. 2022;17:47–51.
- Mulita F, Liolis E, Tchabashvili L, et al. 1630P The impact of the COVID-19 outbreak on surgical site infections in elective colorectal cancer surgery: one potential benefit of the pandemic? *Ann Oncol*. 2021;32:S1156.
- Zeng H, Li G, Weng J, et al. The strategies of perioperative management in orthopedic department during the pandemic of COVID-19. *J Orthop Surg Res*. 2020;15:474.
- Fleisher LA, Schreiber M, Cardo D, Srinivasan A. Health care safety during the pandemic and beyond - building a system that ensures resilience. *N Engl J Med*. 2022;386:609–611.
- Patel PR, Weiner-Lastinger LM, Dudeck MA, et al. Impact of COVID-19 pandemic on central-line-associated bloodstream infections during the early months of 2020, National Health care Safety Network. *Infect Control Hosp Epidemiol*. 2021;43:790–793.
- Baker MA, Sands KE, Huang SS, et al. The impact of COVID-19 on health care-associated infections. *Clin Infect Dis*. 2021;74:1748–1754.