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Surgical reorganization during the COVID-19 pandemic and impact on case-mix and surgical site infections: A multicenter cohort study in Italy

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ABSTRACT

Background: The coronavirus 2019 (COVID-19) pandemic led to major disruptions in surgical activity, particularly in the first year (2020). The objective of this study was to assess the impact of surgical reorganization on surgical outcomes in Northern Italy in 2020 and 2021.
Methods: A retrospective cohort study was conducted among 30 hospitals participating in the surveillance system for surgical site infections (SSIs). Abdominal surgery procedures performed between 2018 and 2021 were considered. Predicted SSI rates for 2020 and 2021 were estimated based on 2018–2019 data and compared with observed rates. Independent predictors for SSI were investigated using logistic regression, including procedure year.
Results: 7605 procedures were included. Significant differences in case-mix were found comparing the three time periods. Observed SSI rates among all patients in 2020 were significantly lower than expected based on 2018–2019 SSI rates (p 0.0465). Patients undergoing procedures other than cancer surgery in 2020 had significantly lower odds for SSI (odds ratio, OR 0.52, 95 % confidence interval, CI 0.3–0.89, p 0.018) and patients undergoing surgery in 2021 had significantly higher odds for SSI (OR 1.49, 95 % CI 1.07–2.09, p 0.019) compared to 2018–2019.
Conclusions: Enhanced infection prevention and control (IPC) measures could explain the reduced SSI risk during the first pandemic year. IPC practices should continue to be reinforced beyond the pandemic context.

1. Background

Surgical site infections (SSIs) are among the four most common type of healthcare-associated infections (HAIs) and are associated with increased morbidity and mortality [1]. SSIs have been associated with increased hospital stay and overall costs of treatment [2,3]. Several risk factors for the development of an SSI have been identified prior to, during, and following surgery, therefore integrated preventive measures are required. Improving basic infection and prevention control (IPC) measures at all perioperative stages, such as appropriate hand hygiene and sterilization practices, has proven to be an effective strategy to reduce SSIs and HAIs in general [4].

The pandemic caused by the severe acute coronavirus 2 (SARS-CoV-2) led to major disruptions in surgical activity [5,6]. During the first year (2020), in the region of Piedmont, in Northwestern Italy, scheduled cancer surgery and urgent/emergent procedures were mostly maintained, while other interventions were postponed, in line with national and international policies [7]. In 2021 there was a progressive but slow return to routine surgical activity.

The pandemic also led health care facilities to implement additional preventive measures (social distancing, increased hand hygiene, use of personal protective equipment, and environmental disinfection) to limit the transmission of SARS-CoV-2 to patients and health professionals; further, an increased awareness to communicable diseases in general and HAIs in particular was noted [8,9]. SSI rates during the pandemic have been previously investigated, with conflicting results. Some reports found a reduction in the incidence of infections [10–13], while others found no impact of the pandemic on SSI rates [14,15] or even increased

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rates [16].

In this context, the active surveillance system for SSIs (Sistema Nazionale Sorveglianza Infezioni del Sito Chirurgico [SNICh]) [17] in the region of Piedmont was maintained throughout the pandemic. All public and some private hospitals of the region participate in a national surveillance system [18,19], which applies a protocol based on European Centre for Disease Prevention and Control (ECDC) definitions and methods [20]. The objective of this study was to assess the impact of surgical reorganization on surgical outcomes in Piedmont in the first two pandemic years (2020–2021).

2. Methods

2.1. Study design

A retrospective cohort study was conducted among hospitals participating in the regional surveillance network. Compared to other procedure categories, SSI occur at a relatively higher rate following abdominal surgery procedures and are a relevant clinical issue for general surgeons [11,18]. Therefore, we focused our analysis on abdominal surgery. Procedures performed between January 1st, 2018, and December 31st, 2021, were considered. Cancer surgery procedures were identified based on International Classification of Diseases, Ninth Revision, Clinical Modification (ICD9-CM) codes [21].

2.2. Data collection

Data were obtained through SNICh, as previously described [18,19]. The national protocol [17] is based on the ECDC HAI-SSI network protocol and applies the same definitions for SSI [20]. Surveillance in each participant ward or hospital must be conducted continuously for at least six months each year, *i.e.* all patients admitted to participant wards within the considered time-frame are included. Data are collected prospectively with a 30-day follow-up period, and include demographic and clinical information, such as the occurrence of infection, and the state at discharge (alive or deceased during hospitalization). Indicators of patient severity (case-mix) are measured, including age, gender, American Society of Anesthesiologists physical status score, length of hospital stay (LOS), and operating time. Surveillance is continued post-discharge if the patient is discharged within 30 days, through postoperative visits in the same hospital or standardized telephone interviews.

2.3. Ethics

SNICh is a HAI surveillance and quality improvement program coordinated by public entities (National Centre for Disease Prevention and Control, Ministry of Health, Emilia-Romagna and Piedmont Regions) [17]. Therefore, the written consent of patients involved or any other authorization from Institutional Review Boards and/or the Data Protection Commissioner are not required. All collected data are anonymized and patients are provided with an information sheet to inform them about their participation in the surveillance program.

2.4. Statistical analysis

Descriptive statistics were used to summarize patient demographics and clinical characteristics. SSI rates among abdominal surgery procedures were assessed by year of participation in the surveillance program, comparing 2020 and 2021 data to pre-pandemic (2018–2019) data. Differences of distributions for categorical variables were investigated using Pearson Chi-squared tests, while continuous variables were evaluated using non-parametric Mann-Whitney-U test due to non-normal distribution at Shapiro-Wilk test.

Expected SSI rates for 2020 and 2021 were estimated based on pre-pandemic SSI rates (2018–2019) and compared with observed rates, using Mantel-Haenzel corrected chi-squared tests. Expected SSI rates were predicted by projecting pre-pandemic rates to 2020 and 2021 data, stratified by Infection Risk Index (IRI), using the methodology proposed by Verberk et al. [22]. Patients that did not complete the 30-day follow-up period were excluded from analyses.

Independent predictors for SSI were investigated using two logistic regression models, considering patients undergoing cancer surgery and other procedures. Analyses were stratified per procedure year, and known risk factors for SSI were also included [19]: age, gender, IRI, pre-operative hospital stay, procedure type (urgent vs. elective), surgical technique (open vs. minimally invasive). Statistical analyses were carried out using SPSS v.28.0.1 (SPSS Inc), setting statistical significance at two-tailed 0.05.

3. Results

Overall, 7997 abdominal surgery procedures, performed in 30 hospitals, were monitored between 2018 and 2021. After excluding records with missing data, 7605 procedures (95 %) were included in our analysis: 2487 in 2018, 2681 in 2019, 1001 in 2020 and 1436 in 2021. A flowchart of included/excluded procedures is presented in Fig. 1.

Table 1 summarizes patient characteristics, stratified according to year of surgical procedure. Several significant differences were found stratifying patients according to the three considered time-periods. Patients were respectively younger and older in 2020 and 2021 compared to the pre-pandemic period and were more often female in 2020. In 2020 there was a significant decrease in operating time, and a subsequent slight increase in 2021 compared to median 2018–2019 data. Patients in 2021 generally had a more severe clinical status, with a higher proportion of American Society of Anesthesiologists (ASA) scores ≥3 and of IRI scores ≥2. A slight decrease in overall hospital stay was observed during the first year of the pandemic. The proportion of cancer surgery patients was lower in 2020 compared to the pre-pandemic period and increased above pre-pandemic levels in 2021. Considering procedure characteristics, a higher proportion of urgent/emergent procedures were performed during 2020 and 2021 compared to 2018–2019. In 2020, the proportion of elective procedures among cancer surgery and other procedures was 78.14 % and 58.71 % respectively. In 2021, the proportion of elective procedures slightly decreased to 75.1 % among cancer surgery procedures and increased to 63.1 % among other

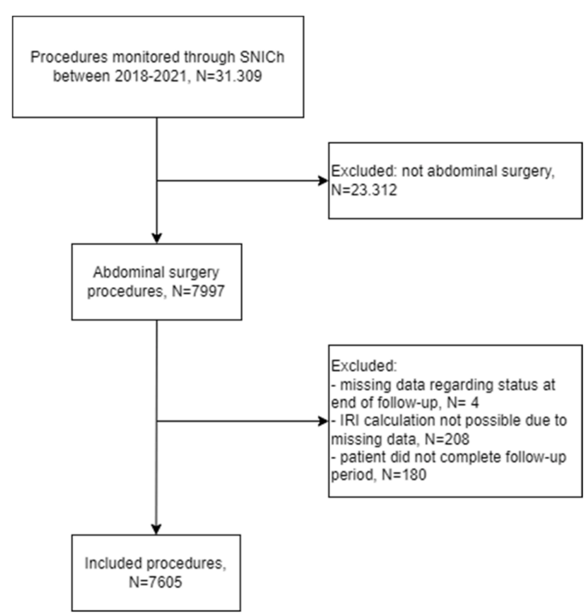

Fig. 1. Study flow chart.
IRI: infection risk index; SNICh: sorveglianza nazionale infezioni del sito chirurgico (Italian surveillance system for surgical site infections).

Table 1
Demographic and clinical characteristics of included patients undergoing abdominal surgery procedures, 2018–2021.

	All (N = 7605)	2018–2019 (N = 5168)	2020 (N = 1001)	2021 (N = 1436)	p-value *
Age, median (IQR)	69 (57–78)	69 (57–78)	66 (43–77)	71 (61–69)	<0.001
Male gender, n (%)	4089 (53.8)	2852 (55.2)	462 (46.2)	775 (54)	<0.001
ASA ≥3, n (%)	3218 (42.3)	2217 (42.9)	365 (36.5)	636 (44.3)	<0.001
Operating time in minutes, median (IQR)	155 (95–220)	160 (95–225)	130 (64–205)	165 (120–222)	<0.001
Infection risk index, n (%)					<0.001
0	2433 (32)	1715 (33.2)	332 (33.2)	386 (26.9)	
1	3277 (43.1)	2206 (42.7)	413 (41.3)	658 (45.8)	
2	1681 (22.1)	1114 (21.6)	228 (22.8)	339 (23.6)	
3	214 (2.8)	133 (2.6)	28 (2.8)	53 (3.7)	
Minimally invasive surgical procedures, n (%)	3387 (44.5)	2393 (46.3)	333 (33.3)	661 (46)	<0.001
Urgent/ emergent procedures, n (%)	1848 (24.3)	1068 (20.7)	335 (33.5)	445 (31)	<0.001
Pre-intervention hospital stay in days, median (IQR)	1 (0–1)	1 (0–1)	1 (0–1)	1 (0–1)	0.529
Overall hospital stay in days, median (IQR)	8 (5–13)	8 (5–13)	7 (5–12)	8 (6–13)	<0.001
Cancer surgery, n (%)	3351 (44.1)	2246 (43.5)	398 (39.8)	707 (49.2)	<0.001

* Differences among categorical and continuous variables investigated using Pearson Chi-squared and Mann-Whitney U tests respectively. ASA: American Society of Anesthesiologists physical status score; IQR: inter-quartile range.

procedures, compared to 2020. There was a significant drop in the proportion of minimally invasive procedures in 2020 compared to both 2018–2019 and 2021.

In total, 434 SSIs were registered during the study period, with a crude overall SSI rate of 5.71 %, and of 5.65 % (n = 292), 3.8 % (n = 38), and 7.24 % (n = 104) in 2018–2019, 2020, and 2021 respectively. The majority of SSIs occurred among cancer surgery patients (53.33 %, n = 176). Considering SSI type, 191 (57.88 %) were superficial, 70 (21.21 %) deep, and 66 (20 %) organ-space.

Observed and expected SSI rates (based on 2018–2019 SSI rates) per considered period are reported in Table 2. Considering all procedures, observed SSI rates in 2020 and 2021 were respectively 33.22 % lower and 22.92 % higher than expected, however only the difference between 2020 observed and expected rates reached statistical significance. Stratifying procedures according to indication, the same pattern emerged. The only statistically significant difference at sub-group analysis was found between observed and expected SSI rates in 2020 for procedures other than cancer surgery (−47.91 %), with the difference in 2021 (+46.44 %) almost reaching statistical significance for this subgroup.

Results of the logistic regression models conducted among cancer patients and other patients are provided in Tables 3 and 4, respectively. In both models, at multivariate analysis IRI ≥2 was significantly associated with higher odds for SSI compared to IRI <2, and minimally invasive technique was significantly associated with lower odds for SSI compared to open procedures. Older age was significantly associated with higher odds for SSI among patients undergoing non-cancer procedures. Concerning cancer patients, patients undergoing surgery in 2020 had lower odds for SSI and patients undergoing surgery in 2021 had higher odds for SSI compared to 2018–2019, however these results did not reach statistical significance (Table 3). Conversely, patients undergoing other procedures in 2020 had significantly lower odds for SSI and patients undergoing surgery in 2021 had significantly higher odds for SSI compared to 2018–2019 (Table 4).

4. Discussion

The COVID-19 pandemic caused severe disruptions in surgical

Table 3
Independent risk factors for surgical site infection (SSI) among cancer surgery patients (N = 3351).

	Univariate			Multivariate		
Predictor	OR	95 % CI	p	OR	95 % CI	p
Procedure year						
2020 *vs.* 2018–2019	0.84	0.53–1.32	0.446	0.78	0.5–1.23	0.287
2021 *vs.* 2018–2019	1.06	0.77–1.48	0.714	1.07	0.77–1.5	0.685
Age						
50–70 *vs.* <50	0.45	0.48–1.35	0.405	0.74	0.43–1.24	0.250
>70 *vs.* <50	0.71	0.47–1.29	0.327	0.65	0.39–1.1	0.107
Female vs. male gender	0.87	0.66–1.14	0.312	0.88	0.66–1.16	0.877
Urgent vs. elective procedure	1.25	0.9–1.74	0.189	0.93	0.63–1.36	0.701
Minimally invasive vs. open procedure	0.55	0.42–0.73	< .001	0.54	0.4–0.72	< .001
Pre-intervention LOS ≥1 day vs. <1 day	1.09	0.78–1.52	0.604	1.2	0.84–1.73	0.318
IRI ≥2 *vs.* <2	1.63	1.23–2.15	< .001	1.627	1.21–2.19	0.001

CI: confidence interval; IRI: infection risk index; LOS: length of stay; OR: odds ratio.

Table 2
Observed and predicted surgical site infection (SSI) rates among included procedures, overall and stratified according to indication, 2018–2021 (N = 7605).

	Observed SSI rate 2018–2019 (95 % CI)	Observed SSI rate 2020 (95 % CI)	Expected SSI rate 2020 (95 % CI)	p-value *	Observed SSI rate 2021 (95 % CI)	Expected SSI rate 2021 (95 % CI)	p-value*
All procedures	5.65 (5.04 - 6.31)	3.8 (2.7 – 5.17)	5.69 (4.37 – 7.31)	0.0465	7.24 (5.96 – 8.71)	5.89 (4.75 – 7.27)	0.153
Cancer surgery	6.81 (5.8 – 7.93)	5.78 (3.7 – 8.55)	6.96 (4.73 – 10.01)	0.47	7.21 (5.42 – 9.38)	6.79 (5.05 – 8.9)	0.755
Other indications	4.76 (4.01 – 5.59)	2.49 (1.4 – 4.07)	4.78 (3.24 – 6.83)	0.0315	7.41 (5.67 – 9.55)	5.06 (3.6 – 6.93)	0.066

* Difference between observed and expected rates, based on 2018–2019 observed SSI rates. CI: confidence interval.

Table 4
Independent risk factors for surgical site infection (SSI) among non-cancer surgery patients ($N = 4254$).

Predictor	Univariate			Multivariate		
	OR	95 % CI	p	OR	95 % CI	p
Procedure year						
2020 *vs.* 2018–2019	0.51	0.3–0.88	0.015	0.52	0.3–0.89	0.018
2021 *vs.* 2018–2019	1.60	1.16–2.22	0.005	1.49	1.07–2.09	0.019
Age						
50–70 *vs.* <50	1.96	1.29–2.98	0.002	1.73	1.11–2.7	0.015
>70 *vs.* <50	1.72	1.13–2.64	0.012	1.29	0.82–2.02	0.274
Female vs. male gender	0.92	0.69–1.21	0.549	1.04	0.78–1.39	0.806
Urgent vs. elective procedure	1.21	0.9–1.63	0.213	1	0.72–1.39	0.992
Minimally invasive vs. open procedure	0.66	0.49–0.9	0.007	0.62	0.45–0.86	0.004
Pre-intervention LOS ≥1 day vs. <1 day	1.02	0.76–1.36	0.902	1.04	0.77–1.41	0.809
IRI ≥2 *vs.* <2	2.08	1.55–2.78	< .001	1.97	1.44–2.71	< .001

CI: confidence interval; IRI: infection risk index; LOS: length of stay; OR: odds ratio.

activity worldwide, with an estimated 28.4 million cancelled elective operations [23]. By rationing and prioritizing surgical procedures, global policies and recommendations aimed primarily to rationalize health care resources - both in terms of preserving bed, intensive care, and operating room capacities, and of protecting healthcare workers from SARS-CoV-2 infection [24,25]. A further concern was the high rate of mortality and respiratory complications observed in patients infected with SARS-CoV-2 undergoing surgery [23]. Surgical activity was therefore limited to urgent/emergent procedures and cancer surgery, with a shift towards non-operative management [24,25]. As elective surgery resumes, health systems must consider the longer term impact of delayed procedures on surgical care and patient outcomes [24]. This study reports prospectively collected data from 30 hospitals in a region heavily affected by the COVID-19 pandemic [26], and provides insight on shifting surgical case-mix and SSI risk among patients undergoing surgery during the first two pandemic years.

According to results of this study, a reduction in surgical volume occurred in both pandemic years, from 0.33 procedures/center/day in 2018–2019 to 0.16 in 2020 (over 50 % reduction) and 0.18 in 2021 (12.5 % increase compared to 2020). In absolute terms, the reduction in surgical activity affected not only elective but also urgent/emergent procedures. This decrease in daily volume is in line with results of previous Spanish and American reports [27,28]. Shao *et al.* opined that the decrease in urgent/emergent surgery could be due to a shift towards non-operative management, to delays in surgical management, and to reduced access of patients to healthcare facilities caused by fear of contracting SARS-CoV-2 infection [27].

Concerning surgical case-mix, this study found significant decreases in both the proportion of patients with an ASA score ≥3 and operating time (which is considered a proxy for operative complexity) [27] in 2020, with a rebound effect in 2021. A significant progressive shift towards more severe IRI scores was also observed, which however did not interest cancer surgery procedures. These trends towards more advanced presentations could be a result of the rationing and delay of surgical activity, in particular concerning urgent/emergent procedures, as previously described [22,24,27].

Significant changes in surgical approach were also highlighted by our study. In particular, the proportion of minimally invasive procedures was reduced by 13 % in 2020 compared to pre-pandemic levels, supporting previous findings [25]. This could be partly explained by the parallel increase in the proportion of urgent/emergent procedures in 2020. Further, guidelines released by several international societies including the UK's Intercollegiate General Surgery Guidance (IGSG) and the Society of the American Gastrointestinal and Endoscopic Surgeons (SAGES) recommended avoiding laparoscopic procedures, when possible, due to fears of aerosolization of viral particles with high flow intraperitoneal gas escape and surgical smoke produced by electrosurgical devices, and the consequent risk for surgical staff [29,30]. Following the publication of several reviews indicating no evidence of increased viral transmission or infection linked to surgical smoke and laparoscopic pneumoperitoneum, updated recommendations no longer cautioned against minimally invasive surgery but were in favor of balancing risk-benefits on a case-by-case base and adopting additional protective strategies [31,32]. In our study, this was reflected by a return to pre-pandemic levels in the proportion of minimally invasive procedures in 2021. Other explanations for the lower proportion of minimally invasive procedures could include diversion of staff to pandemic response and patient-related factors for attrition, such as fear of contracting COVID-19 and fear of postoperative complications [33]. Interestingly, changes in surgical approach and in the proportion of urgent/elective procedures appear not to have affected LOS and operating time. In 2020, median overall hospital stay was reduced by one day compared to 2018–2019, which could reflect policies enacted to avoid patients acquiring perioperative SARS-CoV-2 infection.

This study found a slight decrease in the proportion of cancer surgery procedures in 2020 compared to the pre-pandemic period, and a subsequent increase in 2021 to levels higher than in 2018–2019. This trend could be due to the fear of operating vulnerable patients at high risk of SARS-CoV-2 infection, severe disease, and mortality [34]. A previous modelling study estimated that during the initial pandemic period, 2.3 million cancer surgery procedures were delayed due to the risk of perioperative SARS-CoV-2 transmission [5]. Surgeons faced the difficult task of balancing risks and benefits of surgery vs. non-operative management and potentially delaying procedures [24,35]. For cancer surgery in particular, previous accounts indicate elective surgery was maintained for patients with time-sensitive conditions or with resectable cancers at risk for progression [36]. Further, the initial delay in cancer surgery should also be considered in the broader context of rationalized healthcare services, with decreased cancer screening tests and diagnostic investigations, leading to a significant decline in the number of new cancer diagnoses [37]. Finally, treatment pathways for cancer patients require a complex and multidisciplinary approach, which could have proven challenging to maintain in the initial pandemic period [25]. The rebound observed during 2021 could be due to the broadening of surgical indications, but also to an increased incidence of new diagnoses due to the resumption of cancer screening and care services [37].

Considering all of these factors combined, a shift towards more severe presentations requiring increasingly complex surgery, in particular for indications other than cancer surgery, appears to have begun to take place in our region in 2021, and could be expected to continue to increase as health services resume [24,35]. Current backlogs contribute to surgeons' increased workloads, and could cause further delays. The delays in time-to-diagnosis and time-to-intervention could translate to poorer patient outcomes in the longer term [37].

Concerning SSI risk, this study found a significant reduction in observed 2020 rates compared to expected rates based on pre-pandemic data. Notably, this decrease occurred even though we recorded significant increases in both the proportion of urgent/emergent procedures and of open procedures, conferring higher risk for SSI [18,19]. Further, our estimates were standardized for IRI, therefore differences in case-mix are possibly not the only explanation for this decrease. At subgroup analysis, significance was maintained only for indications other than cancer surgery, which is interesting considering the higher proportion of urgent/emergent procedures in this subgroup. After adjusting for known risk factors for SSI, non-cancer procedures performed in 2020 were associated with significantly lower odds for infection of almost 50 % compared to procedures performed in 2018–2019. Other Authors have hypothesized a protective effect of enhanced IPC measures, increased IPC training, heightened awareness towards infection, shortened hospital stay, and restricted access to visitors [11,12,14,22,27,38]. As cancer patients are at increased risk of SSI due to clinical characteristics and treatments [39], it is possible that surgeons performing cancer surgery in our region already effectively implemented preventive measures prior to the pandemic, whereas other interventions had a greater margin for improvement in terms of adherence to IPC practices.

On the other hand, an increase in SSI rates was observed in 2021 compared to expected rates. In particular, being operated on in 2021 was identified as an independent risk factor for SSI among patients undergoing non-cancer procedures, which could indicate an effect of the delay in procedures. Even though IPC activities were not investigated in our study, other Authors have hypothesized a reduction in adherence to IPC standards due to the prolonged emergency situation could have occurred in the later stages of the pandemic, as well as difficulties in maintaining IPC activities due to the diversion of resources to pandemic management [22]. If this trend persists, other strategies should be considered to maintain the high levels of implementation and effectiveness of IPC practices achieved during the initial phases of the pandemic [16].

This study had several limitations that should be considered. First, there were limitations due to the retrospective, surveillance-based study design. SSI surveillance in our region must be performed continuously for a period of at least six months each year, however we cannot exclude that variations in surgical specialties and specific procedures during the pandemic could have not been accurately reflected in our database. We cannot exclude a certain degree of selection bias, also due to the number of procedures excluded from analysis due to missing data or follow-up information (Fig. 1). Also due to study design, causal relations between investigated factors cannot be inferred based on our results. Second, participant hospitals applied and maintained a standardized methodology for data collection prior to and throughout the pandemic, therefore no information was collected on the occurrence of perioperative SARS-CoV-2 infection or on changing implementation levels of IPC practices. Concerning statistical analyses, we approximated surgical reorganization by year and did not perform more in-depth analysis of time frames specific to each participant hospital. Several known risk factors for SSI were included in multivariable analysis, however other clinical characteristics, such as cancer stage, were not taken into account.

5. Conclusion

Despite these limitations, due to reporting requirements our data can be considered representative of surgical activity performed in acute-care hospitals in our region and provide some insight on how patient characteristics and outcomes were affected by shifting surgical priorities due to the pandemic. Importantly, SSIs are considered an indicator of care quality [40]. Regular analysis of SSI data can provide critical information to identify prevention gaps and opportunities for improvement. IPC practices should continue to be reinforced beyond the pandemic context, with the focus now shifting towards building resilient and sustainable programs [16].

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CRediT authorship contribution statement

Costanza Vicentini: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Elettra Ugliono:** Data curation, Methodology, Visualization. **Heba Safwat Mhmoued Abdo Elhadidy:** Data curation, Investigation, Writing – original draft. **Giovanni Paladini:** Investigation, Data curation. **Alessandro Roberto Cornio:** Investigation, Data curation. **Federico Cussotto:** Data curation, Investigation. **Mario Morino:** Supervision, Writing – review & editing. **Carla Maria Zotti:** Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

None.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.healthpol.2024.105113.

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