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ORIGINAL ARTICLE

Impact of lockdown for SARS-CoV-2 (COVID-19) on surgical site infection rates: a monocentric observational cohort study

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Abstract

Surgical site infections are the most common in-hospital acquired infections. The aim of this study and the primary endpoint is to evaluate how the measures to reduce the SARS-CoV-2 spreading affected the superficial and deep SSI rate. A total of 541 patients were included. Of those, 198 from March to April 2018, 220 from March till April 2019 and 123 in the COVID-19 era from March to April 2020. The primary endpoint occurred in 39 over 541 patients. In COVID-19 era, we reported a lower rate of global SSIs (3.3% vs. 8.4%; *p* 0.035), few patients developed a superficial SSIs (0.8% vs. 3.4%; *p* 0.018) and none experienced deep SSIs (0% vs. 3.4%; *p* 0.025). Comparing the previous two "COVID-19-free" years, no significative differences were reported. At multivariate analysis, the measures to reduce the SARS-CoV-2 spread (OR 0.368; *p* 0.05) were independently associated with the reduction for total, superficial and deep SSIs. Moreover, the presence of drains (OR 4.99; *p* 0.009) and a Type III–IV of SWC (OR 1.8; *p* 0.001) demonstrated a worse effect regarding the primary endpoint. Furthermore, the presence of the drain was not associated with an increased risk of superficial and deep SSIs. In this study, we provided important insights into the superficial and deep SSIs risk assessment for patients who underwent surgery. Simple and easily viable precautions such as wearing surgical masks and the restriction of visitors emerged as promising tools for the reduction of SSIs risk.

Keywords Surgical site infections · SARS-CoV-2 · COVID-19 · Italy lockdown

Background

Surgical site infections (SSIs) are the most common in-hospital acquired infections, adding up to 46.4% of all infections, as reported by the CDC [1]. The first site of infection, in terms of timing, is the superficial incision [2]. We must not underestimate this problem because it has a significant impact on morbidity, mortality, length of hospital stay and overall costs [3]. There are many ways to reduce the rate of SSIs both peri- and intra-operatively.

The optimization of the modifiable patient risk factors (e.g., smoking cessation, optimal glycemic control, bathing, screening for resistant bacteria) is the first step to pursue in the prevention of SSIs [1]. World Health Organization (WHO) introduces the "global guidelines for the prevention of SSI" [4, 5] where pre- and intraoperative measures are the use of antimicrobial prophylaxis, alcoholic Clorexidine for skin decontamination, skin barriers and maintenance of intraoperative homeothermy [6–8]. Concerning the postoperative prevention of SSIs, it is necessary to use a bundle of strategies and shared protocols such as a meticulous hand hygiene and asepsis during wound care [9]. The presence of a wound-care supervisor in the surgical team is another fundamental strategy to drastically reduce the incidence of SSIs [7].

The SARS-CoV-2 Pandemia has added other recommendations to those guidelines. In particular, WHO recommended contact and droplets precaution during the care of suspected COVID-19 patients to protect healthcare workers.

SSIs mostly occur in patients who underwent abdominal surgery; for this reason, the general surgeon deals with this important clinical problem on a daily basis [3].

The WHO has issued guidelines for the protection of health care workers (HCWs) which recommend contact

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and droplet precautions during suspected COVID-19 patient support [10] and the US Center for Disease Control (CDC) implemented these guidelines adding the constant use of a face mask (e.g., surgical masks, FFP-2, FFP-3, KN95) to gain source control [11–13].

These measures were implemented from March 8th, 2020 when the Italian lockdown started. The healthcare operators were adequately trained for prevention and control of infection related to assistance (ICA) and the hospitals were improved to manage any suspected/probable/confirmed case that may occur among patients [14–16]. These rules were also applied in our unit: the access to the General Surgery Service for the patients' parents and visitors was strictly forbidden. Use of gloves and surgical masks, hand-rubbing with alcoholic solution before and after the patients' contact was mandatory. On the other hand, we enhanced a higher use of hand hygiene and limited the movement of staff and patients.

All patients admitted for urgent or emergency surgery were previously tested for COVID-19: if negative they could access our department, if positive, the patients were sent to the COVID-19 dedicated unit.

The aim of this study was to evaluate how the scrupulous hygiene rules and the restriction of human contacts during the COVID-19 pandemic affected the SSIs rate of the General Surgery Department of a tertiary center (Trieste, Italy).

Methods

Study design

Patients

We consecutively enrolled and retrospectively analyzed a total of 541 patients. Of those, 198 underwent surgery from March 08th 2018 to April 17th, 2018, 220 from March 08th 2019 till April 17th of the same year and 123 in the COVID-19 era from March 08th 2020 to April 17th 2020. All patients were routinely followed-up (in office or by phone) for 30 days after surgery.

Eligible patients included those of 18 years and older undergoing elective and emergency surgical procedures. All patients were admitted to the department only if they had a negative COVID-19 swab.

Exclusion criteria were antibiotic use within 5 days before surgery, preoperative strategy of an open abdomen, current abdominal wall infection and known allergy to chlorhexidine gluconate or iodine. Most patients received antibiotic prophylaxis with Cefazoline 2 g according to the Surgical Department guidelines. The antibiotic was re-dosed if the operation lasted longer than 4 hours. All operations were performed by a senior surgeon with a surgical resident. The surgical site was prepared with a careful skin disinfection using chlorhexidine–alcohol or iodine povacrylex–alcohol if allergies.

For open surgery and for the mini-laparotomies during laparoscopic procedures, we routinely used wound protectors such as Alexis (Alexis wound protectors, Applied Medical Resources Corporation—Rancho Santa Margarita, CA, USA). For open surgery, especially for urgent/emergency surgery we also used iodine wound dressings.

Outcomes

The primary endpoint was the occurrence of superficial and deep SSIs within 30 days after surgery. CDC (Centers for Disease Control and Prevention) definitions were used to classify superficial and deep skin infections [17–19]. Other secondary endpoints included organ and space infections, type of infectious pathogen, length of stay, and time to SSI.

Surgical site infections

A superficial SSI is defined as "an infection that occurs within 30 days after the operation and only involving the skin and subcutaneous tissue [18, 19]. It must be associated with purulent drainage from the surgical site or organisms isolated from an aseptically obtained culture of fluid or tissue from the surgical site or at least one of signs or symptoms of infection such as pain or tenderness, localized swelling, redness or heat". A deep incisional SSI is defined as "infection that occurs within 30 days after the surgical procedure if no implant is left in place that involves deep soft tissues of the incision associated with one of the following: purulent drainage from the deep incision, but not from the organ/space component of the surgical site; a deep incision spontaneously dehisces (opens up) or is deliberately opened by the surgeon and is culture positive or not cultured when the patient has at least one of the following symptoms: fever or localized pain or tenderness; an abscess, or other evidence of infection involving the deep incision is found on direct examination, during re-operation, or by histopathologic or radiologic examination" [18, 19].

Clinical assessment

Preoperative evaluation included a medical history, physical exam, and routine laboratory testing. All diabetic patients underwent a pre-operatory counseling in the Diabetes Unit to assess and improve the glycemic status. Perioperative information included prophylactic antibiotic therapy, vital signs, and other relevant information were obtained from anesthesiologic and nursing records. Vital signs, laboratory values, relevant postoperative events, and wound culture data, if available, were also recorded by the blinded assessor.

Patients were monitored up to 30 days after hospital discharge. Follow-up was discontinued if a wound infection was confirmed by CDC diagnosis. In addition, if the patients were seen in the office at POD 30 and presented a well-healed wound without infection, they were discharged from the study.

Statistical analysis

Summary statistics of clinical and instrumental variables at enrolment were expressed as mean and standard deviation, or median and interquartile range, or counts and percentage, as appropriate. Comparisons between groups were made by the ANOVA test on continuous variables, using the robust Brown–Forsythe test when appropriate. The Chi-square test was calculated for discrete variables using the Fisher exact test when necessary. Markers predictive of SSIs were searched by means of univariable logistic regression models, testing all clinical and instrumental variables measured at enrolment. Then a multivariable logistic regression model for SSIs was estimated, entering the list of statistically significant and clinically relevant parameters at the univariable analysis, and we reported only the subset of significant ones at the multivariable modeling selected by means of a backward-conditional stepwise algorithm. An internal validation procedure using a bootstrap technique was done to evaluate the amount of overfitting [20, 21].

To verify the robustness of the variable selection procedure, we estimated also a penalized multivariable logistic regression model, starting from the full initial list of potential predictors, using the R library "logistf" [22, 23]. Results were regarded as statistically significant when $p < 0.05$. All calculations were performed using IBM SPSS 19.0 and the R package 3.10.

Results

Characterization of patients with SSI

Table 1 (first column) shows the baseline characteristics of the 541 enrolled patients (62 ± 17 years of age, 39.8% male). There were no significant differences among the patients in each group regarding demographics, comorbidities, timing of surgery, preoperative medical therapies or perioperative antibiotics and in the use of surgical wall protectors.

The majority of patients received antibiotic prophylaxis within an hour before the incision as previously reported.

Overall, they had a good BMI (26 ± 16) and most of them were admitted for elective surgery (more than 72% of the cases). Among them 50.8% underwent breast and thyroid surgery, 37.9% received digestive surgery and 11.3% underwent HBP surgery.

Preoperative skin treatment with chlorhexidine was performed in the majority of cases (93% vs 6,8% of betadine use).

The median duration of surgery was 115 [20–720] minutes and in 52% of the cases, a drain was used. Concerning operative cases, according to the CDC surgical wound classification (SWC) [6], we have classified the 65.4% as clean (I), 13.7% as clean/contaminated (II), 14.2% as contaminated (III) an 6.7% as dirty (IV).

The primary endpoint occurred in 39 over 541 patients (7.2% of the overall population): 23 (4.3%) as superficial SSI, 14 (2.6%) as deep SSI and 17 (3.2%) as organ-space SSI.

The baseline characteristics of the patients experiencing primary endpoint during SARS-CoV-2 period, compared to the patients enrolled before COVID-19 era, are reported in Table 1 (second and third column).

The two subgroups were mostly similar, although all patients enrolled in the COVID-19 era did not receive parent visits and surgeons mandatorily wore surgical masks and gloves all the time, according to the Italian SARS-CoV-2 guidelines [15].

During the study period (Fig. 1c), we reported a lower rate of global SSI (3.3% vs. 8.4%; p 0.035). Among them, just a few patients developed a superficial SSI (0.8% vs. 5.3%; p 0.018) and none of the patients experienced deep SSI (0% vs. 3.4%; p 0.025). A reduction of incidence of organ-space SSI was noted (1.6% vs. 3.6%; p 0.209).

In Table 2, we stratify our analysis by type of surgery and we can see how clean surgery (breast and thyroid surgery) has almost no SSIs in all patients, and colorectal and HBP surgeries have a significant reduction both in superficial and deep SSIs. No differences are reported for organ/space SSIs.

Comparing the SSI index in the pre COVID-19 era (Fig. 1), we can see that the incidence of both superficial and deep SSI is higher than during COVID-19 era (Fig. 1a, b).

On the other hand, if we compare the previous two "COVID-19-free" years (Fig. 1d), we can report only an organ-space SSI increase in 2018 vs. 2019 (Table 1 fifth and sixth columns, Fig. 1d).

Finally, we explore in Table 3 the association of SSIs in the setting of the elective surgery versus urgent/emergent surgery.

In the SARS-CoV-2 era, we operated a total of 95 elective patients and 28 patients in the urgent/emergent setting. Of them, we do not see any statistical difference in the rate of SSIs in the two groups (Table 3).

If we compare the SSIs rate in the SARS-CoV-2 era versus pre-SARS-CoV-2 era in the different surgical setting, we can see a significative reduction of superficial and deep SSIs both in elective and urgent/emergent surgery during SARS-CoV-2 era (Table 3).

Table 1 Characteristics of the study population according to the primary endpoint and SSIs

	Total population *n* = 541	Pre-SARS-CoV-2 era (2018–1019) *n* = 418	SARS-CoV-2 era (2020) *n* = 123	p value	Pre-SARS-CoV-2 era (2018) *n* = 198	Pre-SARS-CoV-2 era (2019) *n* = 220	*p* value
Age (years)	62 ± 17	62 ± 17	62 ± 16	0.905	61 ± 18	61 ± 16	0.949
Male gender*	(215) 39.8%	(177) 42.4%	(39) 31.7%	0.022	(81) 40.8%	(96) 43.6%	0.322
ASA	2	2	2	0.168	2	2	0.561
BMI (kg/m^2)	26 ± 16	27 ± 19	24.2 ± 4.5	0.125	26.4 ± 7.3	27 ± 25	0.579
Smoke	(133) 25%	(100) 24%	(33) 27%	0.311	(45) 23%	(55) 25%	0.39
Diabetes	(74) 14%	(62) 15%	(12) 10%	0.12	(28) 14%	(34) 16%	0.291
Cardiovascular	(227) 42%	(181) 43%	(46) 37%	0.224	(91) 46%	(90) 41%	0.186
Timing (elective patients)	(392) 72.4%	(297) 71%	(95) 77%	0.154	(141) 71%	(156) 71%	0.459
Open	(396) 73%	(305) 73%	(91) 74%	0.365	(139) 70%	(166) 75%	0.168
Chlorhexidine	(504) 93%	(394) 94.3%	(110) 89.4%	0.053	(183) 92.4%	(211) 95.9%	0.094
Betadine	(37) 6.8%	(24) 5.7%	(13) 10.6%	0.053	(15) 7.6%	(9) 4.1%	0.094
Antibiotic prophylaxis	(526) 97.3%	(403) 96.5%	(123) 100%	0.232	(191) 96.5%	(212) 96.4%	0.971
Gloves	(541) 100%	(418) 100%	(123) 100%	1	(198) 100%	(220) 100%	1
Surgical mask*	(123) 22.7%	(0) 0%	(123) 100%	0.0001	(0) 0%	(0) 0%	1
Visitors*	(123) 22.7%	(0) 0%	(123) 100%	0.0001	(0) 0%	(0) 0%	1
Surgical wall protectors	(90) 16.6%	(67) 16%	(23) 18.7%	0.283	(44) 22.2%	(23) 10.5%	0.001
Length of surgery (min)*	115 [20–720]	109 [20–720]	135.8 [28–500]	0.003	113.2 [20–530]	133 [20–720]	0.384
Drain*	(283) 52%	(203) 48.6%	(80) 65%	0.001	(100) 50.5%	(103) 47%	0.256
LOS (days)	7 [0–75]	7 [0–75]	6 [1–32]	0.337	8 [0–75]	6 [0–74]	0.078
SSI (total)*	(39) 7.2%	(35) 8.4%	(4) 3.3%	0.035	(21) 10.6%	(14) 6.4%	0.083
Superficial SSI*	(23) 4.3%	(22) 5.3%	(1) 0.8%	0.018	(12) 6.1%	(10) 4.7%	0.338
Deep SSI*	(14) 2.6%	(14) 3.4%	(0) 0%	0.025	(8) 4%	(6) 2.8%	0.334
Organ-space SSI	(17) 3.2%	(15) 3.6%	(2) 1.6%	0.209	(12) 6.1%	(3) 1.4%	0.01
POD infection (days)	3 [0–60]	3 [0–60]	3 [0–10]	0.326	3 [0–11]	1 [0–6]	0.07
Wound swab	(541) 100%	(418) 100%	(123) 100%	1	(198) 100%	(220) 100%	1
Clavien–Dindo*							
1	(15) 2.8%	(14) 3.3%	(1) 0.8%	0.023	(7) 3.5%	(7) 3.2%	0.0001
2	(25) 4.6%	(22) 5.2%	(3) 2.4%		(17) 8.6%	(5) 2.3%	
3a	(5) 0.9%	(5) 1.2%	0%		(4) 2%	(1) 0.5%	
3b	(15) 2.8%	(15) 3.6%	0%		(12) 6.1%	(3) 1.4%	
4	(0) 0%	(0) 0%	0%		(0) 0%	(0) 0%	
5	(10) 1.8%	(10) 2.4%	0%		(8) 4%	(2) 0.9%	
Sepsis*	(17) 3.2%	(17) 3.3%	0%	0.011	(11) 5.6%	(6) 2.8%	0.118
SWC*							
I	(354) 65.4%	(270) 64.6%	(84) 68.3%	0.002	(116) 58.6%	(154) 70%	0.001
II	(74) 13.7%	(48) 11.5%	(26) 21.1%		(31) 15.7%	(17) 7.7%	
III	(77) 14.2%	(69) 16.5	(8) 6.5%		(29) 14.6%	(40) 18.2%	
IV	(36) 6.7%	(31) 7.4%	(5) 4.1%		(22) 11.1%	(9) 4.1%	

Values are mean ± SD, %, or median [interquartile range]

ASA American Society of Anesthesiologists score, *BMI* body max index, *LOS* length of stay, *POD* post-operative day, *SSIs* surgical site infections, *SWC* surgical wound classification [6]

*Statistically significant difference between SSIs index before and during COVID-19 era

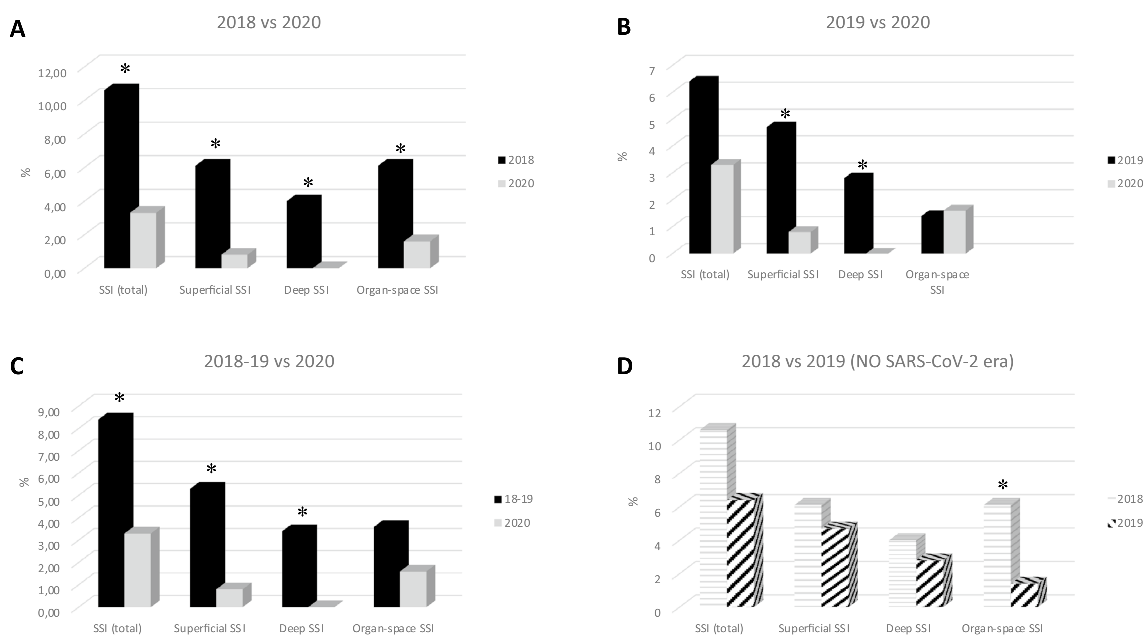

Fig. 1 SSI index before and during the COVID-19 era. SSI index in the years before the COVID-19 era. Incidence of both superficial and deep SSI is higher than during the COVID-19 era (**a**, **b**). In the previous two "COVID-19-free" years (**d**), we can report only an organ-space SSI significantly increase in 2018 vs. 2019 (see Table 1 fifth and sixth column). *p value: <0.05

Table 2 SSI stratification by type of surgery

	Pre-SARS-CoV-2 era (2018–1019) $n=164$	SARS-CoV-2 era (2020) $n=41$	p value	Pre-SARS-CoV-2 era (2018–1019) $n=47$	SARS-CoV-2 era (2020) $n=14$	p value	Pre-SARS-CoV-2 era (2018–1019) $n=207$	SARS-CoV-2 era (2020) $n=68$	p value
Colorectal surgery				HBP surgery			Breast–thyroid surgery		
Gloves	100%	100%	1	100%	100%	1	100%	100%	1
Surgical mask	0%	100%	0.0001	0%	100%	0.0001	0%	100%	0.0001
Open to visitors	100%	0%	0.0001	100%	0%	0.0001	100%	0%	0.0001
Timing (election)	(87) 53%	(19) 46.3%	0.276	(33) 69.6%	(8) 57.1%	0.29	(178) 86%	(67) 98.5%	0.03
Surgical wall protectors	(47) 28,7%	(17) 41.5%	0.083	(16) 34%	(6) 42.9%	0.382	(4) 1.9%	0%	0.319
Length of surgery (min)	144.68 ± 83.8	162.9 ± 97	0.229	96 [35–300]	253 [50–500]	0.0001	85 [20–720]	95 [28–300]	0.291
Drain	(118) 72%	(31) 75.6%	0.05	(21) 44.7%	(11) 78.6%	0.05	(64) 30.9%	(38) 55.9%	0.202
SSI (total)*	(30) 18.3%	(1) 2.4%	0.005	(3) 6.4%	(2) 16.4%	0.128	(2) 1%	0%	0.566
Superficial SSI*	(20) 11.9%	0%	0.01	(2) 4.3%	0.00%	0.01	(1) 0.5%	0%	0.753
Deep SSI*	(14) 8.2%	0%	0.046	0%	0%	1	(1) 0.5%	0%	0.753
Organ-space SSI	(13) 8.2%	(1) 2.4%	0.176	(2) 4.3%	(2) 14.3%	0.223	0%	0%	1

Values are mean ± SD, %, or median [interquartile range]

*Statistically significant difference between SSIs index before and during COVID-19 era. For the other abbreviations, see Table 1

Early parameters associated with SSIs.

A multivariable analysis (Table 4) was performed on the basis of the variables significantly associated with SSI at univariable analysis. During the COVID-19 era [odds ratio (OR): 0.316; 95% confidence interval (CI): 0.103–0.970; *p* 0.015], the mandatory wearing of surgical masks and the absence of visitors were independently associated with the reduction of SSI index.

Moreover, the presence of drains (OR 4.99; CI 1.507–16.573; *p* 0.009) and a Type III-IV of SWC (OR 1.8; CI 1.290–2.605; *p* 0.001) demonstrated a worse effect regarding the primary endpoint.

If we only consider the predictors of superficial and deep SSI (Table 5), we confirm that, during the COVID-19 era (OR 0.129; 95% CI 0.017–0.961; *p* 0.046), the mandatory wearing of surgical mask and the absence of visitors emerged as independently associated with the reduction of superficial and deep SSI.

Type III–IV of SWC seems to be strongly associated with a high risk of developing superficial and deep SSI (OR 2.638; CI 1.793–3.882; *p* 0.0001). Furthermore, the presence of the drain was not associated with an increased risk of superficial and deep SSI.

The internal validation procedure showed that the amount of overfitting was negligible: the randomization estimate of optimism was 0.04 and estimated shrinkage was 0.09 (if optimism is absent, shrinkage factor is equal to 1).

Table 3 SSI stratification by type of surgery setting

	Elective setting ($n=392$)			Urgent/emergent setting ($n=149$)			*p* value
	Superficial SSI	Deep SSI	Organ-space SSI	Superficial SSI	Deep SSI	Organ-space SSI	
SARS-CoV-2 era	0%** (0/95)	0%** (0/95)	2.1% (2/95)	3.6%** (1/28)	0%** (0/28)	0%** (0/28)	> 0.05
Pre-SARS-CoV-2 era	3.7%* (11/297)	2.4%† (7/297)	2.7%† (8/297)	9.1%* (11/121)	5.8%† (7/121)	5.8%† (7/121)	*0.045 †0.05
	$p=0.045$	$p=0.05$	$p=0.232$	$p=0.05$	$p=0.02$	$p=0.02$	

Values are % (number of cases/total population)

**Statistically significant difference between SSIs index before and during COVID-19 era

*,†Statistically significant difference between elective vs. urgent/emergent setting. For the other abbreviations, see Table 1

Table 4 Uni- and multivariate independent predictors of all SSI in SARS-CoV19 era

Univariate				Multivariate		
Variables	OR	CI 95%	*p*	OR	CI 95%	*p*
COVID era (surgical mask wearing and department close to visitors)*	0.19	0.001–0.366	0.009	0.316	0.103–0.970	0.044
Lenght of surgery*	1	1.001–1.006	0.003	1.006	1.002–1.009	0.001
Drain*	3.95	1.468–10.604	0.006	4.99	1.507–16.573	0.009
Type III–IV of SWC*	2.68	2.039–3.508	0.001	1.8	1.290–2.605	0.001
Type of surgery	0.985	0.885–1.095	0.776			

CI confidence interval, *HR* hazard ratio. For the other abbreviations, see Table 1

*For every unit increase

Table 5 Uni- and multivariate independent predictors of superficial and deep SSI in SARS-CoV19 era

Univariate				Multivariate		
Variables	OR	CI 95%	*p*	OR	CI 95%	*p*
COVID era (surgical mask wearing and department close to visitors)*	0.018	0.001–0.568	0.023	0.129	0.017–0.961	0.046
Lenght of Surgery*	1.004	1.001–1.007	0.003	1.004	1–1.009	0.029
Drain*	1.224	0.411–3.650	0.717			
Type III–IV of SWC*	3.069	2.070–4.551	0.001	2.638	1.793–3.882	0.0001
Type of surgery	1.021	0.924–1.130	0.680			

CI confidence interval; HR: hazard ratio. For the other abbreviations, see Table 1

*for every unit increase

Discussion

The main findings of the present study are: 1) approximately 7% of a large population of surgical patients enrolled with homogeneous criteria at the same institution experienced SSI after surgery; Less than 1% of them had a superficial–deep SSI during the COVID-19 era; 2) the mandatory wearing of a surgical mask and the absence of visitors in the Surgical Unit, as the expression of the measures for the containment of the COVID-19 emergency, emerged as independently associated with reduction in both total and superficial–deep SSI; 3) patients with a high SWC (Type III–IV) and the presence of a drain are exposed to an increased risk of global SSI (especially deep and organ-space SSI).

Reducing the occurrence of SSIs is the main focus of numerous quality improvement initiatives because SSIs are a common and costly cause of potentially preventable patient morbidity.

To our knowledge, this is the largest available case series of surgical patients specifically evaluated for the incidence of surgical site infection during the lockdown for the SARS-CoV-2 pandemic.

Our findings might be helpful to identify strategies to adopt for an early preventive measure which are the use of surgical masks both for patients and surgeons during wound care, and the reduction of the number of visitors in the surgical unit.

Prevalence of SSI

Surgical-site infections (SSIs) complicate 2–5% of all surgical procedures, 8% of major abdominal procedures [24–27]. Despite multiple infection control initiatives and quality improvements, SSIs remain a major concern for reliable safe surgery [28, 29]. The rate of SSI in this study was comparable with other studies [27]. In our experience, we report a global index of 7.2% of total SSIs for all procedures (included both emergency/urgent surgery and elective surgery, breast and thyroid surgery, colorectal and HBP surgery). Among them, we have a deep reduction of the total number of SSIs during SARS-CoV-2 lockdown, especially for superficial and deep SSIs. SSIs are associated with an increased risk of postoperative morbidity, prolonged hospitalization, postponement of chemotherapy, increased healthcare costs, and in some oncological cases, poor long-term outcomes due to a worsening of the clinical stage [30].

Characterization and prognostic assessment of SSIs

Several studies on colorectal SSI aggregate superficial, deep, and organ-space SSI together as one group when examining the effects of different risk factors [31, 32].

BMI and creation/revision/reversal of a stomy were independently associated with incisional SSI, while perioperative transfusion and previous abdominal surgery were independently associated with organ-space SSI in a Blumetti et al. study paper [32].

In our study, we included all types of surgery performed in this surgical unit and not only the colorectal or HBP operations because in our experience, both superficial and deep SSIs are more related to the environmental factors and surgeon expertise than to the type of surgery.

The presence of a drain and a contaminated or dirty type of surgery (according to SWC) could increase the overall rate of SSIs, but the presence of a drain did not demonstrate an increased risk of superficial and/or deep SSIs.

On the other hand, protection with surgical masks for both patient and surgeon during the post-operative period in the surgical unit and the absence of visitors, dramatically reduced superficial and deep SSIs. These two simple precautions emerged as independently associated with the reduction of both superficial and deep SSIs.

Quality improvement initiatives aimed at reducing SSI rates are often hindered by limited or even conflicting evidence for proposed interventions to reduce SSI [33].

For example, the debate regarding the risk–benefit balance of mechanical and oral antibiotic bowel preparation prior to colorectal procedures is ongoing, with conflicting data supporting each side [34, 35].

Even surgical procedures based on published evidence can produce disappointing results. In 2010, the Surgical Care Improvement Project was created with the aim to reduce postoperative SSIs by focusing on a series of preoperatory precautions such as perioperative prophylactic antibiotic administration, skin-hair clipping, and normothermia [36].

However, despite evidence supporting the importance of these processes, high compliance is only weakly linked to improved outcomes [37, 38].

We also aimed to perform an in-depth analysis of the pathogens causing superficial and deep SSIs and their antibiogram; however, culture data were available for only 11 of 26 patients with superficial and deep SSIs. Most of these findings (7 of 11) were enteric bacteria (*E. coli and E. faecium*), supporting the need for coverage of Gram-negative bacteria and an adequate wall protection while performing abdominal open surgery. These data can not be generalized because of the small number of cases.

Finally, as known, emergency surgery has a higher risk of experiencing SSIs [39, 40]. Based on these considerations, in our study, we demonstrate that measures adopted to contrast SARS-CoV-2 spread could be also effective in reducing the risk of SSIs in the emergency setting.

Study limitations

Several limitations need to be acknowledged. The biases of different selection criteria, protocols and treatment are some of them, as in every observational studies.

Furthermore, the relatively small number of SSIs and the short period of observation might underestimate the role of some potential predictors. The proposed multivariable model should, therefore, be validated in larger series.

Conclusions

Surgery and the postoperative management of surgical wound carries a non-negligible risk of SSIs. In this study, we provided important insights into the superficial and deep surgical site infection risk assessment for patients who underwent surgery.

Simple and easily viable precautions such as wearing surgical masks (both patient and surgeon) and the restriction of visitors emerged as promising tools for the SSIs risk reduction.

Future multicentric studies, possibly incorporating the most recent and promising techniques for risk prevention, such as the routinary application of the Single-Use Negative Pressure Wound Therapy Device (PICO), are needed to confirm these results and to further improve the management of surgical wounds.

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Compliance with ethical standards

Conflict of interest There is no conflict of interest for all authors regarding the publication of this manuscript and there are no financial issues to disclose.

Research involving human participants The manuscript reports an observational retrospective study on the basis of the resolution of the Authority for the Protection of Personal Data (Gazzetta Uf-ciale N° 72; https://www.garanteprivacy.it/garante/doc.jsp?ID=1878276). This study was conducted in accordance with the ethical standards of the Declaration of Helsinki.

Ethical approval The institutional ethical board approved the study.

Informed consent Informed consent was obtained under the institutional review board policies of hospital administration. There are no relationships with industry.

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