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Risk of surgical site infection in hand trauma, and the impact of the SARS-CoV-2 pandemic: A cohort study

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Summary *Background:* Despite the ubiquity of hand trauma, there remains insufficient published data to reliably inform these patients of surgical site infection (SSI) risk. We describe the risk of SSI in a single-centre cohort of patients with hand trauma, with an analysis of the impact of the coronavirus disease-2019 (COVID-19) pandemic.
Methods: Retrospective data collection of consecutive patients who underwent surgery for hand and wrist trauma in a single plastic surgery centre over two, three-month periods. Demographic, injury and operative details, alongside prophylactic antibiotic use, were recorded. Burn injuries and wounds infected at presentation were excluded. Presence of SSI at 30 days (90 days if a surgical implant was used) was assessed.
Results: Overall, 556 patients - 'Pre-COVID-19' ($n = 310$) and 'During COVID-19' ($n = 246$) - were included. Risk of SSI was 3.6% in the aggregated cohort. Female patients were more likely to develop an SSI, even when adjusted for their greater prevalence of bite aetiologies (adj OR 2.5; 95% CI, 1.00-6.37 and $p < 0.05$). The absolute risk of SSI in the 'Pre-COVID-19' group was

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2.3% and 5.3% in the 'During COVID-19' group. The relative risk of developing an SSI in the 'During COVID-19' group was 2.34 (95% CI, 0.95–5.78 and $p = 0.06$). Baseline characteristics were equivalent between the two groups.

Conclusion: The risk of SSI in hand trauma is the same as the nationally estimated risk for all surgeries; 3–5%. Changes in presentation and practice associated with the first wave of the COVID-19 pandemic did not appear to alter the risk of SSI in patients undergoing surgery for hand trauma.

Introduction

European data suggest that hand trauma accounts for up to one-in-five of all Emergency Department attendances.[1,2,3] In the United Kingdom (UK) alone, around five million people per year injure their hand or wrist, accounting for over 250,000 operations per year.[1,4] As with all surgeries, these procedures carry a risk of developing a surgical site infection (SSI). SSI is defined by the Centers for Disease Control (CDC) criteria as an infection associated with an operative procedure that occurs at or near the surgical incision, within 30 days following the procedure or within 90 days if a prosthetic implant is used during surgery.[5,6] SSIs are the most common preventable complication following surgery and the most common nosocomial infection.[7,8] SSIs complicate approximately 3–20% of all surgical procedures with a national study from the UK finding an SSIs risk of 5%.[7,8] However, this figure may be an underestimate, given that over 60% of SSIs become evident after discharge and may be treated in the community.[9]

Many have purported a lower SSI risk in hand and wrist surgery, with the anatomical region's excellent blood supply being the explanation.[10,11,12] It has been stated that hand surgeons are 'privileged to operate in an anatomic region that is less vulnerable to infection than most sites of the body'.[10] However, this is not substantiated by reliable data. Of the small number of studies that directly assess SSI in hand and wrist trauma, the risk ranges from 3% to 10%, reflecting similar risk as for all operative procedures.[8,13,14,15] There remains insufficient published data to reliably inform hand trauma patients of SSI risk.

The coronavirus disease-19 (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) virus, was officially declared by the World Health Organisation on 11 March 2020.[16] Since then, changes in practice across all specialties, including altered referral pathways and changes to surgical management, have become necessary to mitigate infection whilst managing the continued influx of day-to-day trauma.[16,17,18] It stands to reason that these changes, whilst introduced with the objective to limit the transmission of COVID-19, may also reduce the risk of other transmissible infections. Recent evidence has also suggested that the patterns of hand trauma presenting to the hospital have changed during the COVID-19 pandemic, with an increase in injuries caused by saws and other household tools.[19] We describe the risk of SSI in a single-centre cohort of patients with hand trauma, with an analysis of the impact of the COVID-19 pandemic.

Materials and methods

An interrupted time series service evaluation was designed in accordance with the STROBE statement checklist.[20] In keeping with UK National Health Service (NHS) Research Authority guidance, ethical approval is not required for such studies.[21] The project was formally and prospectively registered. All patients who underwent surgery for hand and wrist trauma in a single secondary plastic surgery unit between 1 May 2019 and 31 July 2019 (Pre-COVID-19) and 16 March 2020 and 16 June 2020 (During COVID-19) were identified from the hospital's operating theatre records and cross-referenced with the plastic surgery department's daily trauma theatre list records. Our time series comprised two cohorts, one from before the COVID-19 pandemic and one group from during the UK's 'first-wave', to evaluate the impact of the pandemic with the resultant changes to practice, patterns of injury and surgical management strategies.

We reviewed the medical notes of included patients and extracted pre-specified data. Consecutive patients within the two periods who had sustained traumatic injuries to the hand and wrist, irrespective of age (including paediatric patients), were included. Hand and wrist trauma was defined as any soft tissue or bony injury that is sustained distal to, and not including, the distal radius. This included all open and closed fractures of the hand and wrist that require surgical fixation; open and closed soft tissue injuries to the hand and wrist requiring surgical repair, including skin, muscle, tendon, ligament, nerve and vessel injuries and all fingertip injuries requiring a surgical procedure. 'Surgical procedure' was defined as: 'a medical intervention performed for an injury in a designated operating room where either a new incision was created, or an open wound was accessed'. Patients were excluded if their injury was caused by thermal burns, caustic agents or electricity or if their wound was infected at presentation. Patients who sustained polytrauma were included if at least one of their injuries fulfilled the aforementioned inclusion criteria. In these cases, only a subsequent SSI of the hand or wrist operative site was counted in our outcome.

Patient demographic details, including age, sex, American Society of Anesthesiologists (ASA) grade and smoking status were extracted, alongside details of relevant comorbidities, such as diabetes, concurrent medication, including steroid use, and any other causes of immunocompromise. Specifics of the injuries were detailed, including whether the patient suffered an open or closed injury. Open injuries were then stratified to one of the three groups:

'sharp laceration', 'blunt laceration' or a 'rip, tear or crush' injury. The contamination status of the wound was gathered.

Operative details, including type of surgery, whether a prosthesis or implant was used, perioperative prophylactic antibiotic use and procedure setting (main theatres or in a minor operating theatre) were captured.

Patients' hospital notes from our centre – including ward notes, follow-up letters, clinic letters, and emergency department attendances – were examined for evidence of the development of an SSI within 30 days (90 days if a surgical implant was used), according to CDC criteria. For these patients, specifics of the treatment for their SSI were extracted, including antibiotic use and re-operation.

Data analysis

Continuous variables were assessed for normality using Shapiro-Wilk Test; normality was rejected if $p < 0.05$. Baseline characteristics were described using means ± standard deviation for continuous normally distributed variables, median and interquartile range (IQR) for continuous variables that were not normally distributed and rounded frequencies (per cent) for categorical variables. *P* values were calculated using an unpaired *t* test for continuous data with Gaussian distribution and using Mann-Whitney U test for non-normal variables. Chi-square test was used to evaluate associations between categorical variables, with Fisher's exact test used when cell values were below five. Statistical significance was defined as $p < 0.05$. When analysing patients with bilateral injuries, the patient was defined as the unit of analysis.[22] All analyses were performed in R (v4.0.3).

We anticipated that there would be a low event rate of SSI, based on current literature, and therefore did not plan to perform any more complex statistical analyses. During data analysis, we encountered an association between sex and SSI risk, which was potentially confounded by bite injury. We therefore proceeded with an *a posteriori* logistic regression analysis to handle this confounding. Bite pattern was prioritised based on clinical reasons before any multivariable analysis was undertaken.

Results

Overall, 556 patients ($n = 310$ in the 'Pre-COVID-19' group and $n = 246$ in the 'During COVID-19' group) underwent surgery for hand and wrist trauma during this time period and were included in this study. Twenty patients developed an SSI, giving an overall risk of 3.6% in the aggregated cohort. All of these patients received antibiotics for the SSI and 12 returned to the theatre for further surgery. The baseline characteristics for all 556 patients are shown in Table 1.

The majority of cases ($n = 406$; 73%) of hand and wrist trauma were sustained by men, and the median age was 39 years. Three hundred and thirty-seven (61%) procedures were carried out in a minor operating theatre. Most were 'sharp' injuries ($n = 238$, 45%), followed by 'rip, tear or crush' injuries ($n = 219$, 39%). Animal bites accounted for 69 (12%) of the injuries. Another 100 (18%) patients had other causes of wound contamination with substances such as wood, soil, metal and gravel.

A greater proportion of female patients developed SSIs than male patients in this cohort (OR, 2.83; 95% CI, 1.15-6.94 and $p < 0.05$). Differences existed between other measured variables of male patients when compared with female patients as potential confounders (Table, Supplemental Digital Content [SDC] 1). A greater proportion of female patients sustaining 'closed' injuries and 'rip, tear or crush' injuries ($p = 0.013$). Female patients also sustained more animal bites (23% vs. 8.4% and $p < 0.0001$), which might be considered particularly prone to infection. The logistic regression model was statistically significant, $\chi^2(4) = 6.198$ and $p = 0.045$. The model explained 42.0% of the variance in SSI, according to Nagelkerke's R^2. Females remained at higher odds of developing an SSI, adjusted for the greater proportion with a bite injury mechanism (adjusted odds OR, 2.5; 95% CI, 1.00-6.37; $p = 0.049$ and Table 2 [Table, SDC 2]).

The 'Pre-COVID-19' group and the 'During COVID-19' group had similar preoperative baseline characteristics in terms of age, sex, and mechanism of injury as can be seen in Table 3. The minor operating theatre was used more in the 'During COVID-19' group ($p < 0.0001$). More patients in the 'Pre-COVID-19' group received prophylactic antibiotics ($p = 0.0012$). The absolute risk of SSI in the 'Pre-COVID-19' group was 2.3% and 5.3% in the 'During COVID-19' group. The relative risk of developing an SSI in the 'During COVID-19 group was 2.34 (95% CI, 0.95-5.78 and $p = 0.06$).

Discussion

The overall risk of SSI in our cohorts was in line with the national UK estimate of 3%-5% for all surgical procedures.[8] The pandemic led to a shift towards the minor operating theatre and local anaesthetic procedures, which did not appear to be associated with an increased risk of SSI.

Our results are comparable with the findings of a recent multi-centre cohort study examining upper extremity surgery, for any indication during the COVID-19 pandemic, which as a secondary outcome, found the risk of SSI to be 3%.[23] These results contrast the findings of an observational study from Italy that reported the rates of SSI to be reduced in general surgery patients during the COVID-19 pandemic.[17] This was accredited to vigilant wearing of face masks and closing the ward to visitors.[17] Our hospital introduced similar measures. Other changes introduced to reduce patient contact at our centre, specific to hand trauma, included the greater use of absorbable skin sutures and a telemedicine follow-up system.

The effect of the pandemic on the clinical pathway of patients with SSI is unclear. It is also possible that patients with hand and wrist SSI may have chosen to avoid hospitals due to the risk of contracting COVID-19, preferentially seeking treatment in primary care settings. In contrast, with the concomitant reduction of primary care availability during the pandemic, it is also feasible that more patients with SSI will have attended the emergency department for treatment. The latter cohort of patients will have been identified in our cohort, whereas the former will not. This could lead to either apparent underestimation or overestimation

Table 1 Patient Characteristics.

Characteristic	All Cases ($n = 556$)		Surgical site infection: No ($n = 536$)		Surgical site infection: Yes ($n = 20$)		*P value*
Median age in years (IQR)	40	(23.3, 58.0)	39	(23.0, 58.0)	47	(25.8, 59.0)	0.4688[§]
Sex (%):							
Male	406	(73.0)	397	(74.1)	10	(50.0)	**0.0347**[†]
Female	150	(27.0)	140	(26.1)	10	(50.0)	
Current smoker (%)	90	(16.2)	88	(16.4)	2	(10.0)	0.7557[‡]
Diabetes mellitus (%)	26	(4.7)	26	(4.9)	0	-	0.6162[‡]
Immunocompromised (%)	9	(1.6)	8	(1.5)	1	(5.0)	0.2826[‡]
ASA Grade (%)							
I	402	(72.3)	388	(72.4)	14	(70.0)	0.9175[‡]
II	123	(22.1)	118	(22.0)	5	(25.0)	
III	31	(5.6)	30	(5.6)	1	(5.0)	
Type of injury (%):							
Closed	47	(8.5)	45	(8.4)	2	(10.0)	0.8251[‡]
Sharp	238	(44.6)	230	(42.9)	8	(40.0)	
Blunt	52	(9.4)	51	(9.5)	1	(5.0)	
Rip, tear and crush	219	(39.4)	210	(39.2)	10	(50.0)	
Wound contamination (%):							
Animal bite[1]	69	(12.4)	64	(11.9)	5	(25.0)	0.0889[†]
Other[2]	100	(18.0)	98	(18.3)	2	(10.0)	0.5524[‡]
Procedure (%):							
Exploration of wound[3]	292	(52.5)	280	(52.2)	12	(60.0)	0.1628[‡]
Nailbed repair	115	(20.7)	114	(23.1)	1	(5.0)	
Fracture fixation	45	(8.0)	44	(8.2)	1	(5.0)	
Extensor tendon repair	46	(8.3)	44	(8.2)	2	(10.0)	
Flexor tendon repair	25	(4.5)	24	(4.5)	1	(5.0)	
Terminalisation	9	(2.9)	15	(2.8)	2	(14.3)	
UCL	8	(1.4)	8	(1.5)	0	-	
Other[4]	8	(1.4)	7	(1.3)	1	(5.0)	
Prosthesis or implant used (%)	48	(8.6)	47	(8.8)	1	(5.0)	0.8251[‡]
Location of procedure (%):							
Main theatres	219	(39.4)	211	(39.4)	8	(40.0)	1.0000[†]
Minor operating theatre	337	(60.6)	325	(60.6)	12	(60.0)	
Perioperative antibiotics used (%)	483	(86.9)	464	(86.6)	19	(95.0)	0.4967[†]

IQR: Interquartile range
[1] Dog, cat, human, rat, squirrel and horse
[2] Wood, soil, metal and glass foreign bodies
[3] Including debridement, washout, repair of laceration and removal of foreign body
[4] Other procedures included the evacuation of haematoma, replant, skin graft and thenar flap reconstruction.
[§] p-value derived using Mann-Whitney U test for non-parametric data.
[†] p-value derived using Chi-square test for categorical variables.
[‡] p-value derived using Fisher's exact test when cell sizes were below five.Significant p-values are highlighted.

Table 2 Univariable and multivariable logistic regression for gender, bite and risk of SSI.

	Univariable analysis (unadjusted)			Multivariable analysis (adjusted)		
	Odds Ratio	95% CIs	*P* value	Adjusted Odds Ratio	95% CIs	*P* value
Sex	2.83	1.15-6.94	0.02	2.53	1.00-6.37	0.049
Bite	2.46	0.86-6.99	0.09	1.89	0.64-5.59	0.246

of SSI risk that is specific to hand and wrist patients during the pandemic. Further evaluation of national primary care datasets would help to ascertain the number of patients who are treated for hand SSI, giving a more accurate representation of overall risk.

Fewer patients received surgery for hand and wrist trauma in our centre during the first wave of the COVID-19 pandemic. Patient characteristics were comparable to those presenting prior to the pandemic, other than fewer patients smoking, which may be explained by data suggesting that smoking cessation attempts have increased in the UK during the pandemic.[24] This similarity between the two groups indicates that a comparable patient population with equivalent types of injuries are presenting with hand and

Table 3 Baseline characteristics and operative variables for hand and wrist trauma patients operated on 'pre-COVID-19 pandemic' and 'during COVID-19 pandemic'.

Characteristic	Pre-COVID-19 ($n = 310$)	During COVID-19 ($n = 246$)	*P value*
SSI (%)	7 (2.3)	13 (5.3)	0.0941[†]
Median age in years (IQR)	37 (22.0, 59.0)	42 (26.0, 58.0)	0.5158[§]
Sex (%):			
Male	226 (72.9)	180 (73.2)	1.0000[†]
Female	84 (27.1)	66 (26.8)	
Current smoker (%)	66 (21.3)	24 (9.8)	**0.0004**[†]
Diabetes mellitus (%)	16 (16.0)	10 (4.1)	0.6848[†]
Immunocompromised (%)	5 (5.0)	4 (1.6)	1.0000[‡]
ASA Grade (%)			
I	216 (69.7)	186 (75.6)	0.2725[†]
II	74 (23.9)	49 (19.7)	
III	20 (6.5)	11 (4.5)	
Type of injury (%):			
Closed	33 (10.6)	14 (5.7)	0.1140[†]
Sharp	131 (42.3)	107 (43.5)	
Blunt	32 (10.3)	20 (8.1)	
Rip, tear and crush	114 (36.8)	105 (42.7)	
Wound contamination (%):			
Animal bite	38 (12.2)	31 (12.6)	0.1976[†]
Other	47 (15.2)	53 (21.5)	0.0590[†]
Prosthesis or implant used (%)	30 (91.0)	18 (7.3)	0.4053[†]
Location of procedure (%):			
Main theatres	177 (57.1)	42 (17.1)	**< 0.0001**[†]
Minor operating theatre	133 (42.9)	204 (82.9)	
Perioperative antibiotics used (%)	282 (91.0)	201 (81.7)	**0.0012**[†]

IQR: Interquartile range
[§] *p*-value derived using Mann-Whitney U test for non-parametric data.
[†] *p*-value derived using Chi-square test for categorical variables.
[‡] *p*-value derived using Fisher's exact test when cell sizes were below five.Significant p-values are highlighted.

wrist trauma during the COVID-19 pandemic, despite national lockdown and changes to peoples' working and social lives. These findings are reflected in other studies examining hand trauma during the COVID-19 pandemic.[19,25] The discourse looking at the specific activity implicated have suggested that sports-related trauma was reduced whilst domestic 'do-it-yourself' injuries and injuries related to deliberate self-harm were more prevalent.[19,25,26]

In our cohort, a greater proportion of females developed SSIs than male subjects, even when adjusted for their greater prevalence of bite aetiologies. Previous literature has demonstrated that SSIs generally occur more frequently in male patients than in female patients. Female patients have been found to be less likely than male patients to develop SSIs when undergoing hip, knee and intra-abdominal procedures, but more likely to develop SSIs when undergoing coronary artery bypass grafting and hernia repairs.[27] Some investigators have argued that these findings may be explained by differences in fat distribution between male and female patients or even due to differences in bacterial skin colonisation between sexes.[27] Differences in attitude towards seeking medical attention may present another confounding factor contributing to this finding. Men are purportedly less likely to consult their doctor, which could lead to reduced rates of detection of SSI in male patients.[28]

Previous discourse examining SSI risk has reported varying degrees of importance of pre- and perioperative factors such as wound contamination, grade of vascular disruption, smoking status, presence of systemic illness, use of prophylactic antibiotics and location of procedure, but their findings are often contradictory.[11,12,14,29] Our study did not reveal any variation in the risk of SSI with different mechanisms of injury, level of contamination, ASA grade or smoking status.

The majority of our patients received perioperative prophylactic antibiotics, including those who later developed an SSI. Prophylactic antibiotics in hand surgery is a contentious issue.[30,31,32,33] Antibiotic stewardship requires evidence-based rationale for the safe and effective use of antimicrobials. For simple hand injuries that require surgery, the findings of a recent meta-analysis of 2,578 patients suggested that prophylactic antibiotics did not significantly reduce subsequent infection.[30]

The indications for hand and wrist procedures that can be performed as day case procedures under local or regional anaesthetic outside of the main operating room is continually growing.[29,34,35] There have been reported worries that these areas may not function with the same stringent level of infection control as the main operating theatre; however, the results of our study, alongside those previously published, have not confirmed this belief.[29,36] We found that

there was increased use of the department's minor operating theatre during the first wave of the pandemic. This is in keeping with guidance published by the British Society for Surgery of the Hand (BSSH) and comparable to other centres in the UK.[18,23] The move away from the main operating theatre may also explain the reduction in patients receiving prophylactic antibiotics.

Limitations

This study only assessed patients who developed SSIs and presented back to our secondary plastic surgery unit. This study will not have assessed any patients who developed an SSI and were managed in primary care or by another hospital, if they were not then referred back to our department. Most patients were discharged the same day and as such, the majority of the 30-day (or 90-day) period in which an SSI may occur was spent away from the hospital with no, or minimal, contact with medical professionals. Given that 60% of SSIs become evident after discharge, this means that there is a possibility that this study will have missed SSIs.[9] This is particularly true for hand trauma, where the vast majority of patients are ambulatory. Future studies investigating this area could be improved by being prospective, with specific patient follow-up to find out if patients develop SSIs and are treated in the community. Severity of SSI, other than the need to return to theatre, and the consequences of the SSI were not assessed by this study. As logistic regression was not originally anticipated, we did not perform an *a priori* sample size calculation to determine power. Because of the potential underpowering of this study, further *posteriori* multivariate models could not be explored because of the risk of providing spurious significant results and leading to data that were not robust.

Conclusion

The risk of SSI in hand and wrist trauma in this cohort is the same as the nationally estimated risk for all surgery; 3–5%.[8] Changes in presentation and practice associated with the first wave of the COVID-19 pandemic did not appear to alter the risk of SSI in patients undergoing surgery for hand and wrist trauma. Our study found that female patients were more likely to develop an SSI, even when adjusted for their greater proportion of bite injuries. It is unclear from this study whether sex represents a true risk factor for the development of SSI in hand and wrist trauma. However, given the previous data showing that sex is an independent risk factor for SSI in other anatomical areas, this should not be ruled out. National-level data analysis may provide a deeper understanding of baseline SSI risk in hand and wrist trauma, along with potential for risk factor exploration and risk stratification.

Ethical approval

None required.

Conflict of Interest

AJB, AJ, AJ, JV, JNR, MT, AM and JCRW declare no conflict of interest.

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Author contribution statement

AJB: Primary author, data collection and analysis and manuscript preparation. **AJ, AJ, JV**: Secondary author, data collection and manuscript preparation. **JNR**: Methodology support and clinical input manuscript preparation. **MT**: Methodology support, clinical input and manuscript preparation. **AM**: Methodology support, clinical input and manuscript preparation. **JCRW**: Senior author, clinical input, methodology support, data analysis, manuscript preparation and guarantor. JCRW is funded by the Royal College of Surgeons of England and Wales and the British Society for Surgery of the Hand.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2021.06.016.

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