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Risk factors for *Staphylococcus aureus* surgical site infections after orthopaedic and trauma surgery in a French university hospital

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ABSTRACT

Background: Surgical site infections (SSI) after orthopaedic surgery are responsible for reduced quality of life, increased length of hospital stay and costs. The most commonly identified organism is *Staphylococcus aureus* but risk factors for *S. aureus* SSI are not well-known. The aim of this study was to evaluate the incidence rate trend of *S. aureus* SSI over the years and risk factors of these infections in a French University Hospital.

Methods: SSI rates were expressed as cumulative incidence rates per year. A case-control study nested within a prospective cohort of patients undergoing orthopaedic or trauma surgery from January 1st 2012 to April 30th 2015 was performed. Cases were patients with *S. aureus* SSI; controls were patients without SSI. Risk factors of *S. aureus* SSI were identified by univariate and multivariable analysis.

Results: Of 7438 interventions, 50 (0.7%) *S. aureus* SSI were identified, without significant increase by years. A total of 46 *S. aureus* SSI was matched to 91 controls. Risk factors for *S. aureus* SSI were smoking (odds-ratio (OR)=8.4, 95%CI 1.2-59.6) and National Nosocomial Infections Surveillance System score (NNISS) ≥ 1 (OR=5.8, 95%CI 1.8-19.1). Having 1 or 2 preoperative antiseptic showers (OR=0.3, 95%CI 0.1-0.7) was a protective factor.

Conclusion: The rate of *S. aureus* SSI is not negligible after orthopaedic and trauma surgery. It seems imperative to strengthen smoking cessation recommendations, and to recall the importance of preoperative antiseptic showers. Systematic screening and decolonization for *S. aureus* carriage before orthopaedic and trauma surgery could be a means to prevent these infections.

Keywords: surgical site infections; orthopaedic surgery; trauma surgery; *Staphylococcus aureus*; risk factors.

INTRODUCTION

In orthopaedic surgery, the cumulative median incidence of surgical site infections (SSI) is 2.7% (Korol et al., 2013). These SSI are responsible for a reduction in quality of life, a longer hospital stay, and increased costs (Kurtz et al., 2012, Whitehouse et al., 2002). *Staphylococcus aureus* is the micro-organism most often identified with a median cumulative incidence of 1.6% (Korol et al., 2013).

The risk factors for monomicrobial *S. aureus* SSI in orthopaedic and trauma surgery have been the subject of few studies and are conflicting (Kalmeijer et al., 2000, Marimuthu et al., 2015, Prattingerová et al., 2019, Ramos et al., 2016). After elective hip or knee arthroplasty surgery, age, the number of days between hospital admission and the intervention, and re-intervention for non-infectious reasons were risk factors for *S. aureus* SSI (Marimuthu et al., 2015). After hip and knee arthroplasty, the male sex, replacing a hip prosthesis, the summer period, an ASA (American Society of Anaesthesiologists) score greater than 1, and an operation length greater than 120 minutes were risk factors for deep *S. aureus* SSI (Prattingerová et al., 2019). Nasal carriage of *S. aureus* has been identified as a risk factor for *S. aureus* SSI after full knee replacement surgery (Ramos et al., 2016) and a high level of nasal carriage of *S. aureus* was identified as a risk factor after full hip or knee replacement surgery, replacement hip or knee prostheses, and back surgery (Kalmeijer et al., 2000).

In France, it is not recommended to screen patients for *S. aureus* and to decolonise them before a scheduled prosthetic orthopaedic surgery or a clean-contaminated surgery, other than cardiac surgery (Lepelletier et al., 2014). This practice is not performed in our facility.

The main objective of this study was to analyse the risk factors for monomicrobial *S. aureus* SSI after orthopaedic or trauma surgery in the absence of systematic screening for *S. aureus*. The secondary objectives were to describe the properties of these monomicrobial

S. aureus SSI and to assess the cumulative incidence of monomicrobial *S. aureus* SSI as a function of the years.

MATERIAL AND METHODS

A case-control study nested within a prospective cohort of patients having undergone an orthopaedic or trauma surgery at the Grenoble Alpes University Hospital (CHU GA), between 1st January 2012 and 30th April 2015, was carried out. The number of beds and hospitalisations in the CHU GA, Trauma Centre level 1, were respectively 2,133 and 219,560 in 2015. The facility has 2 orthopaedics departments on 2 geographically different sites (North and South sites). The number of beds in the North and South orthopaedics departments were 52 and 71 respectively in 2015. More than 6,000 orthopaedic and trauma surgical interventions are carried out each year. Study ethics approval was obtained on 04 November 2016 (CECIC Rhône-Alpes-Auvergne, Clermont-Ferrand, IRB 5891).

Interventions defined by the national surveillance protocol (Astagneau et al., 2009) and carried out at the orthopaedics operating unit or at the emergency unit in the North Hospital as well as at the traumatology unit in the South Hospital were included. These interventions were knee and hip joint prostheses, knee and hip prosthesis replacements carried out between 2012 and 2015 and osteosyntheses of the upper end of the femur and other osteosyntheses (except for cranial and vertebral) carried out from 2013. Surgeries on the bones of the hand, the scaphoid and the carpus, interventions or re-interventions for an infection, and interventions involving patients under 16 years of age were excluded. SSI have been defined according to the Centres of Disease Control and prevention (CDC) (Horan et al., 2008), we considered a delay of 1 year after surgery. SSI were reported to the hospital hygiene department by the surgeon or were brought to light by the detection system

implemented by the hospital hygiene department, which consisted of cross-referencing the computer data on the identity of patients having undergone a surgery followed with the data on antibiotic prescriptions and the data from the microbiology laboratory. Patients were put into three categories: patients having presented a monomicrobial *S. aureus* SSI, patients having presented another SSI (monomicrobial SSI with another micro-organism other than *S. aureus*, polymicrobial SSI, or SSI without any micro-organism detected), and patients not having presented an SSI in the recovery suites.

Age, sex, body mass index (BMI), the operating theatre, the operation length, the type of procedure, the ASA score (Daabiss, 2011), the Altemeier classification (Fry, 1986) and the NNISS score (National Nosocomial Infections Surveillance System) (Hughes, 1987) were collected prospectively for the cases and the controls as per the national methodology (Astagneau et al., 2009). The comorbidities making up the Charlson Index (Charlson et al., 1987) were collected. The data concerning lifestyle were active smoking at the time of the intervention or having weaned off less than a month, alcoholism and drug abuse at the time of the intervention or having weaned off less than 6 months, and the patient's bodily hygiene. The preoperative and clinical data were the preoperative hospital stay, the completion of a prior intervention on the same site, the oncological nature of the surgery, the presence of isolated fever, of preoperative infection and taking antibiotics in the 15 days before the intervention, the context of emergency surgery (not scheduled 24 hours before the intervention), accidentology, the presence of a fracture and the closed or open nature of the fracture. The data concerning the SSI prevention measures were the antiseptics used for skin preparation, antibiotic prophylaxis and the antiseptic preoperative showers and bathing in 2 categories: no antiseptic preoperative shower and one or two antiseptic preoperative showers carried out the day before/morning of the intervention. The data concerning the surgery were the season during which the intervention took place, carried out on a non-business day, its

number in the running order of the interventions schedule, the number of people on the operating team, the multifaceted nature of the surgery, the skin condition around the incision, the occurrence of septic intra-operative incidents (material falling, desterilisation of the operating field, etc.) or non-septic intra-operative incidents (difficult reduction, additional fractures off of the main one, significant bleeding, etc.). The postoperative data collected were the extension of antibiotic prophylaxis, the overall length of the hospital stay, death during hospitalisation, and the date of last contact with the patient.

The data specifically concerning the *S. aureus* SSI cases were the date and the type of SSI (superficial or deep infection, or organ/space infection), time before occurrence of the SSI, the resistance of the *S. aureus*, re-intervention for the SSI, and the prescription of an antibiotic treatment.

Scar swab type clinical samples, samples from tissues in contact with the osteosynthesis material, etc. were placed in Columbia sheep blood agar (bioMérieux^{MD}, Marcy l'Etoile, France) in the microbiology laboratory. The isolated bacterial strains were identified by VITEK 2^{MD} with the VITEK 2^{MD} GP identification cards for gram-positive cocci.

One case was matched to 2 controls randomly over the year (2012, 2013, 2014, from 1st January to 30th April 2015), age (year classes of 5 years), sex, and type of intervention. The SSI rates were expressed as cumulative incidence rates per year (number of SSI per 100 interventions, %). The analysis of the progression of the SSI incidence rate as a function of the years was carried out by testing the slope of the linear regression. Regarding the quantitative variables, they were expressed as medians and interquartiles (IQ), and the qualitative variables were expressed as numbers (n) and percentages (%). In univariate analysis, the risk factors were compared between the cases and the controls with nonparametric Mann–Whitney U tests, and with Pearson's chi-squared test or Fisher's exact

test if the test application conditions were not respected. Variables including the p-value that were inferior to the threshold of 0.1 in univariate analysis were integrated into a multivariable model. The multivariable analysis was carried out by unconditional logistic regression (Pearce, 2016). The collinear variables were not considered. The interactions between the variables were tested with the coefficient test of the interaction variable. The results were expressed as odds-ratio (OR) and confidence interval at 95% of the odds-ratio (CI_{95%}). The Hosmer–Lemeshow test was carried out. The area under the Receiver Operating Characteristic (ROC) was calculated. The significance threshold was 0.05. These statistical analyses were carried out with STATA version 14.0.

RESULTS

From 1st January 2012 to 30th April 2015 inclusive, 38,684 interventions were carried out in the emergency, orthopaedics, and trauma units, and 10,132 interventions were the subject of SSI surveillance (**Figure 1**). A total of 2,422 non-orthopaedic and non-trauma surgeries in the emergency unit, 203 surgeries of the hand, the scaphoid, and the carpus, as well as 69 surgeries involving patients younger than 16 years of age were excluded. Among the 7,438 orthopaedic and trauma interventions selected, a total of 137 (1.8%) SSI were identified: 50 (0.7%) monomicrobial *S. aureus* SSI (cases) and 87 (1.2%) SSI not involving monomicrobial *S. aureus*.

In 2012, 2013, 2014 and 2015, the incidence rates of monomicrobial *S. aureus* SSI were, respectively, 0.3%, 0.7%, 0.7% and 0.8%. The progression of the cumulative instances of monomicrobial *S. aureus* SSI is presented in **Figure 2**. The slope of the linear regression test on the incidence rate as a function of the years shows that there was no significant increase in SSI (coefficient=0.1, p=0.16).

Among the 50 monomicrobial *S. aureus* SSI, in 14% of the cases there was a superficial infection, in 70% of the cases a deep infection, and in 16% of the cases an organ/space infection. The median time before occurrence of these infections was 29.5 days; 46 (92%) were Methicillin-sensitive *S. aureus* and 4 SSI (8%) were Methicillin-resistant *S. aureus*. In total, 86% of the SSI required re-intervention and 92% required an antibiotic treatment.

In total, 46 monomicrobial *S. aureus* SSI were matched to 91 controls. The population of the 137 patients had a median age of 70.3 years and was 56.2% female (**Table 1**). In total, 62.8% of patients had a Charlson index of 0. For 36.6% of the population, the NNISS score was equal to 0. Osteosyntheses represented 62.8% of the interventions, 32.1% of the interventions were hip or knee prosthesis surgeries, and 5.1% were replacements. In 35% of cases, the interventions were carried out as emergencies. The indication for surgery was the presence of fracture in 73% of the cases, 92% of these fractures were closed fractures. Antibiotic prophylaxis was not compliant in 23.7% of the cases. The median follow-up time for the overall population was 384 days. Demographic and anthropometric data, comorbidities, lifestyle and postoperative data did not changed by years (data not shown).

The comparison of the cases and controls is laid out in **Table 1**. In univariate analysis, the cases had diabetes significantly more often than the controls (19.6% vs 7.7%), hemiplegia or paraplegia (6.5% vs 0%) and there were significantly more of them with an NNISS score ≥ 1 (82.6% vs 53.4%). Significantly fewer of the cases had received 1 or 2 antiseptic preoperative showers compared to the controls (43.5% vs 79.1%), and significantly more of them received an antibiotic prophylaxis with a non-compliant molecule (7.1% vs 0%).

For the multivariable analysis, the interactions between the NNISS score and smoking, and the NNISS score and diabetes were evaluated. The interaction between the NNISS score and diabetes was not significant. The interaction between the NNISS score and

smoking was significant (coefficient $\gamma = -2.3$, $p=0.04$) and was integrated into the multivariable model. The operation length was not integrated into the multivariable model for reasons of collinearity with the NNISS score. In multivariable analysis, 134 patients were analysed, 46 cases and 88 controls (**Table 2**). Having 1 or 2 antiseptic preoperative showers was a protective factor for *S. aureus* SSI with respect to not having an antiseptic preoperative shower (OR=0.28, CI_{95%}: 0.1-0.7, $p=0.003$). The NNISS score ≥ 1 was a risk factor for *S. aureus* SSI in comparison to an NNISS score of 0 (OR=5.8, CI_{95%}: 1.8-19.1, $p=0.004$). It is true only for non-smokers due to the interaction. Smoking was also a risk factor for *S. aureus* SSI (OR=8.4, CI_{95%}: 1.2-59.6, $p=0.03$). Diabetes was not a risk factor for *S. aureus* SSI in this population of patients, but it was at the limit of significance (OR=3.2, CI_{95%}: 0.9-11.3, $p=0.07$).

DISCUSSION

Out of a total of 7,438 orthopaedic and trauma interventions carried out between 1st January 2012 and 30th April 2015, 50 *S. aureus* SSI were identified, or an average incidence of 0.7%, without a significant increase over the years. Smoking, an NNISS score ≥ 1 and not having had at least one antiseptic preoperative shower were risk factors for *S. aureus* SSI in this population of patients.

There were no significant increases in the rates of *S. aureus* SSI over the years; the rate doubled between 2012 and the following years, which can be explained by the introduction of the monitoring of osteosyntheses from 2013. Out of the 47 SSI from 2013 to 2015, 70% of the SSI occurred after osteosynthesis and nearly 3 times as many interventions were monitored from 2013.

The proportion of *S. aureus* SSI in relation to the entirety of SSI in our patient population was significant (36.4%). These infections required a re-intervention in 86% of

cases and an antibiotic treatment in 92% of cases, confirming that *S. aureus* SSI represent a burden in terms of morbidity and cost.

In a univariate analysis of the risk factors for monomicrobial *S. aureus* SSI in orthopaedic surgery, Kalmeijer et al. (2000) showed that suffering from an underlying disease (presence of a malignant tumour or diabetes) and having nasal carriage of *S. aureus*, of a low or high level, were risk factors. In our univariate analysis, diabetes was a significant risk factor but not the presence of a malignant tumour. Screening for carriage of *S. aureus* in patients about to undergo an orthopaedic surgery is not recommended in France, therefore it was not possible to test this risk factor. Of note, emergency surgery or accidentology were not risks factors of monomicrobial *S. aureus* SSI in our study.

In multivariable analysis, nasal carriage of *S. aureus* or a high level of nasal carriage of *S. aureus* were the only significant risk factors for *S. aureus* SSI in the study by Ramos *et al.* (2016) and by Kalmeijer et al. (2000). In the multivariable analysis of the risk factors for *S. aureus* SSI after hip or knee arthroplasty surgery, Marimuthu et al. (2015) did not test for the nasal carriage of *S. aureus*; advanced age was a protective factor for *S. aureus* SSI, the number of days between admission and the intervention and the re-intervention for non-infectious reasons were risk factors for *S. aureus* SSI. In the study by Pratingerova *et al.* (2019), the summer period, an ASA score >1, an operation length >120 minutes, the male sex, and replacement hip or knee prostheses were risk factors for *S. aureus* SSI. Sex, age, and the type of intervention could not be tested in our study as these were pairing criteria. In our univariate analysis, the length of the preoperative stay, the re-intervention for non-infectious reasons, the ASA score, the seasons, and the operation length were not significant risk factors. In the study by Marimuthu et al. (2015), the effect of the NNISS score was not studied specifically in hip or knee arthroplasty surgery; an NNISS score ≥ 2 was a significant risk factor for *S. aureus* SSI, all surgeries combined. Smoking was identified as a risk factor

for *S. aureus* SSI in our study, but it was not analysed by Marimuthu et al. (2015), Kalmeijer et al. (2000), Prattingerova et al. (2019) or Ramos *et al.* (2016). Nevertheless, in a study on SSI after surgeries on closed elbow fractures (Claessen et al., 2016), where 59% of the SSI were due to monomicrobial *S. aureus*, smoking was a significant risk factor for SSI. This was also found in a study on the open reduction and the internal fixation of bicondylar fractures of the tibial plateau, where *S. aureus* was the causal agent in 66% of cases (Morris et al., 2013). Furthermore, a recent case-control study (Nolan et al., 2017) including 2452 SSI cases (not only *S. aureus* SSI) and 4467 matched controls after elective clean and clean-contaminated surgery (only 16% of orthopedics surgery) demonstrated that smoking was significantly and independently associated with SSI when adjustment is made for potentially relevant covariates. Of note, this study also demonstrated that smoking on the day of surgery was independently associated with the development of SSI. In general, preoperative smoking was found to be associated with an increased risk of the postoperative complications (Grønkjær et al., 2014). This increased risk may result from both an increased prevalence of smoking-related diseases and the acute effects of smoking, which increases exposure to several toxins. For example, carbon monoxide induces a decrease in oxygen supply that could contribute to the development of SSI (Hopf et al., 1997).

Having 1 or 2 antiseptic preoperative showers, compared to not having had any antiseptic preoperative shower, was a significant protective factor for SSI in our multivariable analysis. In France, it is recommended to have at least one preoperative shower, without recommendations on the type of soap to use, antiseptic or otherwise (Société Française d'Hygiène Hospitalière, 2003). Within our facility, it is required to use an antiseptic soap made of povidone-iodine or chlorhexidine. In a meta-analysis of the Cochrane group (Webster and Osborne, 2015), three tests compared preoperative showers with chlorhexidine with the absence of specific instructions for preoperative antiseptic showers; the relative SSI

risk was not significant. However, even though these patients did not have instructions regarding preoperative antiseptic showers, it could not be excluded that they had them anyway. On the other hand, the 3 studies compared in this review involved other types of surgery than orthopaedic or trauma surgery and did not specifically analyse *S. aureus* SSI. The effect of the shower as a protective factor for SSI in our study can be explained in part by the fact that *S. aureus* is a cutaneous flora micro-organism, and thus the microbial load can be reduced by carrying out preoperative antiseptic showers.

There are limitations to this study. Firstly, the control selection bias is a major problem inherent to all case-control studies. It was nevertheless limited by carrying out a random draw when pairing the cases and the controls. The controls were paired within the same year, by age, sex, and the type of intervention. Secondly, the plotted antiseptic preoperative shower variable depended on the carers tracking it. A shower may have been carried out but not tracked, but it is a non-differential bias between the cases and controls. Moreover, the evaluation of best practices and how exactly to proceed with the preoperative showers was not carried out. Regarding smoking, the veracity of this data depended on patient statements, which could have also constituted a classification bias, but a non-differential one, between the cases and controls. Thirdly, some patients had a follow-up of under a year, which could have limited the identification of potential SSI cases that may have occurred after the last established hospital contact with the patient. However, the median time before occurrence of the SSI was 29.5 days, the majority of the SSI thus occurring relatively early. The hypothesis that an SSI could have been treated by another facility can nevertheless not be excluded. Fourthly, we evaluated a rare occurrence, or 50 monomicrobial *S. aureus* SSI over 3 years and 4 months of monitoring and over 7,438 interventions selected, the number of SSI risk factors analysed was thus limited by this small number of events. Other risk factors such as a prior *S. aureus* infection, the presence of postoperative hematoma, or

the placement of a drain could not be studied. Fifthly, some finding/association might be due to chance due to the high number of test performed. Finally, this study was mono-centric, even though it studied the interventions carried out on two geographically distinct sites. A prospective multi-centric study is now necessary in order to include more monomicrobial *S. aureus* SSI and to confirm the significance of the risk factors identified.

CONCLUSION

Smoking, an NNISS score ≥ 1 , and not having had at least one antiseptic preoperative shower were identified as risk factors for monomicrobial *S. aureus* SSI after orthopaedic and trauma surgery in our patient population. As smoking is the major risk factor in our study, it seems imperative to highlight the recommendations for quitting smoking in preoperative consultation for scheduled surgeries and to reiterate the message during hospitalisation or post-surgery. As antiseptic preoperative showers are a protective factor in our study, it seems necessary to draw attention to the importance of carrying them out and tracking them, and to carry out audits on this practice. In case of fractures, and of difficulties carrying out preoperative showers, antiseptic wipes could be an alternative. Finally, as the proportion of *S. aureus* SSI in relation to the entirety of the SSI in our patient population was significant, it also appears necessary to us to implement screening for *S. aureus* and to decolonise positive patients before orthopaedic and trauma surgery, as has been recommended by the WHO since 2016 (Allegranzi et al., 2016). As such, the position of this risk factor in relation to smoking, to the NNISS score, and to taking a preoperative shower can be assessed.

Conflict of Interest: All authors report no conflicts of interest relevant to this article.

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Table 1. Description and univariate comparison of the properties of monomicrobial *S. aureus* surgical site infection cases and controls after orthopaedic and trauma surgery

Properties	Total n=137	Cases n=46	Controls n=91	p-value
Demographic and anthropometric data				
Age, years, median (IQ)	70.3 (57-84.6)	70.9 (57.3-85)	70.2 (55.2-84.6)	0.99
Female sex, n(%)	72 (52.6)	24 (52.2)	48 (52.8)	0.95
BMI, kg/m ² , median (IQ)	24.8 (22-29.8)	24 (21.7-30.4)	25.3 (23-29.5)	0.42
Comorbidities, n (%)				
Charlson Index				0.87
0	86 (62.8)	29 (63)	57 (62.6)	
1-2	34 (24.8)	11 (23.9)	23 (25.3)	
3-4	9 (6.6)	4 (8.7)	5 (5.5)	
≥5	8 (5.8)	2 (4.4)	6 (6.6)	
Cerebrovascular disease	2 (1.5)	1 (2.2)	1 (1.1)	0.99
Congestive heart failure	12 (8.8)	2 (4.4)	10 (11)	0.34
Chronic obstructive pulmonary disease	9 (6.6)	2 (4.4)	7 (7.7)	0.72
Dementia	10 (7.3)	1 (2.2)	9 (9.9)	0.16
Diabetes without organ involvement	13 (9.5)	8 (17.4)	5 (5.5)	0.03
Mild liver disease	2 (1.5)	0 (0)	2 (2.2)	0.55
Myocardial infarction	4 (2.9)	1 (2.2)	3 (3.3)	0.99
Peripheral vascular disease	9 (6.6)	3 (6.5)	6 (6.6)	0.99
Peptic ulcer	0 (0)	0 (0)	0 (0)	-
Rheumatic disease	1 (0.7)	1 (2.2)	0 (0)	0.37
Diabetes with organ involvement	3 (2.2)	1 (2.2)	2 (2.2)	0.99
Hemiplegia or paraplegia	3 (2.2)	3 (6.5)	0 (0)	0.04

Malignant tumour (including lymphoma, leukaemia)	8 (5.8)	1 (2.2)	7 (7.7)	0.27
Kidney disease	8 (5.8)	3 (6.5)	5 (5.5)	0.99
Moderate or severe liver disease	1 (0.7)	0 (0)	1 (1.1)	0.99
AIDS	0 (0)	0 (0)	0 (0)	-
Metastatic solid tumour	3 (2.2)	1 (2.2)	2 (2.2)	0.99
Lifestyle, n (%)				
Smoking	19 (13.8)	10 (21.7)	9 (9.9)	0.06
Alcoholism	8 (5.9)	3 (6.7)	5 (5.5)	0.99
Drug abuse	2 (1.5)	0 (0)	2 (2.2)	0.60
Incorrect bodily hygiene	2 (1.5)	1 (2.2)	1 (1.1)	0.99
Preoperative and clinical data				
Preoperative length of stay, days, median (IQ)	1 (0.7-2.3)	1.4 (0.7-3.4)	0.9 (0.7-2)	0.17
Previous intervention on the same site, n (%)	28 (20.4)	8 (17.4)	20 (22)	0.53
Oncological surgery, n(%)	5 (3.7)	1 (2.2)	4 (4.4)	0.66
Preoperative infection, n(%)	15 (11)	4 (8.7)	11 (12.1)	0.55
Preoperative antibiotic treatment, n(%)	12 (8.8)	2 (4.4)	10 (11)	0.34
Preoperative isolated fever, n(%)	5 (3.7)	0 (0)	5 (5.5)	0.17
Emergency surgery, n(%)	48 (35)	13 (28.3)	35 (38.5)	0.24
Accidentology, n(%)	31 (22.6)	10 (21.7)	21 (23.1)	0.86
Fracture, n(%)	100 (73)	35 (76.10)	65 (71.4)	0.60
Fracture, n(%)				0.71
Open	8 (8)	2 (5.7)	6 (9.2)	
Closed	92 (92)	33 (94.3)	59 (90.8)	

Prevention measures				
Number of preoperative antiseptic showers, n(%)				0.01
0	45 (32.9)	26 (56.5)	19 (20.9)	
1 or 2	92 (67.2)	20 (43.5)	72 (79.1)	
Skin preparation, n(%)				0.26
Alcoholic povidone-iodine/Alcoholic Betadine^{MD}	66 (78.6)	23 (76.7)	43 (79.6)	
Povidone-iodine/Dermal Betadine^{MD}	12 (14.3)	3 (10)	9 (16.7)	
Alcoholic chlorhexidine/ChloraPrep^{MD}	6 (7.1)	4 (13.3)	2 (3.7)	
Antibiotic prophylaxis, n(%)				
Non-compliant*	32 (23.7)	13 (29.6)	19 (20.9)	0.27
Indicated and not done	3 (2.2)	2 (4.6)	1 (1.1)	0.25
Non-compliant molecule	3 (2.3)	3 (7.1)	0 (0)	0.03
Non-compliant dose	13 (9.9)	5 (11.9)	8 (8.9)	0.76
Non-compliant delay	16 (12.6)	5 (13.2)	11 (12.4)	0.99
Non-compliant re-injection	1 (0.8)	0 (0)	1 (1.1)	0.99
Data regarding the surgery				
Season, n(%)				0.53
Winter (january to march)	49 (35.8)	14 (30.4)	35 (38.5)	
Spring (april to june)	43 (31.4)	14 (30.4)	29 (31.9)	
Summer (july to september)	24 (17.5)	11 (23.9)	13 (14.3)	
Autumn (october to december)	21 (15.3)	7 (15.2)	14 (15.4)	
Carried out on a non-business	16 (11.7)	8 (17.4)	8 (8.8)	0.14

day, n (%)

Unit, n(%)				0.56
Orthopaedics	37 (27)	15 (32.6)	22 (24.2)	
Traumatology	66 (48.2)	20 (43.5)	46 (50.6)	
Emergency	34 (24.8)	11 (23.9)	23 (25.3)	
Running order, n(%)				0.87
1	35 (29.7)	11 (28.2)	24 (30.4)	
2	26 (22)	8 (20.5)	18 (22.8)	
3	28 (23.7)	11 (28.2)	17(21.5)	
4	18 (15.3)	5 (12.8)	13 (16.5)	
5	9 (7.6)	4 (10.3)	5 (6.3)	
6	2 (1.7)	0 (0)	2 (2.5)	
Number of people in the unit, median (IQ)	6 (5-7)	6 (5-8)	6 (4-7)	0.22
Type of surgery, n(%)				0.80
Other osteosyntheses	74 (54)	27 (58.7)	47 (51.7)	
Osteosynthesis of the upper end of the femur	12 (8.8)	2 (4.4)	10 (11)	
Knee prosthesis	21 (15.3)	7 (15.2)	14 (15.4)	
Hip prosthesis	23 (16.8)	8 (17.4)	15 (16.5)	
Re-intervention	7 (5.1)	2 (4.4)	5 (5.5)	
Multifaceted procedure, n(%)	10 (7.3)	2 (4.4)	8 (8.8)	0.50
Non-intact skin condition around the incision, n(%)	48 (35)	19 (41.3)	29 (31.9)	0.27
Septic incident, n(%)	0 (0)	0 (0)	0 (0)	-
Non-septic incident, n(%)	4 (2.9)	1 (2.2)	3 (3.3)	0.99
Operation length greater than	52 (38)	22 (47.8)	30 (33)	0.09

the 75 th percentile, n(%)				
Altemeier classification, n(%)				0.60
1	103 (75.2)	35 (76.1)	68 (74.7)	
2	27 (19.7)	10 (21.7)	17 (18.7)	
4	7 (5.1)	1 (2.2)	6 (6.6)	
ASA Score, n(%)				0.16
1	38 (28.4)	12 (26.1)	26 (29.6)	
2	51 (38.1)	13 (28.3)	38 (43.2)	
3	38 (28.4)	18 (39.1)	20 (22.7)	
4	7 (5.2)	3 (6.5)	4 (4.6)	
NNISS Score, n(%)				0.001
0	49 (36.6)	8 (17.4)	41 (46.6)	
1 or 2	85 (63.4)	38 (82.6)	47 (53.4)	
Postoperative data				
Total length of stay, days,	10 (7-16)	12.5 (7-21)	10 (6-15)	0.10
median (IQ)				
Extension of antibiotic	3 (2.3)	0 (0)	3 (3.3)	0.55
prophylaxis, n(%)				
Death during hospitalisation,	6 (4.4)	1 (2.2)	5 (5.5)	0.70
n(%)				
Time between the intervention	384 (148-676)	493 (160-744)	360 (120-637)	0.10
and last contact, days, median				
(IQ)				

IQ: Inter Quartiles, BMI: Body Mass Index, AIDS: Acquired Immune Deficiency Syndrome, ASA: American Society of Anaesthesiologists, NNISS: National Nosocomial Infections Surveillance System.

*Indicated and not done or non-compliance of the molecule, of the dose, of the administration-incision time period or non-compliance of the re-injection

Table 2. Multivariable analysis of the risk factors for monomicrobial *S. aureus* surgical site infection after orthopaedic and trauma surgery.

Risk factors	OR	p-value	[CI] 95%
Number of showers:			
0	Ref.		
1 or 2	0.3	0.003	[0.1-0.7]
NNISS:			
0	Ref.		
1 or 2	5.8	0.004	[1.8-19.1]
Tobacco	8.4	0.03	[1.2-59.6]
Diabetes	3.2	0.1	[0.9-11.3]

OR: Odds-ratio, CI_{95%}: Confidence Interval at 95%, Ref: Reference, NNISS: National Nosocomial Infections Surveillance System.

NNISS*Tobacco Interaction was take into account in the model. The p-value from the Hosmer–Lemeshow test was 0.9 (Chi2 = 2.14). The area under the ROC curve was 0.8.

Figure 1. Flow chart for the distribution of cases and controls in the cohort

SSI: Surgical site infections

*From 1st January to 30th April 2015; **monomicrobial with another micro-organism, polymicrobial, micro-organism not found

Figure 2. Incidence (%) of monomicrobial *S. aureus* surgical site infections after orthopaedic and trauma surgery as a function of the years.

- ◆— Incidence of monomicrobial *S. aureus* surgical site infections after orthopaedic and trauma surgery and trend as a function of the years.
- Linear regression line of the incidence of monomicrobial *S. aureus* surgical site infections after orthopaedic and trauma surgery as a function of the years.

38,684 interventions performed in the emergency, orthopaedics, and trauma unit
2012 n= 9,508, 2013 n= 9,517, 2014 n= 9,763, 2015* n=3,484

10,132 tracked interventions performed in the emergency, orthopaedics, and trauma unit
2012 n=1,565, 2013 n=3,534, 2014 n=3,640, 2015* n= 1,393

2,422 non-orthopaedic interventions in the emergency unit excluded
2012 n=617, 2013 n=718, 2014 n=787, 2015* n=300

7,710 orthopaedic and trauma interventions (knee or hip prostheses, replacement hip or knee prostheses, osteosyntheses of the upper end of the femur and other osteosyntheses, except for cranial and vertebral)
2012 n=948, 2013 n=2,816, 2014 n=2,853, 2015* n=1,093

203 interventions for surgery of the hand, the scaphoid, and the carpus excluded
2012 n=0, 2013 n=81, 2014 n=88, 2015* n=34

7,507 orthopaedic and trauma interventions of interest
2012 n=948, 2013 n=2,735, 2014 n=2,765, 2015* n=1,059

69 patients aged under 16 years
2012 n=0, 2013 n=37, 2014 n=22, 2015* n=10

7,438 interventions selected
2012 n=948, 2013 n=2,698, 2014 n=2,743, 2015*

50 interventions followed by a monomicrobial *S. aureus* SSI
2012 n=3
2013 n=19
2014 n=20
2015* n=8

87 interventions followed by another SSI**
2012 n=11
2013 n=33
2014 n=27
2015* n=16

7,301 interventions not followed by SSI
2012 n=934
2013 n=2646
2014 n=2,696
2015* n=1,025

