JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Original Article

Incidence of surgical site infections and prediction of risk factors in a hospital center in Morocco

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Abstract
Introduction: Surgical site infections (SSIs) remain the major cause of morbidity and mortality in the postoperative period and are important surgical and hospital quality indicators. In this context, our study aims to identify SSIs associated risk factors and to develop a predictive model.
Methodology: 2521 patients who underwent surgery, between June 2018 and May 2019, in four surgery departments, at the Taza Provincial Hospital (Morocco) were diagnosed for SSI according to the standards of the Center for Disease Control and Prevention. The SSIs' risk factors were assessed by univariate statistical analysis and logistic regression using the Scikit Learn function of Python.
Results: The average age of the studied population was 35 ± 1 years. The overall SSI incidence was 6.3% (17.95%, 6.86%, 6.67% and 3.16% respectively in child, female, male and gynaecological-obstetrical surgeries. The univariate statistical analysis has shown a highly significant ($p < 0.001$) and a very significant ($p < 0.01$) relationship between SSIs and almost all risk factors; and the logistic regression model has revealed a strong association between SSI and people who have had previous surgery, urinary catheter, antibiotic use duration, co-morbidity, American Society of Anesthesiologists (ASA) score, duration of intervention, emergency preoperative and postoperative durations, service, specialty and age range. The prediction score exceeds 96% which justifies our model's quality.
Conclusions: SSIs are generally frequent among postoperative patients. Therefore, pre-operative preparation, post-operative surveillance and the environment quality of the wards are necessary to reduce SSI rates in the hospital.

Key words: incidence; surgery; surgical site infection; hospital; prediction.

J Infect Dev Ctries 2022; 16(7):1191-1198. doi:10.3855/jidc.15289

(Received 07 May 2021 – Accepted 25 April 2022)

Introduction
Surgical site infections (SSIs) are among the most common nosocomial infections in the hospital environment, which occur in hospitalised patients undergoing surgery and differ from one hospital establishment to another [1]. Indeed, these infections are ranked second among nosocomial infections after urinary tract infections [2] and their rate worldwide is between 2.5% and 41.9% [3]. In Africa, the incidence of SSIs varies from 6.8% to 26% with significant heterogeneity depending on the specialty and the surveillance method [4].

Moreover, SSIs are the most frequent post-operative consequences in patients, and associated with morbidity, at a mortality rate of 3% to 75%; in addition to an increase in the length of stay and the cost of care, both for the State and for the patients [5]. Patients who develop SSI are twice as likely to die compared to patients who do not [6].

According to the Center for Disease Control and Prevention (CDC) several risk factors are linked to SSIs as predisposing factors. The American Society of Anesthesiologists' (ASA) System Index classifies patients according to their clinical status; while the National Nosocomial Infection Risk Index Surveillance

System (NNIS) classifies patients based on the surgical wound classification, duration of surgery, and co-morbidity. The World Health organization (WHO) recommends periodic surgical monitoring of patients and risk factors control procedures to reduce SSIs [7].

However, studies on the SSI incidence are rarely conducted in Morocco. The last survey on nosocomial infections prevalence, conducted in 2011, estimated its rate at 5.5% of which 38.8% are surgical site infections [8]. To the best of our knowledge, there are no studies carried out in the provincial hospital center Ibn Baja of Taza in Morocco, which is the site of our study. Therefore, this study aims to determine, for the first time, the incidence rate of SSIs and to show the SSIs predictors in the specialised surgery departments of this provincial hospital center. The results of our study will provide basic information on the incidence and risk factors of SSIs.

Methodology

Study type and medium

We carried out a prospective study over the period of one year, from June 2018 to May 2019, in the Provincial Hospital of Taza (Fez-Meknes region, north-eastern Morocco) which has a bedding capacity of 317 beds. 42% of the bedding capacity is distributed within four of the surgical care units (36 beds in the men's surgery unit, 26 beds in the women's surgery unit, 26 beds in the infant surgery unit and 43 beds in obstetric gynecology surgery unit).

The study population

The studied population included 2521 patients, corresponding to all patients, in the specialized surgical wards during the above-mentioned study period, who had undergone surgery. Patients who were admitted in the day hospital and those who did not undergo any surgery were excluded from this study.

Data collection instruments

We used a standardized form for data collection. The SSI was considered as a dependent variable; while the independent variables included: the care unit characteristics (specialty and pathology), patient characteristics (admission number, age, sex, and admission date to hospital), patient's exposure characteristics (urinary catheter, venous catheter, drain, antibiotic use, and associated pathologies), surgical intervention characteristics (date of surgery, wound class, American Society of Anesthesiologists (ASA) score), surgery duration and nature (urgent or scheduled), and surgical site infection' characteristics (SSI, date and site of infection).

Nursing staff and nursing students, of the departments concerned, were trained to collect patient data when registering according to the pre-established standardized form.

Monitoring SSI in the hospital

It should be noted that the determination of surgical site infection characteristics used in the diagnosis of SSIs was performed according to the Center for Disease Control and Prevention (CDC) standards [9]. Surgical site infections occur within 30 days after surgery, but when a prosthetic implant is used, it may occur after one year. There are three types of SSIs and the presence of at least one component at each infection site confirms the infection type at the surgical site: superficial, deep, or organ infection. Nursing students and nurses practicing in the surgical departments were trained in the criteria for identifying an SSI according to CDC standards, when changing dressings.

Monitoring SSI after discharge from hospital

Upon discharge from hospital, each patient was given a blue discharge card for wound monitoring at the health centers located near the patient's home. These patients were asked to return to the ward if one or more signs of SSI were observed during bandage change. Unfortunately, patients who lived far away from the hospital center, such as in rural areas, were not able to return. This is one of the main limitations of this study.

Statistical analysis

Data were analyzed using Python. Steps for data analysis and processing included data cleansing, removing missing values, transformation and conversion of data to unified formats, and attribute engineering (adding attributes for the improvement and analysis of our model). The data was then reviewed and summarized to understand the data and the distribution of the variables. Finally, we calculated the global incidence of SSIs according to the period of study, as well as the Odds Ratio (OR) and the 95% confidence interval (CI) to estimate the risk factors at a significance level < 5%. We considered the p value < 0.001 highly significant, the p value < 0.01 very significant, and the p value < 0.05 significant.

Predictive analysis

A multivariate logistic regression was used to study the indicator variables in our study. The indicator variables of the SSIs were transformed to: yes = 1 and no = 0, in order to predict the SSIs according to the indicator variables. The methodology included the following steps:

Step 1: Data preparation and engineering: creation, normalization and transformation of attributed data (e.g. age transformation from continuous to age range)

Step 2: Balancing the target SSI values: the simple random method was used in this step to balance values from the unbalanced data (the absence of SSI far exceeded the presence of SSI).

Step 3: The logistic regression model: in this step our data set was divided, into two random sets: a training set with 70% of the values and a test set with 30% of the values. The training set was considered as

Table 1. Univariate analysis of the risk factors of SSI in Taza's hospital center.

	Total	SSI + n = 159	SSI- n = 2362	Odds ratio	95% CI	*p* value
Services						
Woman surgery	437	30 (06.86%)	407 (93.14%)	-	-	< 0.001
Man surgery	599	40 (06.67%)	559 (93.33%)			
Infant surgery	284	51 (07.95%)	233 (82.05%)			
Gyneco-obstetrics	1201	38 (03.16%)	1163 (96.84%)			
Age						
< 20 yrs	525	59 (11.23%)	466 (88.77%)	-	-	< 0.001
20-40 yrs	1243	45 (03.62%)	1198 (96.38%)			
40-60 yrs	413	26 (06.29%)	387 (93.71%)			
> 60 yrs	340	29 (08.52%)	311 (91.48%)			
Venous catheter						
Yes	2477	153 (06.17%)	2324 (93.83%)	0.4171	[0.1713; 1.2263]	0.055
No	44	06 (13.63%)	38 (86.37%)			
Gender						
Female	1713	86 (05.02%)	1627 (94.98%)	0.5323	[0.3802; 0.7469]	< 0.001
Male	808	73 (09.03%)	735 (90.97%)			
Redon drain						
Yes	464	63 (13.57%)	401 (86.43%)	3.2073	[2.2541; 4.5395]	< 0.001
No	2057	96 (04.66%)	1961 (95.34%)			
Antibiotic treatment						
Yes	2303	156 (07.23%)	2147 (87.07%)	5.2054	[1.7238; 25.7315]	< 0.001
No	218	03 (01.37%)	215 (98.63%)			
Comorbidity						
Yes	295	27 (09.15%)	268 (90.85%)	1.5978	[0.9954; 2.4866]	0.040
No	2226	132 (05.92%)	2094 (94.08%)			
Urinary catheter						
Yes	1512	71 (04.69%)	1441(95.31%)	0.5158	[0.3677; 0.7216]	< 0.001
No	1009	88 (08.72%)	921 (91.28%)			
Emergency admission						
Yes	2114	150 (07.09%)	1964 (92.11%)	3.3764	[1.7119; 7.5935]	< 0.001
No	107	09 (02.21%)	398 (97.79%)			
ASA Score						
1	2218	131 (05.90%)	2087 (94.10%)	-	-	0.06
2	284	27 (09.50%)	257 (90.50%)			
3	19	01 (05.26%)	18 (94.74%)			
Wound class						
Clean	211	38 (18.01%)	173 (91.99 %)	-		< 0.001
Clean- contaminated	746	25 (03.35%)	721 (96.65%)			
Contaminated	1495	74 (04.94%)	1421 (95.06%)			
Dirty - infected	69	22 (31.88%)	47 (68.12%)			
Surgical intervention in the last months before surgery						
Yes	2490	145 (05.82%)	2345 (94.18%)	0.0753	[0.0342; 0.1685]	< 0.001
No	31	14 (45.16%)	17 (41.94%)			
The postoperative duration						
≤ 5 days	2253	36 (01.59%)	2217 (98.41%)	0.0192	[0.0124; 0.0292]	< 0.001
> 5 days	268	123 (45.89%)	145 (54.11%)			
The preoperative time						
≤ 3 days	2158	124 (05.74%)	2034 (94.26%)	0.5715	[0.3821;0.873]	0.007
> 3 days	363	35 (09.64%)	328 (09.36%)			
The duration of the intervention						
≤ 90 min	1555	67 (04.30%)	1488 (95.69%)	0.4279	[0.3041; 0.5996]	< 0.001
> 90 min	966	92 (09.52%)	874 (90.47%)			
Antibiotic use duration						
≤ 8 days	2421	91 (03.75%)	2330 (96.24%)	0.0185	[0.0112; 0.0301]	< 0.001
+ 8 days	100	68 (68%)	32 (32%)			

SSI: Surgical Site Infection; ASA: American Society of Anesthesiologists; CI: Confidence Interval.

input in our logistic regression model, with SSI as Y variable and the risk factors as X variables, and used to test the predicted values.

Step 4: Model evaluation: score accuracy and the indicator (recall/precision) were applied to develop the Receptor operating characteristic (ROC).

Ethical considerations

This study was conducted by maintaining confidentiality, anonymity and the informed consent of the patients, the authorisation was approved by the regional health service of Fez-Meknes (DRS Fez-Meknes Number: 2146.04.2018).

Results

Demographic characteristics

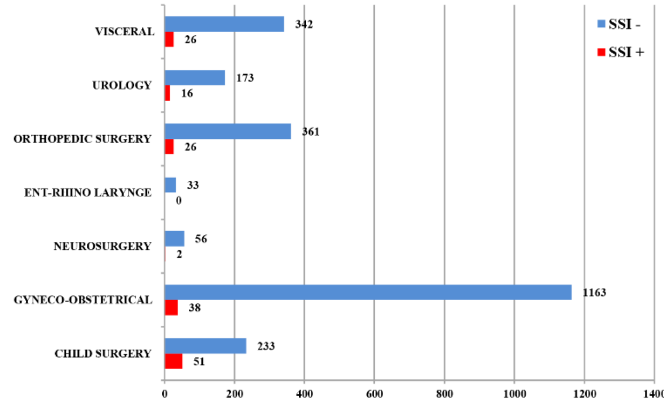
There were 2640 registered patients and 2521 of them were followed up. This set of patients included 68% female and 32% male with a mean age of 35 years (±1) and a standard deviation of 19.94. Four patients died during the study and two of them had developed SSIs. The study population was distributed in four departments: 11% in child surgery, 17% in women surgery, 24% in men surgery, and 48% in obstetric gynecology.

Incidence of surgical site infections

During this study, 159 patients developed SSI with an incidence rate of 6.3% (95% Confidence Interval (CI): [5.358%, 7.256%]). The incidence of SSIs varied from one service to another: 6.86% in female surgery, 6.68% in male surgery, 17.96% in child surgery, and 3.16% in gynecological-obstetrics. Among the SSIs sites, 89 are superficial infections, 60 are deep infections and 10 are dirty or organ infections according to the criteria established by CDC. The SSI's distribution according to specialties was as follows: child surgery is most affected (n = 51), followed by gyneco-obstetrics (n = 38), orthopedic and visceral surgery (n = 26), urology (n = 16), and neurosurgery (n = 02), and SSIs are absent in otolaryngeal surgery (Figure 1).

Risk factors

Figure 1. Distribution of surgical site infections according to specialties.



SSI-: Absence of surgical site infections; SSI+: Presence of surgical site infections.

The risk factors associated with patients according to the pre-established criteria were: 11.7% (n = 295) had co-morbidity; 83.86% (n = 2114) were admitted in emergency; 9.13% (n= 2303) were taking antibiotics; 18.41% (n= 464) were under Redon's drain; and 9.98% (n= 1512) had urinary catheters. The ASA score distribution was: ASA1: 87.98% (n = 2218), ASA2: 11.27% (n = 284), ASA 3: 0.75% (n = 19). The wound classes were as follows: clean: 29.59% (n = 746), clean contaminated: 59.30% (n = 1495), contaminated: 8.37% (n = 211), infected: 2.74% (n = 69)). 1.23% of the patients (n = 31) had another surgery within the last month; 10.63% (n = 268) were postoperative more than 5 days; 14.39% (n = 363) were > 3 days preoperative; and 38.31% (n = 966) more than 90 minutes postoperative.

With regards to the association between SSIs and the risk factors, there has been a highly significant relationship between SSIs and services, age, sex, Redon drain wearer, antibiotic use, emergency admission, wound class, urinary catheter, surgical intervention in the last months before surgery, postoperative duration and duration of intervention ($p < 0.001$); a very significant relation was identified between SSIs and preoperative duration ($p < 0.01$) and a significant relationship between SSIs and associated pathology.

Table 2. Distribution of interventions according to the NNIS score.

Interventions	Number of interventions	Number of SSI	Incidence rate %	IC 95%
TOTAL	2521	159	6.30%	[5.35%,7.256%]
NNIS 0	746	37	4.95%	[3.40%, 6.51%]
NNIS 1	1617	88	5.44%	[4.33%, 6.54%]
NNIS 2- 3	158	34	2.15%	[15.11%, 27.92%]

NNIS: National Nosocomial Infections Surveillance; IC: interval of confidence.

However, no association has been noticed between SSIs, venous catheter and ASA score ($p > 0.05$) (Table 1).

With regard to the National Nosocomial Infections Surveillance (NNIS) scores, our study shows 29.60% (n = 746) for NNIS 0; 64.14% (n = 1617) for NNIS 1 and 6.26% (n = 158) for NNIS 2 indicating that about 65% of the studied population is classified in the NNIS 1 score (Table 2).

SSI prediction model

Logistic regression was applied to predict and understand the risk factors. The choice of this model is justified by the fact that the responses of our SSIs target are binary (yes or no) on the one hand, and the techniques for adjusting our variables and evaluation are very efficient compared to other models in the scientific field.

Results of the logistic regression model show that the prediction model was based on a 70% random sample of the cohort; validation was performed on the remaining 30% random sample. In this part of the test cohort and after controlling for concurrent risk factors of logistic regression analysis, variables with *p*-values > 0.05 were eliminated, and those having *p* values < 0.05 were kept.

A strong association with SSIs has been found for the following variables: patients who had previously undergone another surgery in the last months, urinary catheter, duration of antibiotic use, ASA, duration of the intervention, emergency, preoperative duration and postoperative duration, service, specialty, age range that remained highly significant for SSIs ($p < 0.001$); and a significant relationship was observed between SSIs, comorbidity and the use of antibiotics ($p < 0.01$) (Table 3).

Table 3.1. Logistic regression of SSIs' risk factors in Taza's hospital center -- Before removing non-significant variables.

	Coef	std err	z	*p*>|z|	[0.025	0.975]
Const	1746.8229	413.708	4.222	0.000	935.971	2557.675
Month	-0.0470	0.030	-1.590	0.112	-0.105	0.011
Gender	0.3985	0.210	1.899	0.058	-0.013	0.810
Surgery in the last few months	2.1080	0.471	4.477	0.000	1.185	3.031
Urinary Catheter	-1.0822	0.225	-4.799	0.000	-1.524	-0.640
Venous Catheter	-0.7549	0.570	-1.324	0.185	-1.872	0.362
Redon drain	0.1621	0.217	0.746	0.455	-0.264	0.588
Antibiotic	1.0272	0.389	2.639	0.008	0.264	1.790
Duration of antibiotic	1.1351	0.052	21.978	0.000	1.034	1.236
Comorbidity	1.0229	0.363	2.821	0.005	0.312	1.733
ASA	-1.3833	0.380	-3.639	0.000	-2.128	-0.638
Duration of the intervention	-0.0285	0.005	-5.892	0.000	-0.038	-0.019
Emergency	3.1848	1.253	2.542	0.011	0.729	5.641
Program	1.8997	1.243	1.528	0.126	-0.536	4.336
Preoperative time	-0.3335	0.038	-8.833	0.000	-0.408	-0.260
Postoperative time	0.3236	0.032	10.267	0.000	0.262	0.385
Service	0.8600	0.157	5.493	0.000	0.553	1.167
Wound class	0.1004	0.103	0.978	0.328	-0.101	0.302
Specialty	-0.2537	0.066	-3.859	0.000	-0.383	-0.125
Age range	0.7269	0.248	2.927	0.003	0.240	1.214

Table 3.2. Logistic regression of SSIs' risk factors in Taza's hospital center -- After removing non-significant variables.

	Coef	std err	z	*p*>|z|	[0.025	0.975]
Const	1506.9643	326.370	4.617	0.000	867.290	2146.638
Surgery in the last few months	2.0948	0.478	4.384	0.000	1.158	3.031
Urinary Catheter	-1.2053	0.201	-6.000	0.000	-1.599	-0.812
Antibiotic	1.0853	0.371	2.922	0.003	0.357	1.813
Duration of Antibiotic	1.1314	0.051	22.299	0.000	1.032	1.231
Comorbidity	1.1154	0.366	3.050	0.002	0.399	1.832
ASA	-1.5594	0.392	-3.976	0.000	-2.328	-0.791
Duration of the intervention	-0.0265	0.004	-5.897	0.000	-0.035	-0.018
Emergency	1.3459	0.304	4.430	0.000	0.750	1.941
Preoperative time	-0.3166	0.036	8.708	0.000	-0.388	-0.245
Postoperative time	0.3176	0.029	10.925	0.000	0.261	0.375
Service	0.7765	0.147	5.300	0.000	0.489	1.064
Specialty	-0.2627	0.065	-4.063	0.000	-0.389	-0.136
Age range	0.6017	0.123	4.909	0.000	0.361	0.842

SSI: Surgical Site Infection; ASA: American Society of Anesthesiologists.

In order to evaluate the results of the predicted SSIs, methods from the Python Scikit Learn family were adopted (cross validation, confusion matrix, Recall accuracy and ROC).

Test evaluation against predicted results yielded 87% ROC code area which justifies the performance of our model (Figure 2).

Discussion

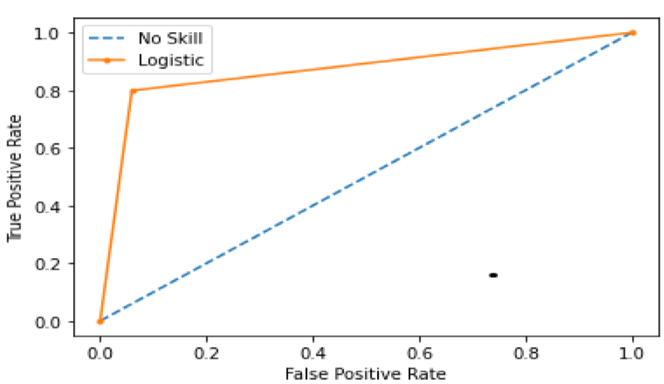
Our study is the first such study carried out in the Provincial Hospital of Taza concerning the incidence of SSIs. The SSIs incidence rate, found in this study (6.3%), corroborates with those reported in other studies carried out in Brazil (6.4%) [10], Turkey (4.09%) [11], India (5%) [12], Pakistan (7.3%) [13], and Algeria (5.4%) [14]; while it is lower than that obtained in many other countries: Ethiopia (13%) [15], Egypt (17.6%) [16], Saudi Arabia (11.4%) [17], Nigeria (27.6%) [18] and Tanzania (26%) [19].

The low incidence rates are generally due to several factors: firstly, the large number of patients with no comorbidities and the low patient's ASA score (ASA 1 represents about 90% of the studied population); and secondly, the patients who had signs of infection after discharge from hospital, but lived in far way inaccessible regions may have been missed.

Several studies showed that more than 50% of SSIs occur within the first week after surgery and about 90% within a fortnight [14]. The age group participating in our study was between 20 and 40 years old, which represent about half of our target population.

Furthermore, in this study, children under 18 years old represent the population most affected by SSIs with an incidence rate of 17%. This incidence rate is high compared to those reported in a number of investigations conducted in other countries [20-22], even though it remains lower than that reported in sub-Saharan African countries [23]. This high SSI incidence can generally be due to the children's post-operative agitation and movement, the quality of care provided to them or their weak immunity.

Figure 2. Receptor Operating Characteristic (ROC) curve diagram of the surgical site infection risk factor prediction model.



The next most affected specialties were orthopaedic and visceral surgeries, showing respective incidence rates of 6.71% and 7.06%. Even though these rates differ from those reported in studies carried out in this context [24-28], they comply with the ISO standards at national level, for both specialties.

The rate for gynaecological and obstetric surgery (3.16%) remains lower than those reported in numerous studies carried out in Africa [29,30] and in other countries of the world [31,32]. Likewise, the incidence rate for urology was low compared to other studies (20.1%) [33]. This was the same in neurosurgery, whereas in nasopharyngeal surgery no SSI was recorded in our study. Furthermore, the number of deaths with SSI recorded in the present study (n = 2), remains too low compared to the studied population sample.

The univariate analysis shows a significant relationship between almost all the studied factors. Moreover, the regression model which showed efficiency and performance with respect to the predicted results, with an ROC code area of 87% (Figure 2), reveals a very significant relationship between SSIs and the use of antibiotics, and co morbidity ($p < 0.01$) and a highly significant relation between SSIs and surgery in the last few months, urinary catheter, duration of antibiotic use, ASA, emergency, preoperative and postoperative duration, duration of intervention, emergency, service, specialty, and age range ($p < 0.001$) (Table 3). These relationships may be related to a modification of the cutaneous and digestive microbial flora of patients during their hospitalization for more than 5 days. Indeed, the hospital environment may contaminate patients during their stay in hospital. The body and clothing hygiene, patient skin preparation, post-operative monitoring of the patient's condition, and the quality of care provided to patients may also be involved. Several studies have explained that the use of antibiotics more than two days after surgery can have a negative impact on the patient's condition, and should be avoided [34]. However, there are no written guidelines and standards for antibiotic prophylaxis of SSI in this hospital centre. Prophylaxis is prescribed depending on the availability of antibiotics in the hospital, which can lead to a mismatch between certain antibiotic's prescription and the patient's health condition, causing SSI incidence to increase and inducing bacterial resistance. The logistic regression analysis did not show any association between SSIs and some factors which have been previously reported in numerous studies, such as the wound class.

Based on the model used, our study shows a significant association between SSIs on the one hand, and pre- and post-operative duration, service, duration of antibiotic use and the patients undergoing a surgical intervention before surgery, on the other hand.

These results present a database for some of SSI's risk factors in the studied hospital center; provide a starting point towards the promotion of new health care practices in surgical departments, and show the value of awareness on the necessary SSI's control measures that need to be implemented to reduce these incidence rates in order to improve not only patient safety, but also the care quality in hospital especially in the pre- and post-operative periods. The adoption of such new health care practices and the professional's awareness on the SSIs control can be extrapolated to other hospitals having similar characteristics and specificities, especially in other developing countries, to reduce the SSIs incidence on the one hand and improve the quality of post-operative care on the other hand.

Finally, the SSIs incidence rates variation from one hospital to another depends both on the ward's characteristics and the patients, and may also be due to differences in the monitoring method. Therefore, it is necessary to standardize an SSI monitoring system to allow valid and efficient comparison of results.

Conclusions

The study aimed to identify the risk factors associated with SSI in a significant number of patients operated over a period of one year in a provincial hospital in Morocco and concluded that the SSI incidence was 6.3%, with predominance in children in the child surgery department followed by women's and men's surgeries and finally the gynaecology-obstetrics department.

Moreover, it shows significantly high relationships between SSIs and almost all risk factors according to the univariate statistical analysis. Strong associations were found based on the logistic regression model between SSIs and patients having recently undergone another surgery, urinary catheter, antibiotic use duration, comorbidity, ASA score, intervention duration, emergency pre- and post-operative durations, service, specialty and age range. Hence, in order to reduce the risks and the severity of these infections, which are frequent among postoperative patients, all hospital partners must commit to ensure the quality of patient care before, during and after surgery, which represents a first step towards raising health professionals' awareness and patient monitoring. Finally, it is important to notice that this study highlights a lot of perspectives, such as focusing next investigations in only one surgical unit to reduce the number of studied surgical services and specimens; and including other risk factors such as body mass index, patients' education level, body hygiene and preoperative preparation.

Acknowledgements

The authors would like to thank the Fez-Meknes regional health directorate. They also thank the team and health professionals of the Ibn Baja provincial hospital center of Taza; for their collaboration, their patience and their precious help.

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Conflict of interests: No conflict of interests is declared.