

Surgical site infections: A prospective study in a pediatric surgery center in resource-limited setting

Infections du site opératoire: Etude prospective dans un centre de chirurgie pédiatrique en contexte de ressources limitées

Samia Belhassen^{1,4}, Afef Toumi^{1,4}, Imene Ben Hawala², Myriam Ben Fredj^{1,4}, Sana Mosbahi^{1,4}, Sabrine Ben Youssef^{1,4}, Sami Sfar^{1,4}, Amine Ksia^{1,4}, Mongi Mekki^{1,4}, Mohsen Belghith^{1,4}, Sawsen Chakroun^{3,4}, Lassaad Sahnoun^{1,4}.

1. Department of Pediatric surgery, Fattouma Bourguiba University hospital, Monastir
2. Department of Hospital Hygiene and Sterilization, Fattouma Bourguiba University Hospital, Monastir, Tunisia
3. Department of Pediatric anesthesiology and reanimation, Fattouma Bourguiba University Hospital, Monastir
4. Research Laboratory LR12SP13, Faculty of Medicine of Monastir, Tunisia

ABSTRACT

Aim: This study aimed to measure the incidence of surgical site infections (SSI) in pediatric population, identify the primary characteristics and risk factors associated with SSI, and propose practical recommendations for controlling and preventing these infections.

Methods: A prospective study was conducted over a 4-month period from February 1 to June 1, 2024, in the Pediatric Surgery Department of Monastir. All patients admitted, operated on, and followed up in the department during this period were included, with specific exclusions. Data on patient demographics, surgical details, and outcomes were collected daily. Statistical analysis involved both univariate and multivariate approaches to identify significant risk factors.

Results: Among the 414 pediatric patients included in the study, the incidence of surgical site infection (SSI) was 3.3%, with an incidence density of 11.9 cases per 1,000 hospital days. The analysis of individual and surgical risk factors for SSI identified several significant associations: Neonates and infants (<2 years) were at higher risk ($p=0.039$), as were patients with drains ($p=0.000$) or gastric tubes. In terms of surgical risk factors, non-ambulatory surgeries ($p=0.002$), emergency procedures ($p=0.013$), surgeries classified as Altemeier class III or IV (13% vs. 2%, $p=0.000$), a higher NNIS score, and extended postoperative hospital stays compared to home discharges ($p=0.001$) were all associated with increased risk. Multivariate analysis revealed that the presence of a drain, age under 2 years, and an NNIS score of 1 or higher were independent risk factors for developing SSI.

Conclusion: Younger children, presence of drain and NNIS score ≥ 1 were independent risk factors of SSI among children. Further prospective studies targeting SSI are needed to identify intrinsic and extrinsic predictive factors.

Key words: Surgical Site Infection, Health Care Associated Infection, Risk Factor, Child, Prevention

RÉSUMÉ

Objectif : Mesurer l'incidence des infections du site chirurgical (SSI) dans la population pédiatrique, identifier les facteurs de risque associés à la SSI.

Méthodes : Une étude prospective a été menée sur une période de 4 mois à partir du 1er févrierSt au 1er juinSt, 2024, au service de chirurgie pédiatrique de Monastir. Tous les patients admis, opérés et suivis dans le service durant cette période ont été inclus, avec des exclusions spécifiques. Des données sur la démographie des patients, les détails chirurgicaux et les résultats ont été collectées quotidiennement. L'analyse statistique a impliqué des approches univariées et multivariées pour identifier les facteurs de risque significatifs.

Résultats : Parmi les 414 patients pédiatriques inclus dans l'étude, l'incidence de l'ISS était de 3,3 %, avec une densité d'incidence de 11,9 cas tous les 1 000 jours d'hospitalisation. L'analyse des facteurs de risque individuels et chirurgicaux pour la SSI a identifié plusieurs associations significatives : les nouveau-nés et les nourrissons (<2 ans) présentaient un risque plus élevé ($p=0,039$), tout comme les patients avec drains ($p=0,000$) ou des tubes gastriques. Les interventions non ambulatoires, les interventions d'urgence, les interventions classées Altemeier de classe III ou IV (13 % contre 2 %, $p=0,000$), un score NNIS plus élevé, ainsi que des séjours hospitaliers postopératoires prolongés par rapport aux sorties à domicile étaient tous associés à un risque accru. L'analyse multivariée a révélé que la présence d'un drain, l'âge de moins de 2 ans et un score NNIS de 1 ou plus étaient des facteurs de risque indépendants pour développer une SSI.

Conclusion : Les jeunes enfants, la présence de drain et le score NNIS ≥ 1 étaient des facteurs de risque indépendants de SSI chez les enfants. D'autres études prospectives ciblant les SSI sont nécessaires pour identifier les facteurs prédictifs intrinsèques et extrinsèques.

Mots clés: Infection du site chirurgical, Infection associée aux soins de santé, Facteur de risque, Enfant, Prévention

Correspondance

Afef Toumi

Pediatric Surgery department; Fattouma Bourguiba University Hospital, Monastir, Tunisia.

Email: afef.toumi@gmail.com

INTRODUCTION

Surgical site infections (SSIs) are healthcare-associated infections (HAIs) that occur within 30 days following a non-prosthetic surgical procedure or within 90 days after a prosthetic surgery. They are among the most common HAI counting more than 30% (1). SSIs are the main postoperative complication, leading to serious outcomes for patients, including increased comorbidity and mortality. They also have a substantial economic impact on the community (2,3). Addressing SSIs should be a public health priority. Preventing these infections requires careful monitoring. However, research on the incidence of SSIs in the pediatric population is limited (4). Through this study, we aimed to measure the incidence of SSI in the pediatric surgery department, to identify the main characteristics of SSI, and to propose protocols and practical recommendations for controlling and preventing SSI.

METHODS

This was a prospective study conducted in the Pediatric Surgery Department of Monastir over a 4-month period, from February 1 to June 1, 2018.

- Inclusion criteria:

All patients admitted, operated on, and followed up in the Pediatric Surgery Department were included in the study.

- Exclusion criteria:

Patients who underwent invasive diagnostic procedures, interventional radiology, reoperations at the same surgical site unless more than 30 days had passed between procedures, circumcisions, superficial skin abscess incisions, or burn dressings.

- Definitions and classifications:

The definitions of surgical site infections (SSIs) are those provided by the Centers for Disease Control and Prevention (CDC) and are classified into: superficial, deep, and organ or space infections (5). The Altemeier classification helped to categorize surgical procedures based on the risk of contamination and postoperative infection (6). For each patient, we calculated the NNIS (National Nosocomial Infection Surveillance) risk index (7,8). This score assesses the risk of acquiring a postoperative infection and is determined by combining three risk factors: the duration of the procedure, the ASA (American society of anesthesiologists) score of the patient (9), and the contamination class.

- Data collection:

Clinical data in relation with the patient, the surgical procedure itself and the outcomes were collected daily by an intern using a pre-established monitoring sheet. Information sources included the patient's guardian, the medical record, the anesthesia chart, and the healthcare team.

All patients included in the study were to be followed up until the 30th postoperative day, whenever possible.

- Statistical analysis:

Qualitative variables were presented using absolute

and relative frequencies. For quantitative variables, we first assessed the normality of their distribution with the Kolmogorov-Smirnov test. Based on the results, we provided appropriate descriptive measures, either as means or medians.

To explore the relationship between patient and perioperative variables and the occurrence of SSIs, we conducted a univariate analysis. The Chi-square test was used to compare categorical variables, while the Student's t-test was employed for comparing means between two groups, and the Mann-Whitney U test was applied for comparing medians. Variables with a P-value below .05 in the univariate analysis were subsequently included in a multivariate regression analysis. Those with a final P-value under .05 were identified as independent risk factors. This comprehensive statistical approach ensured that our findings were robust and accurately reflected the data.

The statistical analysis was performed using SPSS statistical data editor.

RESULTS

Between February 1 and May 1, 2017, 414 patients were included in our study. The distribution of patients by age group revealed that 58.7% of the population were children over 2 years old. The sex-ratio was 1.4. In our study population, 79.5% of patients across all types of surgery were seen for follow-up in the outpatient clinic within 30 days postoperatively. Among pediatric patients who underwent ambulatory surgery, 83% were seen for follow-up, while 73.5% of those who underwent inpatient surgery were seen for follow-up.

There were 11 cases of SSI, corresponding to an incidence rate of 3.3%. The incidence density was estimated at 11.9 cases per 1,000 hospital days. The distribution of SSIs by site revealed that 4 cases were superficial infections, while 7 were organ or space infections. The time of onset for infections after surgery ranged from 1 to 22 days, with a median of 9 days. The infection developed after discharge in 4 patients (36%), with 1 patient requiring rehospitalization. Seven patients showed clinical signs of SSI during their hospital stay, with 1 requiring additional surgery and the remaining 6 being treated with antibiotics. The outcome was favorable in 10 cases, but there was 1 unfavorable outcome resulting in death. Bacteriological examinations were conducted for 4 patients, leading to the identification of 5 microorganisms: *Escherichia coli*, *Enterobacter cloacae*, methicillin-resistant coagulase-negative staphylococcus (MRCONS), *Klebsiella pneumoniae*, and *Candida tropicalis*. Bacteriological sampling was performed only when a purulent discharge, intraoperative specimen, or drained collection was available. Many SSI cases were superficial infections managed on an outpatient basis or had already received empirical antibiotics, which limited culture sampling.

The estimated total direct cost attributable to SSIs alone is 53,291.87 TND, averaging 4,844.71 TND per infected patient. One neonate required a reoperation

for secondary peritonitis, corresponding to an additional surgical cost of 112 TND (Table.1)

Table 1. Total cost of SSI

	Price (TND)
Cost of additional hospital days	38868
Cost of medications	13098,270
Cost of additional diagnostic tests	1213,600
Cost of additional surgery	112
Total	53291,870

TND : Tunisian dinar

The analysis of individual risk factors revealed that neonates and infants are at a higher risk of developing SSIs ($p=0.039$). The presence of a drain or a gastric tube was also associated with an increased risk of SSIs. Gender, ASA classification, neutropenia, anemia, malnutrition, obesity, low birth weight, preterm birth, mechanical ventilation, parenteral nutrition, and the use of central or peripheral venous catheters did not show statistically significant associations with SSI risk in our study population. The results are summarized in Table 2.

Regarding risk factors related to surgical procedures, small bowel surgery was the most frequently associated with SSI (27%). The average preoperative stay for patients with SSI was $1.82 \text{ days} \pm 3.19 \text{ days}$, compared to $0.70 \text{ days} \pm 2.45 \text{ days}$ for those without SSI, with this difference being statistically significant ($p=0.000$). Non-ambulatory surgeries and emergency procedures were both significantly linked to a higher risk of SSI ($p=0.002$ and $p=0.013$, respectively). SSI were more common in procedures classified as Altemeier class III and IV. Additionally, a higher NNIS score was significantly associated with an increased risk of SSI ($p<0.005$). Longer postoperative hospital stays also contributed to the risk of SSI (Table.3)

After multivariate analysis, the presence of a drain age under 2 years, and an NNIS score of 1 and 2 were identified as independent risk factors for SSI. Results are detailed in table 4.

DISCUSSION

Our study is an incidence survey conducted in the pediatric surgery department, providing baseline data on the frequency and characteristics of SSI within the department. It also allowed us to compare our findings with existing literature. Our incidence rate of 3.3% is significantly lower than those reported in some developing countries (10–12), but is comparable to rates observed in certain developed countries which varies according to studies from 2% to 3.8% (13–17). The results of our study revealed that the incidence of SSIs varied significantly based on patient characteristics and their exposure to specific risk factors. Notably, the incidence was higher among patients under 2 years of age.

Table 2. Individual risk factors for SSI

Variables		ISS				P-value
		Yes N	P	No N	P	
Age	<2 years	8	6%	131	94%	0,039*
	≥2 years	3	2%	187	98%	
Gender	Male	7	3%	259	97%	0,23
	Female	4	6%	59	93%	
ASA	1	11	3%	313	97%	1,000
	2	0	0%	5	100%	
Neutropenia	No	5	3%	170	97%	0,328
	Yes	0	0%	64	100%	
Anemia	No	5	3%	173	97%	0,353
	Yes	6	4%	137	96%	
Denutrition	No	9	3%	299	97%	0,151
	Yes	2	10%	19	90%	
Obesity	No	11	3%	312	97%	1,000
	Yes	0	0%	6	100%	
Birth weight < 2500g	No	11	3%	302	97%	1,000
	Yes	0	0%	16	100%	
Gestational age < 37 weeks	No	11	4%	297	96%	1,000
	Yes	0	0%	21	100%	
Other diagnoses	No	10	4%	277	97%	1,000
	Yes	1	2%	41	98%	
Mechanical ventilation	No	11	3%	316	97%	1,000
	Yes	0	0%	2	100%	
Parenteral nutrition	No	11	3%	317	97%	1,000
	Yes	0	0%	1	100%	
Central venous catheter	No	10	3%	314	97%	0,157
	Yes	1	20%	4	80%	
Peripheral intravenous catheter	No	0	0%	0	0%	1,000
	Yes	11	3%	318	97%	
Urinary catheter	No	8	3%	285	97%	0,107
	Yes	3	8%	33	92%	
Drain	No	6	2%	302	98%	0,000*
	Yes	5	24%	16	76%	
Gastric tube	No	7	2%	290	98%	0,015*
	Yes	4	13%	28	86%	

N : number of patients; P :percentage; ASA: American society of anesthesiology; * $p \leq 0.05$: statistically significant

It is well-established that newborns are more susceptible to infections compared to older children and adults, as they represent a special population that is thought to be at higher risk for infection due to their immature immune systems (16,18). However, in the systematic review by Catania et al. (19), which included over 27,000 patients, the incidence of SSI was 5.5% and notably the overall SSI rate in the neonatal group was similar to that reported in older pediatric patients (20,21). We did not find obesity to be a risk factor of SSI.

Table 3. Surgical Risk Factors and Postoperative Stay for SSI Cases

Surgical procedure characteristics		ISS		P-value	
		YES N	P	NO N	P
Type of surgery:	Ambulatory	2	18%	208	82% 0,002*
	Non-ambulatory	9	82%	110	18%
Altemeier Contamination Class	I and II	4	2%	271	98% 0,000*
	III and IV	7	3%	47	87%
Surgery context	Emergency	5	10%	43	90% 0,013*
	Elective	6	2%	275	98%
Surgical approach	Laparotomy	11	3%	305	97% 1,000
	Laparoscopy	0	0%	13	100%
Surgeon	Resident	1	1%	109	99% 0,108
	Senior	10	5%	209	95%
Surgery duration	≤75th percentile	9	4%	250	96% 1,000
	>75th percentile	2	3%	68	97%
NNIS score	0	2	1%	224	99% 0,000*
	1	9	11%	72	89%
	2	0	0%	2	100%
	Hospital	10	8%	120	92% 0,001*
Postoperative Stay	Home	1	1%	198	99%

N : number of patients; P :percentage; *p ≤ 0.05 : statistically significant

Table 4. Independent risk factors for SSI

Risk factors	P-value	IC à 95%
Age	0,011*	1,79-84,58
Drain	0,001*	3,55-158,44
NNIS 0	0,024*	-
NNIS 1	0,006*	1,93-53,44
NNIS 2	0,998	-

*p ≤ 0.05 : statistically significant; IC : interval of confidence

However, Winfield et al. (22) and Meijs et al. (23) concluded that obesity or morbid obesity heightened the likelihood of developing SSI across various types of surgeries. The presence of a drain or a gastric tube was identified as a predisposing risk factor for SSI. This could be explained by the fact that the placement of a drain or gastric tube is an indicator of disease severity or an associated comorbid condition (21). Children who had a prolonged hospital stay prior to surgery were at risk of developing an SSI (24,25). This link can be attributed to the duration of the preoperative stay, which likely serves as a marker of disease severity. Additionally, the extended stay may result in alterations to the skin's microbial flora within 3 to 4 days, leading to colonization by multi-resistant hospital pathogens (26). In our study, small bowel surgery was the most common procedure

associated with SSIs. Our findings align with the literature, which suggests that this association may be due to contamination of the surgical site by intestinal contents (11,27,28). Non-ambulatory surgeries were also significantly associated with an increased risk of SSI, a finding consistent with the literature (29,30). This association can be attributed to the organization of the ambulatory surgery unit, where preoperative stays are minimized and ambulatory surgeries are performed first. In our study, the context of emergency surgery and contaminated surgeries were significantly associated with a higher risk of SSI. Some authors have broadly categorized risk factors for postoperative infections into procedural, hospital facility, and intraoperative factors (31–33). Procedural risk factors include the complexity of surgeries and emergency procedures, as well as the classification of wounds. This could be explained by the fact that urgent procedures typically involve conditions such as peritonitis, intestinal obstruction, and other scenarios where contamination of the operative field has already occurred. The literature review confirms the proportional correlation between the degree of contamination and the occurrence of SSI (11,24,28,34). In our study, NNIS score of 1 was identified as a significant risk factor for SSI, aligning with findings reported in the literature (12,35). Furthermore, our research revealed that an extended postoperative hospital stay was a notable risk factor for SSI, potentially due to patients being in a critical phase of their illness (21).

We noted deficiencies in the traceability of care procedures, specifically regarding the documentation of preoperative skin preparation. Therefore, it is imperative to implement a strategy that enhances traceability and fosters a stronger culture of prevention within the department. To address the identified deficiencies, we propose an improvement plan that includes: Implementing a periodic surveillance system for SSI, developing and disseminating relevant documentation (protocols, checklists, etc.) across key areas, organizing continuing education to enhance staff awareness of infection risks and promote safety culture, enhancing material resources with better supplies of antiseptics and sterile products, upgrading and maintaining sanitary facilities in the pediatric surgery department and scheduling a follow-up evaluation to assess the effectiveness of these corrective measures.

CONCLUSION

Younger children, presence of drain and NNIS score ≥1 were independent risk factors of SSI among children. Further prospective study targeting SSI are needed to identify intrinsic and extrinsic predictive factors. Preventing SSI primarily involves strict adherence to hygiene recommendations, judicious use of antibiotics, and implementing surveillance systems to provide epidemiological indicators for evaluating effectiveness. These measures are part of a comprehensive policy aimed at improving patient safety throughout their care continuum.

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