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Original Articles

# Surgical site infections in infants admitted to the neonatal intensive care unit ☆

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ABSTRACT

*Background:* Surgical interventions are common in infants admitted to the neonatal intensive care unit (NICU). Despite our awareness of the broad impact of surgical site infection (SSI), there are little data in neonates. Our objective was to determine the rate and clinical impact of SSI in infants admitted to the NICU.
*Methods:* Provincial population-based study of infants admitted to a tertiary care NICU. SSI, explicitly defined, was included if it occurred within 30 days of a skin/mucosal-breaking surgical intervention.
*Results:* Among 724 infants who underwent 1039 surgical interventions very low birth weight (VLBW) infants were over-represented. The overall SSI rate was 4.3 per 100 interventions [CI 95% 3.2 to 5.7], up to 19 per 100 dirty interventions (wound class 4) [CI 95% 4.0 to 46]. Rates were higher in infants following gastroschisis closure (13 per 100 infants [CI 95% 5.8 to 24]), whereas they were generally low following a ligation of a ductus arteriosus. Infants with SSI required longer hospitalization after adjusting for co-morbidities ($p < 0.001$).
*Conclusions:* Data from this relatively large contemporary study suggest that SSI rates in the NICU setting are more comparable to the pediatric age group. However, VLBW infants and those undergoing gastroschisis closure represent high risk groups.



Surgical Site Infection (SSI) constitutes a major post-operative complication resulting in serious morbidities and mortality in children and adults [1,2]. In North America, one fourth of hospital-acquired infections are SSI, resulting in billions of dollars in hospitalization costs annually; therefore, major efforts are concentrated on prevention [3–5]. A considerable proportion of infants admitted to the neonatal intensive care unit (NICU) require surgical interventions. However, very little data are available on the impact of SSI in the neonatal age group.

Neonates are presumed to be at higher risk of SSI due to a greater immunological vulnerability and specific co-morbidities [6] including prematurity [2,7] and prolonged parenteral nutrition dependence [8]. Also, neonates are commonly exposed to pre-operative antibiotics, raising additional concerns of microbial resistance [9]. Previous studies in the pediatric age group included a limited number of neonates and infants, and did not discriminate risk based on the type of surgical intervention [10]. Some studies excluded significant neonatal risk groups such as very low birth weight (VLBW) infants [11–13]. Finally, other neonatal studies were performed in an ambulatory care setting or in resource-limited countries [12,14–19], which limit generalization of data to the neonatal intensive care setting where most high-risk interventions occur [10,20]. Given the frequent occurrence of surgical interventions and serious clinical consequences of infection in neonates, and the lack of recent data reporting rates of SSI in this age group, we sought to determine the incidence and clinical impact of SSI in a population-based cohort of infants admitted to a large provincial tertiary care neonatal unit. Our data provide contemporary estimates of rates of SSI in the neonatal age group.

## 1. Materials and methods

### 1.1. Study population

We retrospectively reviewed data from all infants admitted to the NICU at the Children's & Women's Health Centre of British Columbia (Vancouver, Canada) between January 2004 and December 2009. The study center is the main tertiary care neonatal referral center for the province of British Columbia (~7500 births per year at this center, with a catchment area of ~44,000 births per year in the province according to 2011–2012 census data). Data for admitted patients were entered prospectively by trained database abstractors. The study was

*Abbreviations:* CAPSNet, Canadian Pediatric Surgery Network; NICU, Neonatal intensive care unit; PA, Prophylactic antibiotics; PDA, patent ductus arteriosus; SSI, Surgical site infection; VLBW, Very low birth weight.

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**Table 1**
Clinical characteristics of infants who required a surgical intervention.

| Clinical characteristics | Infants who required surgery n = 724 | Entire NICU population n = 3907 |
|---|---|---|
| Gestational age, weeks (mean ± SD) | 33 ± 5.8 | 34 ± 4.8 |
| Birth weight, g (mean ± SD) | 2154 ± 1155 | 2256 ± 1035 |
| Infant of very low birth weight (%) | 36 | 28 |
| Day of life of surgery, (median [IQ]) | 12 [4–57] | N/A |
| Length of stay (median days [IQ]) | 26 [9–75] | 8 [3–22] |
| Endotracheal ventilation days, (median [IQ]) | 4 [1–18] | 0 [0–3] |
| Perioperative antibiotic use (%) | 22 | N/A |

SD: standard deviation; IQ: interquartile range; N/A: Not applicable.

approved by the University of British Columbia Children's & Women's Clinical Research Ethics Board (certificate # H10-02409).

### 1.2. Inclusion criteria and case definitions

In a first-pass review, 238 infants were initially identified in our NICU database by screening for infants who either had a diagnosis of surgical infection and/or who received antibiotics for more than 5 days. To confirm data integrity within the entire dataset, we initially performed a random database abstraction (5% charts) against a medical chart review. In a second-pass review the medical chart of these infants was manually reviewed by two neonatologists (IS and PML) to determine whether they met a diagnosis of SSI, defined based on Centers for Disease Control National Nosocomial Infections Surveillance System criteria combining subtypes (i.e. superficial, deep and organ/space), and within 30 days of the surgical intervention [21]. To exclude the small possibility that infants may have been missed due to an untreated SSI, or partially treated SSI, we also searched our database for infants with a diagnosis 'infection', who underwent a surgical procedure and reviewed the detailed hospitalization narrative for these infants. In addition, all cases of SSI were also consistent with diagnoses made by attending surgeons/neonatologists. Using this method, we established dataset accuracy (>99%) over fields of interests. Infants who underwent an intervention requiring a surgical incision were included in the surgery group, whereas infants with non-incisional interventions (e.g. percutaneous, endoscopic and laser procedures) were excluded in our analysis. Surgical interventions were classified by body cavity (e.g. thoracic, abdominal) and wound class (1 to 4), as described [22], and whether antibiotics were used pre-, peri- or post-operatively. Wound classifications for surgical interventions were manually assigned by a pediatric surgeon (ES). Peri-operative antibiotic treatment of any duration was defined as antibiotics initiated within 24 h of the surgical intervention, which also encompass traditionally defined prophylactic antibiotics (PA). In our centre, we routinely use 2% w/v chlorhexidine gluconate or 70% v/v isopropyl alcohol for disinfection of skin prior to a surgical procedure.

### 1.3. Data analysis and statistics

Data were analyzed on a per surgical intervention and per infant basis. Rates of SSI were reported with 95% confidence intervals using the exact method. Differences between groups were compared using chi-square, Student-t or Mann–Whitney U tests as indicated. Significant co-morbidities in univariate analyses were tested for association with SSI in separate models, by stepwise multiple regressions with an entry p value of 0.1, using SPSS for Windows v11.0.1. In multivariate models with SSI, a maximum of three independent variables was tested. Due to a high co-linearity, the influence of gestational age and birth weight was assessed separately. A threshold (p value) of 0.05 was considered significant, unless otherwise specified.

## 2. Results

### 2.1. Clinical characteristics of study population

During the study period, 3907 neonates were admitted to our NICU. Of those, 724 (18.5%) underwent a total of 1039 surgical interventions (up to 11 surgical intervention per infant). The clinical characteristics of infants who required surgical interventions are presented in Table 1. Although characteristics of infants who required surgical interventions, such as gestational age and birth weight, were representative of infants admitted to the NICU, infants of VLBW were significantly over-represented. Infants who required surgical intervention required mechanical ventilation for longer periods and had longer lengths of hospital stay (Table 1). The all-cause mortality rate among infants who required surgical interventions was 8.0% (CI 95% 6.1% to 10%).

### 2.2. Incidence of SSI

Among 1039 interventions, 45 were complicated with an SSI, for a rate of 4.3 SSIs per 100 interventions (CI 95% 3.2 to 5.7). When

**Table 2**
Surgical site infections according to selected frequent interventions.

| Type | Subtype | # infants/procedure | % infants[a] | SSI rate per 100 infants/procedure | |
|---|---|---|---|---|---|
| | | | | Rate | 95% CI |
| Central nervous system | V-P Shunt | 24 | 3.1 | 4.2 | 0.1 to 21 |
| Airway/ENT | TEF Repair | 28 | 3.7 | 0 | 0 to 12 |
| Chest | PDA ligation | 173 | 23 | 0.6 | 0 to 3.2 |
| | CDH Repair | 36 | 4.7 | 5.6 | 0 to 18 |
| Abdominal | Laparotomy with | 165 | 22 | 7.9 | 4.3 to 13 |
| | or without bowel resection | 92 | 12 | 3.3 | 0.7 to 9.2 |
| | Gastroschisis — primary closure | 48 | 6.3 | 15 | 6 to 28 |
| | — delayed closure | 14 | 1.8 | 7.1 | 0.1 to 34 |
| | G- tube insertion | 59 | 7.7 | 5.1 | 1.1 to 14 |
| Pelvic | Inguinal hernia repair | 56 | 7.3 | 3.6 | 0.4 to 12 |
| Other | CVL placement | 68 | 8.9 | 0 | 0 to 5 |
| Total number of procedures | | 763 | | | |

ENT: Ear, nose & throat; PDA: Patent ductus ateriosus; V-P: Ventriculo-peritoneal; TEF: Tracheo-esophageal fistula; CDH: Congenital diaphragmatic hernia; CVL: central venous line.
[a] Percentage total infants who underwent each procedure.