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Pediatric Wound Infections

A Prospective Multicenter Study

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Objective

Surgical wound infections remain a significant source of postoperative morbidity. This study was undertaken to determine prospectively the incidence of postoperative wound infections in children in a multi-institutional fashion and to identify the risk factors associated with the development of a wound infection in this population.

Summary Background Data

Despite a large body of literature in adults, there have been only two reports from North America concerning postoperative wound infections in children.

Methods

All infants and children undergoing operation on the pediatric surgical services of three institutions during a 17-month period were prospectively followed for 30 days after surgery for the development of a wound infection.

Results

A total of 846 of 1021 patients were followed for 30 days. The overall incidence of wound infection was 4.4%. Factors found to be significantly associated with a postoperative wound infection were the amount of contamination at operation ($p = 0.006$) and the duration of the operation ($p = 0.03$). Comparing children who developed a wound infection with those who did not, there were no significant differences in age, sex, American Society of Anesthesiologists (ASA) preoperative assessment score, length of preoperative hospitalization, location of operation (intensive care unit *vs.* operating room), presence of a coexisting disease or remote infection, or the use of perioperative antibiotics.

Conclusions

Our results suggest that wound infections in children are related more to the factors at operation than to the overall physiologic status. Procedures can be performed in the intensive care unit without any increase in the incidence of wound infection.

Postoperative wound or surgical site infections (SSI) place a significant burden on both patients and surgeons. SSIs are the second most common nosocomial infection, accounting for 24% of all hospital-acquired infections, and are a major source of morbidity, prolonged hospital stay, and increased health care costs.[1] Despite the numerous publications on the incidence of and risk factors for SSI in adults, there have been only five reports in the English literature that specifically address the problem of wound infections in children.[2–6] Combined, these studies have reported widely varying overall wound infection rates, ranging from 2.5%[6] to 20%.[3] Furthermore, some of these reports have excluded day surgery cases and operations performed in the intensive care unit (ICU) and have followed patients from only a single surgical unit.[2,4,6] This study was performed to determine, in a prospective, multicenter fashion, the frequency of postoperative SSI in infants and children and to identify the risk factors associated with SSI in these patients.

METHODS

All patients (neonates, infants, toddlers, and children) undergoing an operation requiring a skin incision on the pediatric surgical services from three institutions (University of Texas Medical School–Houston and Hermann Chil-

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dren's Hospital, Houston, TX, Wilford Hall USAF Medical Center, San Antonio, TX, and Bowman Gray School of Medicine, Winston-Salem, NC) during a 17-month period (February 1995 through June 1996) were prospectively followed for the development of a wound infection.

Demographic and clinical variables were recorded at the time of operation. Data collected included age, weight, sex, primary diagnosis, presence of any coexisting diseases or anomalies, presence of a distant site infection, total number of days hospitalized before surgery, duration of operation, location of procedure (operating room *vs.* ICU), class of operation determined by wound contamination, the American Society of Anesthesiologists preoperative assessment (ASA) score, and administration of perioperative antibiotics. Nutritional parameters and the use of parenteral nutrition were not examined. Wound closure techniques, suture material, and intraoperative wound irrigation were at the discretion of each surgeon. Each patient was followed for 30 days after surgery, either in the hospital or as an outpatient. Patients who were not physically examined for a complete 30 days after surgery received a telephone questionnaire regarding the occurrence of a wound infection.

Patients undergoing circumcision and drainage of cutaneous abscesses were excluded from the study. Patients were also excluded for incomplete (<30 days) follow-up and death before the 30th postoperative day. Multiple operations that required more than one incision (*e.g.*, bilateral inguinal herniorrhaphy) were considered as a single operation.

Wound infections were determined according to the Centers for Disease Control and Prevention (CDC) definitions for an incisional (superficial or deep) SSI.[7] Criteria for a superficial incisional SSI were an infection occurring at the incision site within 30 days after surgery that involved only the skin and subcutaneous tissue and at least one of the following: purulent drainage from the incision or a drain located above the fascial layer; an organism isolated from a culture of fluid from the superficial incision; incisional pain, tenderness, localized swelling, redness, or heat, and the wound was opened (unless culture of the incision was negative); and a diagnosis of superficial incisional SSI made by the surgeon or attending physician. Criteria for a deep SSI were an infection related to the operative procedure occurring within 30 days after surgery if no implant was left in place or within 1 year if an implant was left in place that involved the deep soft tissues (fascial and muscle layers) and at least one of the following: purulent drainage for the deep incision but not from the organ/space component; the incision spontaneously dehisced or was deliberately opened when the patient had the previously described signs and symptoms of infection (unless culture of the incision was negative); an abscess or other evidence of infection involving the deep incision found on direct examination, during reoperation, or by histopathologic or radiologic examination; and a diagnosis of deep incisional SSI made by the surgeon or attending physician.

For the purposes of this study, all surgical incisional infections were grouped together. Surgical wounds were classified according to the definitions proposed by Altemeier et al.[8]: clean, clean-contaminated, contaminated, and dirty/infected.

Statistical analysis was performed with a statistical package program (StatView 1992–93; Abacus Concepts, Berkeley, CA). Continuous variables were analyzed with Student's t test and discrete variables were analyzed with chi square tests and Fisher's exact test where appropriate. All means are expressed as plus or minus standard error. A p value of less than 0.05 was considered significant.

RESULTS

A total of 1021 patients underwent an operative procedure with a skin incision during the 17-month period. Complete follow-up was obtained on 846 patients (83%), who make up the study group. Twenty-one patients died before the 30th postoperative day and 154 patients were lost to follow-up. Thirty-eight patients developed an SSI during the study period (4.4%). There were no significant differences in wound infection rates between the three reporting institutions (3.6% *vs.* 4% *vs.* 5%, $p = 0.72$). There were 545 boys and 301 girls, with a mean age of 3.48 ± 0.14 years and a mean weight of 17.1 ± 0.7 kg. There were 124 neonates (≤30 days old), 212 infants (31 days to 1 year), 347 toddlers (1 to 5 years), and 163 children (>5 years). A coexisting disease or anomaly was present in 306 patients (36.1%). The mean duration of hospitalization before operation was 7.96 ± 0.81 days (range, 0 to 369 days). Patients undergoing day surgery or same-day admission patients made up 57% of the study population.

A concurrent remote infection was documented in 30 children (3.5%) at the time of operation. Preoperative antibiotics were administered to 485 patients (57.3%). Of these, 54% were administered 2 hours or less before operation and 46% were administered more than 2 hours before operation. Thirty-seven percent of the patients who underwent a clean operation received preoperative antibiotics, and 94% of clean-contaminated, contaminated, and dirty/infected patients were given antibiotic prophylaxis.

The most commonly performed procedures were inguinal herniorrhaphy ($n = 165$), central venous access ($n = 95$), and antireflux operations with or without gastrostomy tube placement ($n = 82$). Table 1 gives a complete listing of the most commonly performed operations.

Ninety-four percent of all operations were performed in the operating room, 6% in the ICU. Procedures performed in the ICU included cannulation for extracorporeal membrane oxygenation, central venous access, intestinal surgery, repair of congenital diaphragmatic hernia, and ligation of patent ductus arteriosus.

The distribution of cases by class and ASA score is shown in Table 2. Sixty-five percent of the operations were considered clean cases, and 70% of patients were either

Table 1. OPERATIVE PROCEDURES

Procedure	Number
Inguinal hernia (unilateral and bilateral)	165
Central venous catheter	95
Antireflux operation	82
Appendectomy	60
Intestinal resection	51
Umbilical hernia	35
Pyloromyotomy	30
Ligation of patent ductus arteriosus	22
Cannulation for extracorporeal membrane oxygenation	21
Stoma closure	18
Gastroschisis/omphalocele	10
Congential diaphragmatic hernia	9

ASA 1 or 2. Thirty-one patients failed to have an ASA score recorded. The mean duration of operation was 78.9 ± 2.2 minutes (range, 12 to 575 minutes). Fifty-four percent of the operations were 60 minutes long or less.

SSIs were significantly associated with the degree of wound contamination (p = 0.006) (Fig. 1). The infection rate increased as wound contamination increased from clean (3.1%) to clean-contaminated (5.8%) to contaminated (12.9%) but decreased to 4.5% in dirty or infected wounds.

The duration of operation was significantly shorter for clean cases than for clean-contaminated, contaminated, and dirty/infected operations. In patients who developed an SSI, the duration of operation was significantly longer than for those who did not develop an infection (101.37 ± 15.35 minutes *vs.* 77.93 ± 2.22 minutes, p = 0.03). Subgroup analysis of SSI *versus* length of operation for each wound contamination class found that only among clean operations was the operative duration significantly longer in patients who developed an SSI compared with those who did not (63.68 ± 2.34 minutes *vs.* 96.75 ± 30.24 minutes, p = 0.02) (Fig. 2).

Factors that were not associated with an increase in wound infections included sex, age, presence of a coexisting disease or distant site infection, location of the operation, ASA score, and use of preoperative antibiotics (Table 3). The length of preoperative hospitalization was longer in patients who did not develop an SSI than in patients who did, but this also was not statistically significant (4.28 ± 2.2 *vs.* 8.13 ± 0.8 days, p = 0.33). Among patients who received preoperative antibiotics, the timing of administration (≤2 or >2 hours before operation) was not significantly associated with the development of a postoperative SSI. There were similar rates of SSI in clean cases that received preoperative antibiotics compared with those that did not (3.9% *vs.* 2.4%, p = 0.34).

Table 2. DISTRIBUTION BY OPERATIVE CONTAMINATION AND ASA SCORE

	Number (%)
Operative contamination	
Clean	546 (64.5)
Clean-contaminated	224 (26.4)
Contaminated	54 (6.4)
Dirty/infected	22 (2.6)
ASA score	
1	346 (40.8)
2	254 (30)
3	169 (19.9)
4	46 (5.4)
5	0

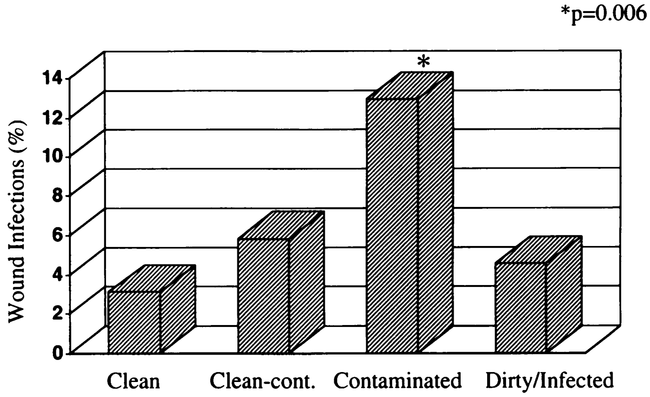

Figure 1. Incidence of wound infections by class of operative contamination.

DISCUSSION

This series of postoperative SSIs is the largest review to date in North America regarding general pediatric surgery. It is also the only report on children that has used a multicenter approach. Our overall SSI rate of 4.4% is similar to that found by Cruse and Foord[9] in a report of nearly 63,000 adult surgical wounds; their overall wound infection rate was 4.7%. Among studies limited to pediatric surgery, our incidence of SSI was lower than that reported in four of the previous five reports[2–5] but higher than the 2.5% from the

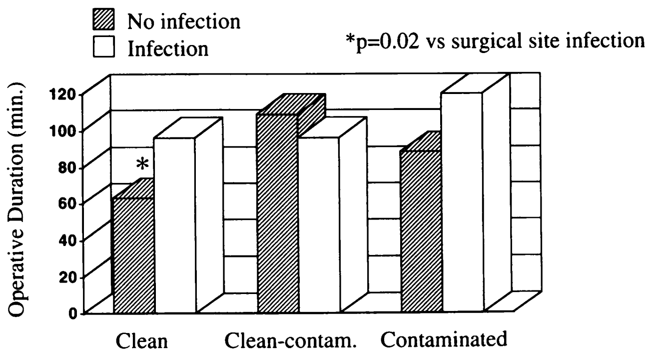

Figure 2. Operative duration and incidence of wound infections for each class of contamination.

Table 3. INCIDENCE OF SURGICAL SITE INFECTIONS FOR INDIVIDUAL VARIABLES

Variable	%	p
Sex		
Boys	4.7	
Girls	3.9	0.5
Age		
≤30 days	4.8	
31 days–1 yr	4.2	
1–5 yrs	3.4	
>5 yrs	6.7	0.4
Coexisting disease		
Yes	5.8	
No	3.7	0.15
Coexisting infection		
Yes	3.3	
No	4.5	0.7
Location of operation		
Operating room	4.5	
Neonatal ICU	4.4	0.8
ASA score		
1	3.7	
2	5.5	
3	3.5	
4	6.5	
5	0	0.6
Preoperative antibiotics		
Yes	5.3	
No	3.2	0.14

study by Bhattacharyya and Kosloske.[6] It is difficult to compare these reports because of the inherent differences in patient selection, differences in the case mix, specific definitions used for SSI, and the duration of patient follow-up. Davis et al.[4] excluded all patients having day surgery and defined an SSI as any wound that drained pus. Doig and Wilkinson[3] studied only a single surgical unit and used a similar definition for SSI. Sharma and Sharma[5] also defined an SSI as the presence of pus draining from the wound. Bhattacharyya and Kosloske[6] excluded operations performed in the ICU and used a numerical grading system to designate wound infections that was designed for antibiotic trials.[10]

We used current standardized CDC definitions of SSI that included not only infections of the skin and subcutaneous tissue but also the fascial and muscle layers. In addition, if the attending physician deemed a wound to be infected, even without purulent drainage, then that wound was classified as infected. The importance of the surgeon's diagnosis in increasing the overall incidence of wound infections was demonstrated by Taylor et al.[11] Their study of more than 3000 patients found that 16% of all surgical wound infections were defined on the basis of the nonstandardized judgment of the attending surgeon rather than from standardized CDC criteria.

We aggressively attempted to follow all patients for a full 4 weeks after their operation by physical examination or telephone questionnaire. Bhattacharyya and Kosloske[6] reported that outpatients were examined at 1- to 2-week intervals until wound healing was complete and inpatients were followed until discharge *or* for 1 month after surgery. In addition, neonates who underwent ligation of their patent ductus arteriosus were followed for only 2 weeks after surgery.[6] Two other large reports of pediatric wound infection surveillance failed to state the actual duration of follow-up used.[2,3]

Follow-up after hospital discharge can be a significant logistic problem, especially with increasing numbers of cases performed on a short-stay or no-stay basis. Because most procedures in children are performed as outpatients, this assumes added significance. Unless wound surveillance is diligently performed in all patients for an extended period of time after the patient leaves the hospital, a significant number of wound infections will be missed. Weigelt et al.[12] confirmed the necessity of wound surveillance after discharge for accurately assessing the incidence of SSI.[12] They found that 35% of all surgical wound infections occurred after discharge and that approximately 22% of all wound infections would have been missed had the surveillance period not extended beyond 14 days. In a 10-year report with nearly 41,000 operations, Olson and Lee[13] found that an average of 29.5% of wound infections were diagnosed after discharge. Similar results have been reported by others.[14–16]

The results of our study suggest that SSIs in children are related more to factors at operation than to the overall physiologic status of the patient. The only factors we found that were associated with SSI were contamination at the time of operation and the duration of the procedure. The importance of these two risk factors is in agreement with most other studies of wound infections in both the adult and pediatric literature.[2–4,6,9,17–19] Our distribution of clean and clean-contaminated cases closely paralleled the data from Bhattacharyya and Kosloske.[6] Our finding of a reduced rate of infection in dirty and infected cases probably represents a bias among individual surgeons to use delayed primary or secondary wound closure in these cases. Increasing the length of the operative procedure theoretically increases the susceptibility of the wound by increasing bacterial exposure and tissue damage; longer operations are also more likely to be associated with increased blood loss and a reduction in the general resistance of the patient.[9] Cruse and Foord reported that in clean cases, the infection rate almost doubled with each hour of operation.[9] Our findings suggest that although longer operations increase the risk for subsequent wound infections, it is only significant in patients undergoing clean operations. It may be in this setting that the administration of prophylactic antibiotics, if the procedure is prolonged, could be efficacious in reducing the incidence of wound infections.

We found no difference in the SSI rate between procedures performed in the operating room and those done in the ICU. Operations performed in the ICU were generally on patients deemed too unstable for transport to the operating room and were not limited to central venous access. Finer et al.,[20] in a 4-year review, found similar infection rates in neonates who underwent a variety of operations in the ICU compared with the operating room.

Although the use of preoperative antibiotics was not found to influence the development of SSIs, there were no attempts to standardize either the individual antibiotics used or the overall duration of therapy before initiation of this study. Preoperative antibiotics were used in more than 95% of all nonclean operations. Among clean cases, there was no reduction in the incidence of SSI in patients who were given prophylactic antibiotics compared with those who were not. Recent evidence in adults suggests that in certain clean cases, perioperative antibiotic prophylaxis may reduce the incidence of postoperative wound infections.[21]

None of the physiologic indices that we examined (coexisting disease or anomaly, concurrent distant site infection, ASA score, age) appeared to be associated with the development of a postoperative SSI. A coexisting disease process was found to increase the risk of wound infection in the report of 676 children by Bhattacharyya and Kosloske.[6] However, that report excluded 61 patients who underwent placement of a central venous catheter; all of them had an associated disease and none of them developed a wound infection. The presence of chronic disease states such as diabetes mellitus, chronic renal failure, liver failure, and obesity, which may increase the risk for wound infection in adults, are rarely encountered in the pediatric population.

The presence of an active remote infection at the time of an elective operation in adults has been shown to influence greatly the development of a subsequent postoperative wound infection.[22] Only 3.5% of our study population had a distant site infection, making definitive conclusions difficult. In addition, all patients were being treated with appropriate antibiotics at the time of operation, which has been reported to reduce the wound infection rate to a level comparable to that of patients without remote infections.[23]

We chose to use the ASA score as a measure of the severity of illness before operation. Garibaldi et al.,[19] using logistic regression analysis for 1852 adults, found that the ASA score was one of four factors highly predictive for subsequent wound infections.[19] Our finding of no association between ASA score and SSI may have been due to the skewed distribution of our population (70% were ASA 1 or 2; 0% were ASA 5) or the documented inconsistency of classification between individual anesthesiologists.[24]

We did not find a higher incidence of SSI in neonates as has been reported by others.[3,5] Despite well-documented deficiencies in neonates' defense mechanisms,[25–28] the results of our study suggest that these deficiencies do not appear to place neonates at an increased risk for postoperative wound infections.

Several important limitations of this study should be emphasized. We were able to follow only 83% of our total population. It is unclear if better follow-up would have reduced or increased our overall wound infection rate. This problem is not unique to our study group. Weigelt et al.[12] stated that follow-up is varied dependent on the patient mix and that actual contact may range from a low of 50% in typical trauma patients to about 95% in the transplant population.[12] Of the five other pediatric reports, only one provides the actual numbers needed to calculate a follow-up rate.[6]

Our study demonstrated both the benefits and the problems associated with a multicenter format. Because of the multicenter nature of our study, we could increase our sample size and determine an overall rate of SSI based on data from more than one institution. However, also due to the design, we could not have a single person to perform all the direct examinations of any suspicious wounds.

Our results suggest that the overall postoperative SSI rate in children is similar to that in adults. It appears that in this group, factors related to the operation (contamination and duration) assume a more important role than the general physiologic condition of the patient in determining the risk for a wound infection. It is well documented in the adult literature that prospective wound surveillance with feedback to individual surgeons results in a reduction in overall wound infection rates.[29] Similar efforts are necessary in pediatric surgery to help reduce the costs of health care associated with postoperative wound infections. These costs include not only those related to the child but also the financial impact on parents who must miss work to take their children to the physician.

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