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Risk Factors Associated with Surgical Site Infection after Pediatric Posterior Spinal Fusion Procedure

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Risk Factors Associated with Surgical Site Infection after Pediatric Posterior Spinal Fusion Procedure

A thesis submitted to the

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by

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ABSTRACT

Objective: To identify risk factors associated with pediatric spinal fusion surgical site infection (SSI).

Design: Retrospective case-control study nested within a hospital cohort.

Setting: A 475-bed, tertiary children's hospital.

Methods: All patients undergoing a posterior spinal fusion from January 1995- December 2006 were included. SSI cases were identified by prospective surveillance using National Nosocomial Infection Surveillance System (NNIS) definitions. Forty-four cases were identified and matched to 3 uninfected controls with matching based on date of surgery (+/- 3 months). SSI risk factors were evaluated by univariate analysis and multivariable conditional logistic regression. Odds ratios (OR) with 95% confidence intervals (CI) and *P* values were calculated.

Results: The average of the annual spinal fusion SSI rates was 4.4%. Significant factors in the univariate analysis included: body mass index (BMI) percentile >95% (OR=3.5; CI 1.5-8.3), antibiotic prophylaxis with clindamycin compared to other antibiotics (OR=3.5; CI 1.2-10.0), inappropriately low antibiotic dosage (OR=2.6; CI 1.0-6.6) and hypothermia (<35.5°C) for a longer percentage of the operative time, (OR=0.4; CI 0.2-0.9). An American Society of Anesthesiologists (ASA) score >2, obesity (BMI percentile >95%), antibiotic prophylaxis with clindamycin and hypothermia were statistically significant in the multivariable model.

Conclusion: An ASA score >2, obesity and antibiotic prophylaxis with clindamycin were independent risk factors for infection. Hypothermia during surgery appears to be protective against infection in this population.

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Figures and Table

Introduction

Surgical site infections (SSIs) are the second leading cause of healthcare-associated infections, accounting for 22% of all healthcare-associated infections.[1] Multiple studies have shown that SSIs result in significant increases in the length of hospitalization and healthcare costs.[2-5] In children with an SSI, the average hospital stay is lengthened by 10.6 days at an excess inpatient cost of over $27,000.[3] Orthopedic SSIs result in a median of 14 extra hospital days and a 3-fold increase in direct healthcare costs.[4] Similarly, SSIs associated with spinal fusion procedures often require prolonged hospitalization, additional surgeries to remove necrotic or infected tissue, and long-term intravenous antibiotics, which result in significant morbidity and increased healthcare costs.[6-9]

Spinal fusion procedures have been associated with higher rates of infection compared to other orthopedic surgeries with rates dependent on the underlying diagnosis and the type of spinal fusion procedure performed.[7, 8, 10] Recent studies have shown spinal fusion infection rates ranging from 1.3% to 6.3%.[7, 8, 10-13] Posterior spinal fusions [7, 10, 14], combined anterior-posterior spinal fusions[7, 8] and fusions involving lumbar or sacral vertebrae [7, 12] all have been have been associated with an increased risk of developing an SSI. The American Society of Anesthesiologists (ASA) score is a marker for the underlying health status of the patient (scale of 1-5).[15] ASA scores > 2 have been associated with increased risk for infection.[13] Patients with neuromuscular scoliosis also have been found to be at increased risk for infection after spinal fusion surgery.[7, 8, 11]

There is limited information examining risk factors and prevention strategies for SSIs related to spinal fusion procedures in children.[7, 12] An increased understanding of SSI risk factors is needed to facilitate the development of prevention strategies in this patient

population. Therefore, the goal of this study was to identify risk factors associated with pediatric spinal fusion SSI by examining characteristics related to the patient, the surgical procedure and tissue hypoxia.

Methods

Study Design and Patient Population

This was a case-control study performed at Cincinnati Children's Hospital Medical Center (CCHMC), Cincinnati, OH, a 475-bed tertiary children's hospital that currently performs an average of 270 spinal fusion procedures annually. The study population included all patients having a spinal fusion procedure between January 1, 1995 and December 31, 2006. Data collected from the hospital's medical record database were used to identify the patient population. *International Classification of Diseases, Ninth Revision, Clinical Modification*[16] procedure codes were used to identify patients who underwent spinal fusion procedures that met the National Nosocomial Infection Surveillance (NNIS) System operative procedure category definition for spinal fusion surgery.[13, 17] In 2006, the NNIS system was converted to the National Healthcare Safety Network[18], but the there were no major changes to the definitions of SSIs. A list of the included procedure codes and their description is listed in Table 1. Secondary data collected for the hospital's infection control database and the orthopedic surgery database were used to verify that all spinal fusion patients had been identified. Overall, 974 patients with 1206 fusion procedures were identified.

Institutional review board (IRB) approval was obtained prior to initiating the study. The primary IRB for this project was the CCHMC IRB. The IRB number was 06-12-40. In addition,

IRB approval from the University of Cincinnati was obtained. The University of Cincinnati IRB number was 07-04-24-03.

SSI cases were identified prospectively by infection control practitioners using NNIS definitions. Case patients were defined as patients who met NNIS criteria for a SSI related to their spinal fusion procedure.[15, 19] Infections were included in the study for patients without surgical implants if the SSI was identified within 30 days of the date of surgery and for patients with surgical implants if the SSI was identified up to a year after the date of surgery. Surveillance identified 46 patients with SSIs related to their spinal fusion procedure. Among these 46 patients, 1 underwent an anterior spinal fusion and 1 patient underwent a posterior cervical fusion. For these 2 patients, this was the only fusion procedure performed. These procedures have been shown to have a lower risk for infection; therefore, the 2 cases were excluded from the analysis.[7, 8, 10, 14, 20] The remaining 44 case patients underwent a posterior spinal fusion procedure involving thoracic or lower vertebrae. The risk factor analyses were restricted to these patients.

A matched case to control ratio of 1:3 was chosen to provide an 80% power to detect significant ($P < 0.05$) differences between cases and controls for most variables (with an odds ratio [OR] in the range of 3.0- 4.0). Control patients were defined as patients who underwent a posterior spinal fusion procedure involving thoracic or lower vertebrae during the same time period who did not develop an SSI. Three control patients were selected randomly without replacement using a random-number generator from the group of uninfected posterior spinal fusion surgery patients. These 3 control patients were matched to a case patient based on the date of surgery (+/- 3 months).

Data Collection

For case patients, cultures were obtained from the surgical wound and sent to the CCHMC clinical microbiology lab. Specimens included fluid, tissue, bone and wound swabs. Trained microbiology laboratory technicians prepared the specimens from the surgical wound for Gram stain, aerobic culture, anaerobic culture, fungal culture and acid fast bacilli stain and culture. Except for wound swabs, specimens were also inoculated into thioglycolate broth. Aerobic cultures were evaluated using a blood-agar plate, an enriched chocolate agar plate, and a MacConkey agar plate. Anaerobic cultures were evaluated using a kanamycin-vancomycin plate, a *Brucella* blood agar plate, and a phenylethyl alcohol anaerobic plate. Fungal cultures were evaluated using a Sabouraud dextrose agar plate, an inhibitory mold agar plate, a chromeg agar plate, and a Sabouraud dextrose agar plate with gentamicin and cyclohexamide. Organisms recovered from positive culture plates were identified using standard microbiology laboratory procedures. SSIs were classified as having either a single or multiple pathogens.

Patient demographics included: age, gender, race, and insurance status (used as a marker for socioeconomic status). Variables evaluating the underlying health status of the patient included: body mass index (BMI) percentile, ASA score, underlying diagnosis for the spinal fusion, and presence of a coexisting infection. BMI percentile, which calculates BMI adjusted for age and gender, was selected as a marker for BMI.[21] Coexisting infections included any untreated or partially treated infection, including acne. If acne was noted in the peri-operative physical or operative notes, it was counted as an untreated or partially treated infection.

Surgery-related factors included: the number of spinal fusion procedures performed on the patient, wound class, use of implants or graft material, duration of surgery (in hours), number and type of vertebrae fused, and presence of any complications. Surgical complications included: excessive bleeding, a break in the sterile field, pulmonary aspiration, nerve conduction abnormalities or incorrect counts of surgical supplies used in the procedure. Excessive bleeding was defined as any documentation in the operative report of a large volume of blood lost during the procedure.

The variables related to receipt of perioperative antibiotic prophylaxis included: the antibiotic chosen, the antibiotic dosage, timing of the initial antibiotic dose, re-dosing of the antibiotic, and whether antibiotics were continued >24 hours after surgery. The appropriate antibiotic dose was defined as receipt of at least the minimum weight appropriate dose of the chosen antibiotic. Correct timing for the initial antibiotic dose was a recorded start time 0-60 minutes before the skin incision for all antibiotics except vancomycin, for which a recorded start time of 60-120 minutes before the skin incision was considered correct. Redosing of the perioperative antibiotic was indicated for procedures lasting > 4 hours. Correct antibiotic re-dosing for was defined as the receipt of the correct dose of antibiotic at the correct time(s) recommended for that antibiotic.[22]

Factors associated with surgical wound hypoxia included: blood loss, volume of blood products transfused, total volume of fluids administered, infiltration of the incision with epinephrine and hypothermia (core body temperature < 35.5°C). Total intravenous fluids administered included normal saline, albumin and all blood products. Fluid volumes were adjusted for the patient's weight. Infiltration of the surgical incision with epinephrine, which is occasionally used to control blood loss, was examined as a possible cause of surgical wound

hypoxia through vasoconstriction. The duration of hypothermia was evaluated by recording the duration of hypothermia in hours to determine the percentage of time that the patient was hypothermic during surgery. The initial, final, lowest and highest operative temperatures were also recorded for each patient.

The variables evaluated in the study are listed in Table 2. Data for each variable were systematically obtained from predetermined locations within the medical record. All data collection was performed by a single investigator (WML) using a standardized data collection sheet, and 15% of the data was collected twice to ensure consistency of the data collection. Only a few minor discrepancies were noted, which were resolved by additional review of the medical records.

Data Analysis

Conditional logistic regression analysis was used to test the unadjusted association between each variable and the development of an SSI. The results were expressed as odds ratios (OR) with 95% confidence intervals (CI) and *P* values. Categorical variables were recoded as dummy variables in order to facilitate analysis. The continuous variable, BMI percentile, was also analyzed as the dichotomous variable, obesity (BMI percentile > 95%) since review of the literature revealed this as an accepted breakpoint associated with an elevated risk of infection.[21] For other continuous variables with no accepted breakpoint, the results for the continuous variables were reported as the mean value for each group, and the ORs and CIs refer to the change in risk from the 75th percentile to the 25th percentile. Multivariable conditional logistic regression was used to identify the joint effect of several risk factors associated with SSIs. The univariate analysis results were used to guide the selection

of variables for development of the multivariable model (*P* value < 0.2). If two or more variables were known to be highly correlated, such as BMI percentile and obesity, the variable with the most significant result was included in the model. In addition, multiple two-way interaction terms were analyzed. A backwards stepwise approach was used to determine the final multivariable model. Validity of the final model was checked by testing for co-linearity. A *P* value < 0.05 was considered statistically significant. SAS 9.1 (SAS Institute Inc., Cary, NC) was used for data analysis.

Results

Infection Rates and Microbiology

The mean of the annual SSI rates for 1995-2006 was 4.4% (range, 1.1- 6.7%). There was no trend in the SSI rate over the time period of the study. Of the 44 SSIs, eight (18%) were classified as superficial incisional infections, 22 (50%) were classified as deep incisional infections and 14 (32%) were classified as bone infections. Seven (16%) of the infections were identified >30 days after the surgery (range 31-50 days). Twenty-three (52%) of the infections were polymicrobial (mean 3 organisms, range 2-5 organisms). The figure shows the distribution of organisms cultured from the surgical wound. The most common organisms cultured from the surgical wound were coagulase-negative staphylococcus (16 isolates), *Pseudomonas aeruginosa* (11 isolates) and *Enterobacter cloacae* (11 isolates). No pathogen was identified by culture for one case.

Patient Characteristics

The demographic characteristics of cases and controls are shown in Table 3. There were 44 case patients and 132 control patients. The mean age was 14.5 years for case patients and 14.7 years for control patients. Of the 176 patients included in the study, 115 (65%) were female, 148 (84%) Caucasian, and 122 (69%) were privately insured. The most common underlying diagnosis for surgery was idiopathic scoliosis (85 patients [48%]) followed by neuromuscular scoliosis (54 patients [31%]).

There were no significant differences in demographic characteristics between cases and controls. The univariate analysis for patient-related risk factors is shown in Table 4. Although neuromuscular scoliosis was more common in cases, the difference was not statistically significant. An ASA score >2 also did not reach statistical significance (OR, 1.7 [95% CI, 0.8- 3.4]). Patients with neuromuscular scoliosis were more likely to have an ASA score >2 (16 [89%] of the 18 case patients and 25 [69%] of the 36 control patients with neuromuscular scoliosis). Case patients were significantly more likely to have neuromuscular scoliosis and an ASA score >2 compared to control patients (OR, 2.3 [1.1- 4.8]) A BMI > 95th percentile (i.e. obesity) was significantly associated with an increased risk of infection (OR, 3.5 [95% CI, 1.5- 8.3]).

Surgery-Related Factors

The univariate analysis for surgery-related risk factors is shown in Table 5. None of the study patients had a wound class >2. Case patients were more likely than control patients to have a longer duration of surgery, but this did not reach statistical significance.

Overall, 145 (82%) study patients received cefazolin, 3 (2%) received vancomycin and 20 (11%) received clindamycin for antibiotic prophylaxis. Seven (4%) study patients received a

non-standard antibiotic and 1 (0.6%) received no antibiotic prophylaxis. Patients receiving clindamycin as their antibiotic prophylaxis were significantly more likely to have an SSI compared to patients receiving cefazolin or vancomycin (OR= 3.5; CI, 1.2- 10.0). All study patients given clindamycin received an appropriate dose. Incorrect timing of the initial dose of clindamycin (33% of cases vs. 36% of controls) and incorrect redosing of clindamycin (78% of cases vs. 73% of controls) were similar for both case and control patients.

Receipt of an inappropriately low antibiotic dose was significantly associated with the development of a SSI (OR, 2.6 [95% CI, 1.0- 6.6]). Incorrect timing of the initial antibiotic dose was more common in case patients than control patients but this did not reach statistical significance. Both case and control patients received antibiotics for longer than 24 hours after surgery 92% of the time.

Tissue Hypoxia-Related Factors

Table 6 shows the univariate analysis for tissue hypoxia-related risk factors. Case patients were less likely than control patients to have an initial or a final core temperature of <35.5°C, but these results were not statistically significant. The mean peak temperature (OR, 2.0 [95% CI, 1.1– 3.7]) was significantly higher for case patients compared with control patients. Conversely, control patients were hypothermic (<35.5°C) for an increased proportion of the operative.time compared to case patients, and this was found to be statistically significant (OR, 0.4 [95% CI, 0.2- 0.9]). The results show that control patients were found to have lower body temperatures and were hypothermic for a longer proportion of the operative time.

Multivariable Model for Spinal Fusion SSIs

The results of the multivariable regression model for spinal fusion SSIs are shown in Table 7. Statistically significant independent risk factors associated with the development of a SSI included obesity (OR, 3.1 [95% CI, 1.1- 9.1]), an ASA score >2 (OR, 2.9 [95% CI, 1.1- 7.9]) and receiving clindamycin as antibiotic prophylaxis (OR, 6.2 [95% CI, 1.5- 25.2]). An increased proportion of the operative time that the patient was hypothermic remained statistically significant as protection against infection (OR, 0.3 [95% CI, 0.1- 0.9]). There were no significant two-way interaction terms, and no collinearity was found in the multivariable model.

Discussion

The average annual spinal fusion SSI rate of 4.4% in our population is comparable to rates reported by others (1.3% to 6.3%). [7, 8, 10-13] Gram-negative bacilli accounted for a higher proportion of isolates in the study reported here (50%) compared with other studies (25-36%). [6, 7] However, in the study reported here, most patients (92%) received antibiotics for >24 hours following surgery, which may have selected for pathogens resistant to the antibiotic prophylaxis used.

For most spinal fusion surgeries and orthopedic surgeries involving instrumentation, a weight appropriate dosage of antibiotic prophylaxis prior to the surgical incision is recommended. Cefazolin is the drug of choice while vancomycin and clindamycin are recommended alternatives in patients unable to tolerate beta-lactam antibiotics.[15, 22, 23] In the study reported here, antibiotic prophylaxis with clindamycin was identified as an independent risk factor for developing an SSI. The increased risk of SSI seen with clindamycin prophylaxis

was not related to inappropriate dosing, timing or re-dosing of clindamycin which were all similar for case and control patients.

Other studies evaluating the effectiveness of antibiotic prophylaxis with clindamycin have reported conflicting results.[24, 25] One of these, a prospective study comparing perioperative prophylaxis with ampicillin-sulbactam vs. clindamycin in head and neck oncology surgery patients, found significantly higher SSI rates in the clindamycin group (27.1% vs. 13.3%; p= 0.02). Gram-negative organisms were isolated more often in the clindamycin group than in the ampicillin-sulbactam group (81% vs. 32%).[25] For surgeries in which gram-negative organisms are common pathogens, clindamycin alone may be inadequate for prophylaxis. When antibiotics are prolonged beyond the perioperative period, which occurred frequently in our patient population, the selective pressure may skew the distribution of infecting organisms, making it difficult to assess the adequacy of any prophylactic antibiotic. It is also possible that the bacteriostatic properties of clindamycin render it less effective than bactericidal agents.

Receiving an inappropriately low antibiotic dose was associated with increased risk of infection in the univariate analysis but was not significant in the multivariable model. Incorrect timing of the initial antibiotic dose did not reach statistical significance in our patient population, but it has been identified by others as an important risk factor in both adult and pediatric spinal fusion studies.[7, 10, 26] This study may have been under-powered to detect statistically significant differences in the number of SSIs for these variables, but the correct dosing and timing of antibiotic prophylaxis are both important to ensure adequate antimicrobial levels in the tissues prior to the surgical incision. [23]

Hypothermia is thought to promote thermoregulatory vasoconstriction resulting in decreased oxygen tension at the surgical site, which has been shown in adult studies to

increase the risk of SSI by impairing neutrophil function and delaying wound healing.[27, 28] Two prospective adult studies comparing maintenance of normothermia with hypothermia showed significant decreases in SSI rates in the normothermia groups.[29, 30] Conversely, two other adult studies showed no significant association between hypothermia and the development of an SSI.[31, 32] One pediatric study evaluated the relationship between hypothermia (ie. core body temperature < 35.1°C) and SSI after pediatric ventriculoperitoneal shunt surgery and found no significant association.[33] Another study evaluating the association of deep hypothermia and SSI in pediatric cardiothoracic surgery patients found a significantly increased risk of infection only in the quartile group with the deepest hypothermia (range 11-20°C).[34]

Studies have shown that hypothermia also affects the host immune response by altering the transcription of inflammatory cytokines. Depending on the cell type and stimulus used, hypothermia can result in either an increase or decrease in cytokine transcription.[35-38] Variations in cytokine production may have accounted for the protective effect seen from hypothermia in ischemia-related cardiac and brain injury and for the increased mortality seen among hypothermic patients with sepsis.[35, 37, 38] It is possible that children are less susceptible to the hypoxic effects caused by hypothermia or that the overall effect of hypothermia on inflammatory cytokine production during surgery is protective in our population.

Obesity has been shown to be associated with an increased risk of healthcare-associated infections in surgical patients.[39, 40] The results from the study reported here support those found in other studies showing that obesity is a significant risk factor for the development of SSI after spinal fusions.[10, 14] In this study, an ASA score of >2 was found to be an independent risk factor for developing an SSI. Sample size may have limited the ability to detect a significant association between neuromuscular scoliosis and infection. Studies have

shown that both an ASA score >2 [13, 41] and neuromuscular scoliosis[7, 8, 11] are significant risk factors for SSI following spinal fusions. Patients with neuromuscular scoliosis often have additional medical problems that result in an ASA score >2. This may account for the apparent association between an ASA score >2 and neuromuscular scoliosis seen in this study.

There are several limitations to this study. The retrospective nature in which the data was collected may have introduced some bias into the study; however, standardization of the data collection process and using a single data collector should have limited this. In the study reported here, case patients, which had been identified prospectively by infection control practiioners, were matched with control patients, which were identified retrospectively from the hospital medical record database. The use of specific standardized definitions for SSI, which were applied to all spinal fusion patients, should have resulted in the correct classification of patients as cases or controls. In addition, the use of a random number generator to identify the control patients should have limited any selection bias. The surveillance system for SSIs at this institution may have missed minor or superficial SSIs managed in an outpatient setting only, but it should have detected all clinically significant SSIs. Surveillance also may have missed SSIs identified and treated at other hospitals, but the orthopedic surgeons at this institution were unaware of any patients with SSIs that did not return to this institution for treatment. While this study had a large number of pediatric cases, it was still limited in its ability to detect smaller potentially significant differences between cases and control patients.

In the study reported here, receiving an inappropriately low antibiotic dose and incorrect timing of the initial antibiotic dose occurred more frequently in case patients than in control patients but did not reach statistical significance in the multivariable model. These trends reinforce the findings of other studies showing the importance of proper antibiotic prophylaxis

in patients having spinal fusions. [7, 10, 23, 26] The results of this study also reveal multiple areas for improvement in current antibiotic prophylaxis practice. Additional studies are needed to determine the optimal antibiotic prophylaxis for children having spinal fusions and may reveal the need for different antibiotic regimens based on the underlying risks of the patient. This study was one of the first studies to evaluate the relationship of hypothermia and the development of SSIs in children and suggests that it may have a different outcome than for adults. Additional studies are needed to better understand the mechanism and possible therapeutic benefits of hypothermia for reducing SSI among children undergoing spinal fusion.

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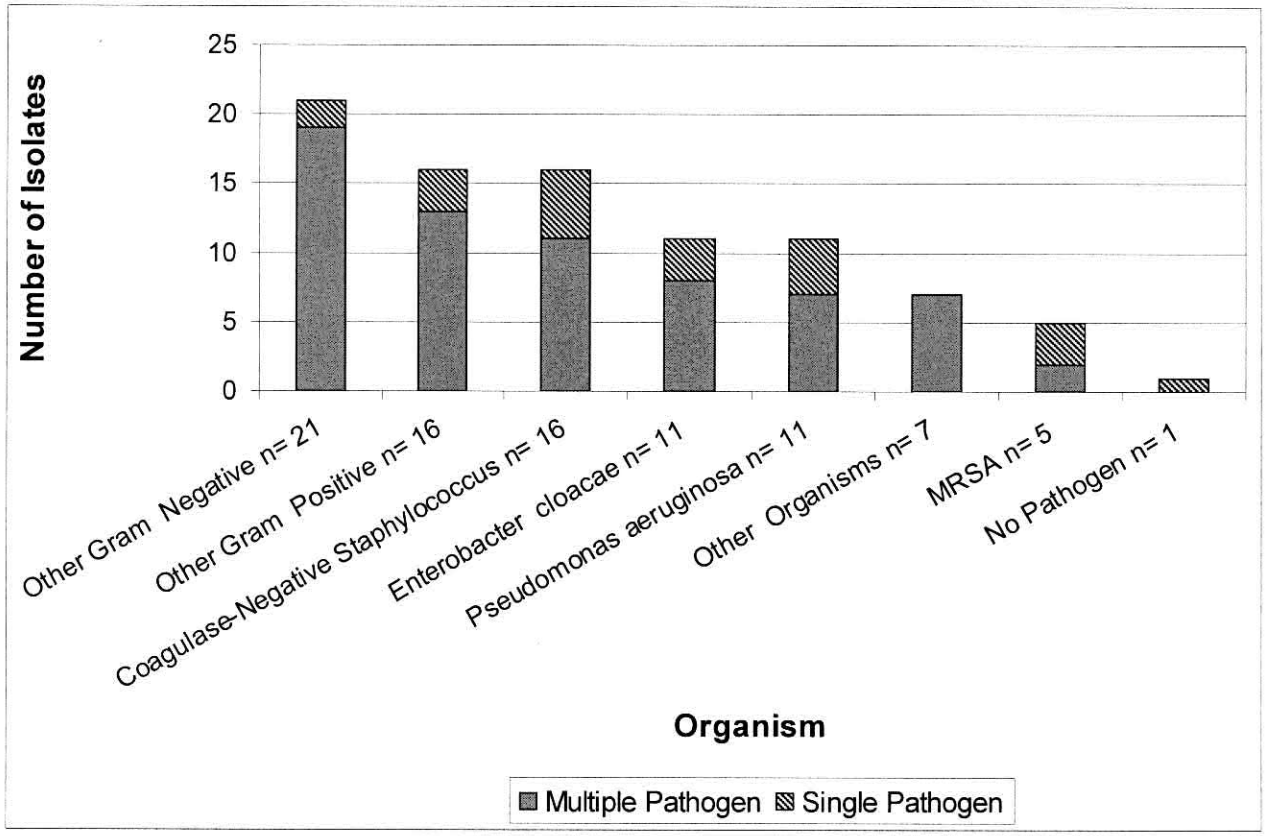

Figure. Distribution of Organisms Cultured from Surgical Wound Samples from Patients who Underwent a Posterior Spinal Fusion Procedure at Cincinnati Children's Hospital Medical Center, from January 1995 to December 2006

Other gram-negative organisms: *Acinetobacter* spp. (4 isolates), *Escherichia coli* (6 isolates), *Flavobacterium* species (1 isolate), *Klebsiella* spp. (4 isolates), *Proteus mirabilis* (3 isolates), *Morganella morganii* (1 isolate), *Pseudomonas* species (1 isolate) and *Serratia marcescens* (1 isolate)
Other gram positive organisms: *Corynebacterium* species (2 isolates), *Enterococcus* species (6 isolates), methicillin-sensitive *Staphylococcus aureus* (4 isolates), *Staphylococcus* species (1 isolate) and *Streptococcus* species (3 isolates)
Other organisms: *Bacteroides* spp. (2 isolates), *Candida* spp. (2 isolates), *Propionibacterium* spp. (2 isolates) and *Pepstreptococcus* species (1 isolate)
MRSA = methicillin-resistant *Staphylococcus aureus.*

Table 1.	**National Nosocomial Infection Surveillance System Operative Procedure Category Definitions for Spinal Fusion Surgery**[13, 18]
ICD-9-CM procedure codes	**Procedure description**
81.00	Spinal fusion, unspecified
81.01	Atlas-axis spinal fusion
81.02	Cervical fusion, anterior technique
81.03	Cervical fusion, posterior technique
81.04	Dorsal/dorsolumbar fusion, anterior technique
81.05	Dorsal/dorsolumbar fusion, posterior technique
81.06	Lumbar/lumbosacral fusion, anterior technique
81.07	Lumbar/lumbosacral fusion, lateral transverse technique
81.08	Lumbar/lumbosacral fusion, posterior technique
81.30	Refusion of spine, unspecified
81.33	Refusion of cervical spine, posterior technique
81.34	Refusion of dorsal/dorsolumbar fusion, anterior technique
81.35	Refusion of dorsal/dorsolumbar fusion, posterior technique
81.36	Refusion of lumbar/lumbosacral fusion, anterior technique
81.38	Refusion of lumbar/lumbosacral fusion, posterior technique
81.39	Refusion of spine
ICD-9-CM equals International Classification of Diseases, Ninth Revision, Clinical Modification.	

Table 2.	List of Variables	
Variable	**Variable type**	**Measurement description**
Demographic characteristics		
Age	Continuous	years
Gender	Categorical	male, female
Race	Categorical	White, African American, Latino, Asian, other, unknown
Insurance status	Categorical	Private, medicaid, self-pay, unknown
Diagnosis for surgery	Categorical	Idiopathic, neuromuscular, congenital, trauma, neoplastic, other
Patient-related risk factors		
BMI percentile	Continuous	BMI percentile
Obesity	Categorical	BMI percentile >95%
ASA score	Categorical	ASA score 1-5, Analyzed as >2 equals yes and ≤2 equals no.
Co-existing infection	Categorical	Yes, no
Surgery-related risk factors		
Duration of surgery	Continuous	Hours
No. of vertebrae fused	Continuous	Number of vertebrae
Multiple fusion procedures		
-Single day	Categorical	Yes, no
-Multiple days	Categorical	Yes, no
Sacral vertebrae fused	Categorical	Yes, no
Wound class	Categorical	Wound class 1-4
Surgical implant	Categorical	Yes, no
Bone graft	Categorical	Yes, no
Bone matrix protein	Categorical	Yes, no
Complications	Categorical	Yes, no
Antibiotic prophylaxis given	Categorical	Yes, no
Antibiotic choice	Categorical	Cefazolin, clindamycin, vancomycin
Antibiotic dose correct	Categorical	Dose (mg/kg) correct: yes, no
Timing of antibiotic incorrect	Categorical	Timing of initial dose correct: yes, no
Antibiotic re-dosing incorrect	Categorical	Yes, no

Antibiotics given >24 h after surgery	Categorical	Yes, no
Tissue hypoxia-related risk factors		
Blood loss	Continuous	mL/kg
Transfusion volume	Continuous	mL/kg
Total fluids infused	Continuous	mL/kg
Duration of hypothermia	Continuous	% of operative time with temp < 35.5°C
Highest operative temp	Continuous	°C
Lowest operative temp	Continuous	°C
Initial operative temp <35.5°C	Categorical	Yes, no
Final operative temp <35.5°C	Categorical	Yes, no
Epinephrine injected into incision	Categorical	Yes, no
Use of "cell saver" blood	Categorical	Yes, no

Table 3.	Demographic Characteristics of Pediatric Patients Who Underwent a Posterior Spinal Fusion Procedure, January 1995 to December 2006, at Cincinnati Children's Hospital Medical Center				
Variable	**Case patients (n=44)**		**Control patients (n=132)**		***P*-Value**
Age, mean (range),years	14.5 yrs	(6.0-22.1)	14.7 yrs	(1.2-27.2)	0.667
Female gender	32	72.7%	83	62.9%	0.212
Race					
-White	38	86.4%	110	83.3%	0.638
-African American	5	11.4%	16	12.1%	0.895
-Other [a]	1	2.3%	6	4.5%	0.500
Insurance status					
-Private	31	70.4%	91	68.9%	0.843
-Medicaid	13	29.5%	41	31.1%	0.843
Diagnosis for surgery					
-Idiopathic scoliosis	17	38.6%	68	51.5%	0.158
-Neuromuscular scoliosis	18	40.9%	36	27.3%	0.098
-Congenital scoliosis	2	4.5%	6	4.5%	0.999
-Neoplastic cause	4	9.1%	5	3.8%	0.192
-Other diagnosis [b]	3	6.8%	17	12.9%	0.252

Data are no. (%) of patients, unless otherwise specified.
[a] Other race includes: Latino, Asian and other races.
[b] Other diagnoses includes: trauma-related and other diagnoses .

Table 4.	Univariate Analysis of Patient-Related Risk Factors Associated With Surgical Site Infection After a Posterior Spinal Fusion Procedure, January 1995 to December 2006, at Cincinnati Children's Hospital Medical Center						
Variable	**Case patients (n=44)**		**Control patients (n=132)**		**OR [95% CI]**		***P*-Value**
Continuous							
Mean BMI percentile[a]	60.4		50.2		2.0	[0.9- 4.2]	0.099
Categorical							
Obesity[a,b]	15	36.6%	18	14.5%	3.5	[1.5- 8.3]	0.004
Diagnosis for surgery							
-Idiopathic scoliosis	17	38.6%	68	51.5%	0.6	[0.3- 1.2]	0.158
-Neuromuscular scoliosis	18	40.9%	36	27.3%	1.8	[0.9- 3.7]	0.098
-Congenital scoliosis	2	4.5%	6	4.5%	1.0	[0.2- 5.3]	0.999
-Neoplastic cause	4	9.1%	5	3.8%	2.4	[0.6- 8.9]	0.192
-Other diagnosis[c]	3	6.8%	17	12.9%	0.4	[0.1- 1.9]	0.252
ASA score >2[d]	18	40.9%	37	28.5%	1.7	[0.8- 3.4]	0.153
Co-existing infection	5	11.4%	15	11.4%	1.0	[0.3- 2.8]	0.999
ASA score >2 and neuromuscular scoliosis[d]	16	36.4%	25	19.2%	2.3	[1.1- 4.8]	0.031

Data are no. (%) of patients, unless otherwise specified. OR = odds ratio; CI = confidence interval; BMI = body mass index; ASA = American Society of Anesthesiologists.
[a] The analysis was based on 41 case patients and 124 control patients.
[b] Obesity is defined as a BMI greater than the 95th percentile.
[c] Other diagnoses includes: trauma-related and other diagnoses .
[d] The analysis was based on 44 case patients and 130 control patients.

Table 5.	Univariate Analysis of Surgery-Related Risk Factors Associated With Surgical Site Infection After a Posterior Spinal Fusion Procedure, January 1995 to December 2006, at Cincinnati Children's Hospital Medical Center						
Variable	**Case patients (n=44)**		**Control patients (n=132)**		**OR [95%CI]**		***P*-Value**
Continuous							
Mean duration of surgery, hours	6.9 hours		6.1 hours		1.4	[0.97- 2.1]	0.066
Mean no. of vertebrae fused	11.8		11.7		1.02	[0.7- 1.4]	0.900
Categorical							
Multiple fusion procedures[a]							
-Single day	12	27.3%	26	19.7%	1.8	[0.8- 4.4]	0.173
-Multiple days	11	25.0%	26	19.7%	1.6	[0.7- 3.8]	0.263
Sacral vertebrae fused	16	36.4%	34	25.8%	1.6	[0.8- 3.3]	0.189
Wound class = 2	3	6.8%	9	6.8%	1.0	[0.3- 3.8]	0.999
Surgical implant	42	95.4%	125	94.7%	1.2	[0.2- 5.6]	0.847
Bone graft[b]	43	97.7%	129	97.7%	1.0	[0.1- 9.6]	0.999
Bone matrix protein[c]	4	9.3%	22	16.9%	0.4	[0.1- 1.7]	0.231
Complications	8	18.2%	18	13.6%	1.4	[0.6- 3.3]	0.481
Antibiotic prophylaxis[d]							
-Cefazolin	30	75.0%	115	89.8%	0.3	[0.1- 0.8]	0.015
-Clindamycin	9	22.5%	11	8.6%	3.5	[1.2- 10.0]	0.021
-Vancomycin	1	2.5%	2	1.6%	3.0	[0.2- 48.0]	0.437
Antibiotic dose low	10	22.7%	14	10.6%	2.6	[1.0- 6.6]	0.045
Timing of initial antibiotic dose incorrect	24	54.5%	54	40.9%	1.8	[0.9- 3.8]	0.100
Antibiotic re-dosing incorrect	31	70.4%	99	75.0%	0.8	[0.4-1.7]	0.564

Antibiotics given >24 h after surgery[e]	38	92.7%	121	92.4%	1.2	[0.2- 6.5]	0.835

Data are no. (%) of patients, unless otherwise specified.
[a] Analysis of multiple procedures is based on the reference group, single fusion procedure/ single day.
[b] Bone graft material includes autograft and allograft.
[c] The analysis was based on 43 case patients and 130 control patients.
[d] The analysis was based on 40 case patients and 128 control patients and compares prophylaxis with the listed antibiotic to prophylaxis with the other two antibiotics.
[e] The analysis was based on 41 case patients and 131 control patients.

Table 6.	Univariate Analysis of Tissue Hypoxia-Related Risk Factors Associated With Surgical Site Infection After a Posterior Spinal Fusion Procedure, January 1995 to December 2006, at Cincinnati Children's Hospital Medical Center						
Variable	**Case patients (n=44)**		**Control patients (n=132)**		**OR [95% CI]**		***P*-Value**
Continuous							
Mean blood loss, mL/kg[a]	34.2 ml/kg		31.8 ml/kg		1.05	[0.8- 1.3]	0.699
Mean transfusion volume, mL/kg	29.0 ml/kg		24.2 ml/kg		1.2	[0.8- 1.7]	0.335
Total fluids, mL/kg	123.8 ml/kg		117.2 ml/kg		1.1	[0.8- 1.5]	0.627
Hypothermia, % of operative time[b]	25.0%		38.5%		0.37	[0.2- 0.9]	0.021
Mean highest temp, °C[c]	36.9°C		36.6°C		2.0	[1.1-3.7]	0.028
Mean lowest temp, °C[b]	35.1°C		34.9°C		1.7	[0.9-2.9]	0.079
Categorical							
Initial operative temp <35.5°C[b]	19	44.2%	67	51.9%	0.7	[0.4- 1.5]	0.398
Final operative temp <35.5°C[d]	5	11.6%	28	21.5%	0.4	[0.1- 1.2]	0.099
Epinephrine injected into incision[e]	28	65.1%	78	59.5%	1.3	[0.6- 2.8]	0.553
Use of "cell saver" blood[f]	23	52.3%	58	43.9%	1.5	[0.7- 3.0]	0.311

Data are no. (%) of patients, unless otherwise specified.
[a] Analysis based on 44 case patients and 131 control patients.
[b] Analysis based on 43 case patients and 129 control patients.
[c] Analysis based on 43 case patients and 128 control patients.
[d] Analysis based on 43 case patients and 130 control patients.
[e] Analysis based on 43 case patients and 131 control patients.
[f] An Intraoperative cell salvage machine that allows transfusion of patient's own blood lost during surgery.

Table 7.	Results of the Multivariable Regression Model for Surgical Site Infections After a Pediatric Posterior Spinal Fusion Procedure					
Variable	**Unadjusted OR**	**[95% CI]**	***P*-Value**	**Adjusted OR**	**[95% CI]**	***P*-Value**
Hypothermia <35.5°C (% operative time)	0.37	[0.2- 0.9]	0.021	0.29	[0.09- 0.90]	0.031
Clindamycin as antibiotic prophylaxis	3.5	[1.2- 10.0]	0.021	6.2	[1.5- 25.2]	0.011
ASA score >2	1.7	[0.8- 3.4]	0.153	2.9	[1.1- 7.9]	0.036
Obesity	3.5	[1.5- 8.3]	0.004	3.1	[1.1- 9.1]	0.039

There were 153 patients included in the multivariable model.
The list of factors included in the model included: hypothermia < 35.5°C (% operative time), clindamycin as antibiotic prophylaxis, ASA score >2, obesity, antibiotic dose low, timing of initial antibiotic dose incorrect, mean duration of surgery, neuromuscular scoliosis, multiple spinal fusion procedures performed on a single day, both ASA score >2 and neuromuscular scoliosis, and fusion including sacral vertebrae.