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Original research

Rate of surface contamination in the operating suite during revision total joint arthroplasty

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ABSTRACT

Background: This study estimated operating room surface contamination rates during aseptic vs septic total joint arthroplasty and evaluated the similarity between clinically infecting organisms and those isolated from contaminated surfaces.
Methods: Patients undergoing total hip and knee revision arthroplasties were identified, and surface and tissue samples were collected. Cases were classified aseptic or septic based on Musculoskeletal Infection Society criteria for prosthetic joint infection. Positive surface cultures were compared with intraoperative tissue cultures. Positive cultures were speciated and tested for antimicrobial sensitivity.
Results: Samples were collected from 31 aseptic and 18 septic cases. Patients had similar demographics and time to explantation. Surface contamination rates for septic revisions were greater than those for aseptic revisions (77% vs 13%). During septic revisions, when intraoperative tissue cultures were positive, the surgical field was contaminated in 14 of 15 cases. The kappa correlation statistic for positive surgical cultures matching the surface sample was 0.9 (95% confidence interval: 0.78-1).
Conclusions: Septic revisions had a significantly higher rate of surgical field contamination than aseptic revisions. Cultures suggest that bacteria contaminating the septic revision surgical field likely originated from the infected joint. Although this observation seems obvious, it is an important piece of information when discussing best practices during a single-stage exchange revision. Further clinical studies will demonstrate the use of a preparation and reset period during a single-stage revision to remove contaminated surfaces.

Introduction

Prosthetic joint infection (PJI) is a well-recognized complication of hip and knee arthroplasty procedures and occurs in 0.7%-2.4% of cases [1,2]; it is projected that it will account for $1.6 billion in health-care costs by the year 2020 [1]. Currently, management of PJI, which may include irrigation and debridement with retention of components in acute PJI, has a substantial risk (64%; range, 11%-84%) of infection relapse [3-6]. Alternatively, management by two-stage exchange may yield greater likelihood of infection control but is associated with an increased morbidity and mortality [4,7,8]. The beneficial effect of two-stage exchange on infection control and survivorship has been addressed by Berend et al. among others, in which factoring the mortality of patients postoperatively brings the success rate to approximately 75% [4,9]. These studies support an increased focus on single-stage exchanges as highlighted by Haddad et al. and Jiranek et al. [10,11]. Evaluation of the single-stage exchange as a treatment for PJI has highlighted the need for strict patient-selection criteria [11-13]. Adherence to these criteria and good surgical technique have led to reported successes equivalent or near equivalent to those of the two-stage exchange with less cost, decreased morbidity, and improved function [3,14,15]. Haddad described the preparation and reset period as the time after

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thorough debridement and explantation of infected implant material when the wound is packed with betadine-soaked sponges and the wound edges temporarily approximated. The complete cleaning or change of surgical rooms is then undertaken with surgeons and assistant(s) changing into clean scrubs, new instruments being opened, and the patient being reprepped and redraped before the reimplantation of the final implants [11]. This step requires additional time for the patient under anesthesia and can add expense to an already costly surgery.

The main aim of this study was to estimate the rate of operative surface contamination during aseptic vs septic total hip and knee revision arthroplasties. Secondary aims were to evaluate the similarity between clinically infecting organisms and those isolated from the contaminated surfaces. Our hypothesis was that septic revisions would demonstrate higher contamination rates than aseptic revisions; although this may seem obvious, we are unaware of any published studies on this topic.

Material and methods

After obtaining institutional review board approval, we prospectively identified consecutive patients undergoing total hip or knee revision arthroplasties from October 2014 to July 2016. All surgeries were performed in one university-based hospital practice among four fellowship-trained orthopedic surgeons. Intraoperative tissue samples were excised with a scalpel from five separate areas, placed into a sterile container, and processed by the clinical microbiology laboratory as per the standard of care. After specimen collection, revisions were classified as either aseptic or septic according to the criteria outlined by the Musculoskeletal Infection Society at that time (current minor criteria have since been altered to exclude the presence of purulence and include leukocyte esterase changes in the synovial fluid.). Septic revisions were those that either had a sinus tract communicating with the prosthesis, a pathogen isolated by preoperative or intraoperative culture from two separate tissue or fluid samples obtained from the affected prosthetic joint, or four of the following six criteria: (1) elevated erythrocyte sedimentation rate and C-reactive protein (erythrocyte sedimentation rate > 30 mm/h; C-reactive protein > 10 mg/L), (2) elevated synovial fluid white blood cell count (>3000 cells/μL), (3) elevated synovial fluid neutrophil percentage (>65%), (4) presence of purulence in the affected joint, (5) isolation of a microorganism in a single periprosthetic tissue or fluid culture, or (6) >5 neutrophils per high-powered field in five high-powered fields observed at ×400 magnification [16].

Aseptic revisions and septic revisions with an identified infecting organism received antibiotics before incision. Antibiotics were held in septic revisions until intraoperative cultures were obtained. Once all implanted components had been removed, five operating room surface samples were obtained in a consistent manner using sponges hydrated with neutralizing buffer (3M, St. Paul, MN). Sample-site acquisition was standardized by the sampling technician for each case and included surgeon's gloves, front of surgeon's gown, light handles, drapes, and scalpel handle. After sample procurement, each case was managed per routine care as determined by the attending surgeon. Sponges were processed immediately after sample attainment by placing them into 50 mL of brain heart infusion broth (Becton Dickinson, Franklin Lakes, NJ) within a sterile bag and stomaching with a Seward Stomacher 80 (Seward, Bohemia, NY) at 256 rotations per minute for 10 minutes. The samples were kept refrigerated overnight, plated on 5% sheep's blood agar plates, and incubated at 37°C for 48 hours. A plate was considered positive if it contained greater than two colony-forming units after 48 hours of incubation. All unique colony morphotypes were identified to genus or species level by matrix-assisted laser desorption ionization time of flight mass spectrometry (Vitek MS; Biomérieux, Durham, NC) using manufacturer-recommended protocols. Standard quality-control testing for all identification and antimicrobial susceptibility testing procedures were verified as acceptable and were performed by a routine automated method (Vitek2 GN81 and GP67 cards, Biomérieux) and/or by manual Kirby-Bauer disk diffusion on Mueller Hinton media with breakpoints and interpretive criteria derived from Clinical Laboratory Standards Institute recommendations (M-100 S26). Contaminated surfaces in the same case with confirmed similar species were only tested for susceptibilities once.

Statistical analysis

A pilot study demonstrated an average aseptic contamination rate of 20% (n = 15 surfaces) and an 80% contamination rate (n = 15 surfaces) in the septic group. With a presumed culture-negative rate of 20% in the septic revisions, a sample population of at least 13 patients would provide 10 culture-positive septic revisions. The collection of at least 23 aseptic cases would provide type II error of less than 0.2 (power = 0.8). An analysis of continuous variables was performed with Student's *t*-test. The Fisher exact test was used due to smaller sample size to compare contamination rates between groups. The degree of correlation was quantified by kappa statistic. Statistical significance was set at $P < .05$. A statistical analysis was performed with JMP statistical software (SAS, Cary, NC).

Results

Patients undergoing revision for aseptic vs septic PJI were of similar sex, age, and body mass index, although the septic group had a slightly increased American Society of Anesthesiologists classification score with a mean difference of 0.35 (95% confidence interval [CI] [0.01-0.69]; $P = .045$) (Table 1). The time to explantation was seven minutes longer in the aseptic group (mean = 54.6 min, time to explantation in septic group, 47.3), but the difference was not significant (95% CI: −8.5 to 23 minutes, $P = .36$). All patients were classified as aseptic or septic revision before the surgery with the exception of one presumed aseptic patient who had 3 on 5 prosthetic tissue cultures positive for bacteria; therefore, this case was recategorized as a septic revision.

There were no positive clinical cultures among aseptic revisions. However, 15 of 18 septic revision cases returned with positive periprosthetic tissue cultures; the remaining three lacked positive tissue cultures but met the criteria of infection and were treated as such (Table 2). The contamination rate among aseptic revisions was 13% (4/31 cases) (95% CI: 5%-29%) with 3% (5/155 surfaces) (95% CI: 1.2%-7.5%) of total sampled surfaces positive for contaminants. By contrast, the contamination rate for septic revisions was 78% (14/18) (95% CI: 54%-92%) with 50% (45/90) (95% CI: 40%-60%) of total sampled surfaces positive for contaminants, which was significantly higher than those for aseptic revisions ($P < .001$).

Table 1
Characteristics of patients by aseptic vs septic revision.

Demographic variable	Aseptic revisions	Septic revisions	*P* value
n	31	18	
Number of females	15	10	.77
Age (y)	62.16	64.72	.48
BMI (kg/m^2)	33.64	34.29	.80
ASA class (1-4)	2.71 (+0.53)	3.06 (+0.64)	.045
Time to explanation (min)	54.62 (±28.93)	47.25 (±21.99)	.36
Total knee revisions	19	12	.77
Total hip revisions	12	6	

ASA, American Society of Anesthesiologists; BMI, body mass index.

Table 2
Characteristics of aseptic vs septic revisions: contamination rates and degree of correlation to the infection organism identified in the surgical cultures.

Recorded results	Aseptic revisions	Septic revisions	*P* value
n	31	18	
Positive clinical cultures	0	15	<.001
Positive cases with surface contamination	13% (4/31) [95% CI: 5%-29%]	78% (14/18) [95% CI: 54, 92%]	<.001
Contamination rate excluding culture-negative cases	13% (4/31) [95% CI: 5, 29%]	93% (14/15) [95% CI: 66%-100%]	<.0001
Percent correlation surgical culture and positive sample	0	93% (13/14) [95% CI: 66%-100%]	<.0003
Average number of positive samples per case	0.16 (0-2)	2.50 (0-5)	<.0001

A case was considered contaminated if one of the surfaces sampled had a positive culture (≥2 colony-forming units/plate).

Furthermore, the mean number of contamination-positive samples per case among aseptic cases (0.16, range: 0-2) was significantly less than that for septic cases (2.5, range: 0-5) ($P < .0001$). Drapes were the most frequently contaminated surface in both aseptic and septic revisions (Table 3).

Comparison of surface culture contaminants with isolates recovered by tissue culture for the 15 culture-positive septic revision cases revealed 14 matches (93%) (95% CI: [66, >99%]) to the species level compared with the 0% (0/31) correlation seen in aseptic revisions ($P < .0001$). In comparison, only 33% (95% CI: 6%-79%) of the culture-negative septic revisions exhibited contamination ($P = .56$). Also, the kappa correlation statistic for positive surgical cultures matching the surface sample was 0.9 (95% CI: 0.78-1). One septic revision case had a positive tissue culture, but no organisms were isolated as contaminants; the patient had been on intravenous antibiotics for several days for the treatment of a concurrent discitis before obtaining intraoperative cultures from the joint. The percent of positive surgical cultures matching the contaminating organism was 93% (13/14) (95% CI: 66, >99%). Organisms identified as surface contaminants are listed in Table 4. Similarly, comparison of antimicrobial susceptibility data between organisms recovered from septic revision tissue cultures and those from corresponding operative surface cultures demonstrated identical profiles in 34 of 34 instances (100%).

Discussion

In this prospective consecutive series of hip and knee revision arthroplasties, septic revisions had a significantly higher rate of surgical field contamination than aseptic revisions. Although it may seem obvious that septic revisions would lead to more contamination of the operative surfaces, this study is the first published finding to support this assumption. The bacteria found as contaminants on the surgical surfaces originated from the infected joint based on matching tissue and surface cultures.

A limitation of this study was the assumption that the antibiotic susceptibility profile was a surrogate for identification of matched organism pairs. Although not as precise as molecular strain analysis techniques (eg, pulse-field gel electrophoresis or multilocus sequence typing), the high degree of correlation between each tissue culture and surface contaminate isolate is of concern and indicates contamination of the field and operating room by the infecting organism. We would emphasize that association of a contaminated field does not provide conclusive evidence for risk of further infection. Although this study provides support that surfaces during a revision PJI often become contaminated, this report does not provide evidence of the impact of contamination on outcomes of these patients. Defining the actual clinical benefit of an intervention aimed at reducing contamination such as a preparation and reset period during a single-stage surgery will ultimately require longer prospective studies with infection-free survival.

This study demonstrated a contamination rate of 13% in aseptic revisions at an average explant time of 54 minutes, which is similar to other reported rates of contamination during the course of surgery [17-19]. Bible et al. described a 9.5% overall contamination rate when comparing covered (2%) to uncovered (16.7%) implant trays [17]. Davis et al. described 63% of cases as having some level of contamination [20]. However, many of the recommendations (eg, removing gloves after initial preparation) are now routinely used by surgeons to mitigate against contamination. We note that the length of time before sampling was not different between the aseptic and septic groups. In reviewing the literature, the duration of surgery has been demonstrated to increase contamination rates. Dalstrom et al. demonstrated a 15% contamination rate at one hour increasing to 30% at 4 hours [18,21]. Ritter et al. found a 35-fold increase in colony-forming units per hour in a room with five people compared with an undisturbed room [22,23]. Although others have found no relationship between time and rates of contamination, [19,20] we felt it important to consider this potentially confounding variable. In 13% of our aseptic cases with contamination, most organisms isolated from surfaces were not typical of PJIs (the single exception being *Staphylococcus epidermidis*). The only difference we found in baseline characteristics was a slightly elevated American Society of Anesthesiologists score in the septic group, which one might expect from a patient population presenting as more acutely ill.

We did find a significantly higher rate of contamination in the septic cases. This percentage is even higher when excluding specimens that had no culturable organisms (culture-negative cases) from clinical specimens. These three cases met Musculoskeletal Infection Society criteria despite sterile intraoperative and/or preoperative cultures. We speculate that the inability to recover organisms from surface sites for these three cases may have been due

Table 3
Number of positive samples per surface for aseptic and septic revisions.

Number of positive samples per surface[a]	Aseptic revisions	Septic revisions	*P* value
Gloves	0	11	<.001
Gown	1	9	<.001
Scalpel handle	1	6	<.0037
Light handle	1	6	<.0037
Drapes	2	13	<.001

[a] Each surface was sampled once during each case. Multiple surfaces could be positive in one case.

Table 4
Highlights the organisms presenting as contaminants from the sampled surfaces.

Contaminant present	
Aseptic cases	Septic cases[a]
Staphylococcus haemolyticus	Methicillin-resistant *Staphylococcus aureus*
Staphylococcus epidermidis	Methicillin-sensitive *Staphylococcus aureus*
Corynebacterium aurimucosum	*Escherichia coli*
	Methicillin-resistant *Staphylococcus epidermidis*
Enterococcus faecalis	Methicillin-sensitive *Staphylococcus epidermidis*
Paenibacillus species	*Serratia marcescens*
	Staphylococcus lugdunensis

[a] All contaminants listed were also found on intraoperative tissue cultures.

to the fastidious nature of the organism(s), which also likely hampered their recovery from clinical samples. We also found that the average number of surfaces contaminated during a septic case vs an aseptic case was significantly different.

The drapes were the most frequently contaminated surface, followed by the surgeon's gloves, surgeon's gown, and then scalpel handles and lights. Prior reports demonstrate a contamination rate of 0%-14.5% for light handles [20,24], 9% for scalpel blades [20], 14%-57% for gloves [20,25], 6%-48% for gowns [20]. These rates were not witnessed in our aseptic revisions, but similar rates were observed in the septic revisions.

This study supports our hypothesis that septic revisions would have higher contamination rates than aseptic revisions. Although this observation seems somewhat obvious, it is an important piece of information in a discussion of the use of a preparation and reset period during a single-stage exchange. Currently, only expert-level opinion (level V evidence) exists to support the removal of drapes and proceeding with total repreparation of the room, all operating room personnel, and the patient during a single-stage exchange [21]. This step prolongs the anesthetic time for the patient and increases the expense of the surgery from a materials standpoint; however, it is thought to be a necessary step for the success of this procedure.

Therefore, the recommendation of Haddad et al. and Jiranek et al. for the wholesale exchange of all operating room materials and for all personnel to change their scrubs while the wound remains temporarily closed merits consideration [10-12,21]. However, further prospective collection of data is required to definitively support this practice.

Conclusions

Septic revision arthroplasties had a significantly higher rate of surgical field contamination than aseptic revisions. Bacteria contaminating the surgical field of septic revisions most often originated from the infected joint itself, based on the matching of surface cultures and tissue cultures. These results may support the practice of exchanging gowns, gloves, drapes, and instruments after prosthesis explantation during septic revisions to eliminate contaminated surfaces and reduce bacterial presence at the time of reimplantation. This topic needs to be studied further in a prospective manner with follow-up with longer term outcomes.

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