The Epidemiology of Chest and Leg Wound Infections Following Cardiothoracic Surgery

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The occurrence of wound infections following cardiothoracic surgery has significant implications. However, the epidemiology of all chest and leg wound infections is infrequently described, and the effects on morbidity, mortality, and cost of care remain undefined. We identified 182 superficial and deep chest and leg infections in 163 patients following 1,554 coronary artery bypass graft (CABG), valve, and CABG/valve procedures over 30 months. The overall infection rate was 11.7%; infections of specific sites involved in the 1,554 procedures occurred at the following rates: 3.1%, superficial chest wounds; 2.3%, deep chest wounds; 4.6%, superficial leg wounds; and 2.2%, deep leg wounds. Chest infection rates were similar for all procedures. Multiple infections occurred in 9.8% of patients and were associated with female sex, diabetes, and prolonged surgery (P < .05). Purulent drainage and fever were more common in chest infections; erythema and pain were more common in leg infections (P < .05). Staphylococcus aureus (32.9%), coagulase-negative staphylococci (27.4%), and Enterobacteriaceae (26.0%) were identified most commonly. Enterobacteriaceae were more commonly isolated from leg wounds (P < .05). Adverse outcomes included reexploration (20.9%), flap surgery (12.3%), and death (4.3%). All adverse outcomes were more commonly associated with deep chest infections (P < .05), but superficial chest and leg infections also had a substantial impact on cardiothoracic surgery-related morbidity. Studies are needed to define site-specific risk factors so that the full potential of prevention and control measures can be realized.

Wound infections contribute substantially to morbidity and mortality following cardiothoracic surgery [1-4]. Deep chest infections may extend to contiguous vital structures, require debridement, result in disfigurement, and have a 10%-40% mortality [3, 5-12]. Total costs are particularly high for treatment of wound infections associated with cardiothoracic surgical procedures, of which >600,000 are performed annually in the United States [2, 3, 5, 13-17]. Prevention and control of cardiothoracic surgical wound infections has become a vital component of quality assurance and hospital cost-containment over the last decade [2, 5, 14-16].

Intensive surveillance of surgical wounds reduces the rate of infection by 20%-50% [1, 2, 4, 18, 19]. Such efforts are costly and time-consuming, but prior stratification by wound class can identify the highest-risk patients for focused surveillance [20, 21]. Recently, the Centers for Disease Control and Prevention (CDC) estimated the surgical wound infection risk associated with cardiothoracic procedures to be 1.03%-33.0% [21]. Development of a cardiothoracic-specific risk index would provide a more sensitive tool for prevention efforts [21, 22].

Much of the literature on cardiothoracic surgical wound infections was published before 1990 and focused on deep chest infections, occurring at rates of 0.5%-5.0% [5-12, 23-31], and the multiple risk factors identified [2, 5-9, 11-14, 17, 23-44]. However, the rates and characteristics of and risk factors for superficial chest infections and both superficial and deep leg infections complicating cardiothoracic surgery are infrequently described [14, 17, 45], and their effects on morbidity, mortality, and cost of care remain undefined. This article describes the clinical nature and outcome of all chest and leg infections following coronary artery bypass graft (CABG), valve, and combined CABG/valve surgery that were identified by prospective surveillance at Barnes Hospital (St. Louis) from April 1991 through September 1993.

Methods

Barnes Hospital is a 1,000-bed tertiary care facility affiliated with Washington University School of Medicine. Cardiothoracic surgeons at the facility perform ~800 procedures per year (70% are performed on patients referred from outside the St. Louis area), including 650 CABG, valve, and combined CABG/valve operations. The cardiothoracic surgery staff in-
cludes 7 attending physicians, 4 cardiac fellows, 4 surgical assistants, 2 nurse specialists, and 2 rotating house-staff members. Patients take a chlorhexidene shower the night before surgery; on the morning of surgery, the chest hair is removed, and then a 1-minute skin scrub with povidone/iodine is followed by application of povidone/iodine solution to the skin site(s). Prophylactic intravenous antibiotics (cefazolin [1 g] or vancomycin [1 g]) are administered 30–120 minutes prior to incision and are given intravenously during prolonged procedures. Prophylactic antibiotic therapy is continued postoperatively until removal of the thoracostomy tubes. Attending physicians and fellows are directly involved in the primary procedure. Vein harvesting is performed by surgical assistants.

One infection control nurse reviews microbiology logs, floor wound infection logs, and floor nursing reports to detect potential wound infections. Formal postdischarge surveillance is not performed. Microbiology reports are screened with use of two expert computer systems (GermWatcher and GermAlert, Medick Informatics, Washington University, St. Louis) previously validated by infection control staff [46]. Wound infections are confirmed by direct bedside examination and review of medical records, with use of National Nosocomial Infection Surveillance (NNIS) System definitions [4]. In this series, deep incisional and deep organ-space infections were considered together as deep wound infections because of the difficulty of distinguishing the two in the chest.

Data concerning demographics, preexisting medical conditions, intraoperative variables, wound infection sites, and wound culture results were collected for all patients with wound infections. The intraoperative use of ≥5 units of packed RBCs defined multiple transfusions. A lengthy procedure exceeded 300 minutes, on the basis of the CDC risk index criteria [21]. Emergent operations immediately followed emergent admission and/or catheterization, and urgent operations were performed within 24 hours of catheterization. Timely administration of the prophylactic antibiotic required initial dosing within 120 minutes before incision. Outcome analysis was based on the most morbid (chest and/or deep) infection for patients with multiple infections. Length of stay included all days of the hospitalization for surgery as well as additional days during subsequent hospitalization(s) for treatment of the wound infection(s).

Data were analyzed with the PC SAS program (SAS Institute, Cary, NC). Categorical variables were analyzed by univariate analysis with the $\chi^2$ or Fisher’s exact test. Continuous variables were analyzed with the Student’s $t$-test (for data with Gaussian distribution) and the Mann-Whitney test (for data with non-Gaussian distribution). A $P$ value of $<.05$ was considered significant on two-tailed testing.

Results

Infection Rates

Prospective surveillance identified 182 wound infections in 163 patients undergoing CABG, valve, and combined CABG/valve surgery from April 1991 through September 1993 (table 1). For 1,554 procedures, the total wound infection rate was 11.7%. The wound infection rate was significantly higher for combined CABG/valve vs. CABG surgery (18.3% vs. 11.8%; $P = .032$). Specific rates of infection among the 1,554 procedures were as follows: 3.1%, superficial chest wounds; 2.3%, deep chest wounds; 4.6%, superficial leg wounds; and 2.2%, deep leg infections. Deep leg infections were more common following combined CABG/valve surgery than following CABG surgery (4.8% vs. 2.0%; $P = .045$). The mean duration of the procedure was longer for infected CABG/valve surgery patients than for infected CABG surgery or valve surgery patients (361.9 minutes vs. 309.9 minutes and 337.0 minutes, respectively; $P = .013$ and $P = .612$, respectively). Infected CABG/valve surgery patients were older than infected CABG surgery or valve surgery patients (mean ages, 69.8 years, 64.5 years, and 53.8 years, respectively), but the differences were not statistically significant.

Characteristics of Patients with Wound Infections

Preexisting medical conditions were common, including smoking (49.7%), diabetes (45.4%), congestive heart failure (40.5%), and obesity (23.9%). Prior infections, documented on 21 occasions in 18 patients (11.0%), included urinary tract infections (10), pneumonia (6), primary bacteremia (4), and purulent phlebitis (1). The mean duration of hospitalization prior to surgery was 8.9 days (range, 0–366 days). Approximately 50% of procedures were urgent or emergent, and 47.9% were lengthy. Preoperative hair removal was documented in 39 (48.8%) of 80 cases and was done with a disposable razor (30.0%), clipper (11.3%), or electric razor (7.5%). Only 83.4% of patients received timely antibiotic prophylaxis.

Most patients (63.2%) had wound infections diagnosed during the initial hospitalization; of the remainder, 30.1% required readmission for treatment of wound infections. Wound infections were identified an average of 21.9 days (range, 3–176 days) following surgery. Excluding 35 infections identified >30 days after surgery, we found that the mean time to diagnosis of the other 147 wound infections was 13.2 days after surgery. Single-site infections occurred in 147 patients (90.2%), affecting 75 chests (41 superficial and 34 deep wounds) and 72 legs (48 superficial and 24 deep wounds). Patients with single chest infections were more likely than those with single leg infections to be smokers (61.3% vs. 43.1%; $P = .027$) and obese (32.0% vs. 13.9%; $P = .009$). Patients with single leg infections were older (mean of 67.3 years vs. 61.6 years; $P = .001$), were more commonly female (47.2% vs. 30.7%; $P = .039$), and more commonly received multiple transfusions than did patients with single chest infections (19.4% vs. 8.0%; $P = .043$).

Thirty-five multiple-site infections occurred in 16 patients (9.8%), affecting 10 chests (8 superficial and 2 deep wounds) and 25 legs (17 superficial and 8 deep wounds). Most patients
Table 1. Comparison of wound infection rates in relation to cardiothoracic procedure.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All procedures</th>
<th>CABG</th>
<th>Valve</th>
<th>CABG/valve</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of procedures</td>
<td>1,554</td>
<td>1,301</td>
<td>127</td>
<td>126</td>
<td>NA</td>
</tr>
<tr>
<td>No. (%) of patients with wound infection</td>
<td>163 (10.5)</td>
<td>138 (10.6)</td>
<td>5 (3.9)</td>
<td>20 (15.9)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Total no. of wound infections</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(% of total procedures)</td>
<td>182 (11.7)</td>
<td>154 (11.8)</td>
<td>5 (3.9)</td>
<td>23 (18.3)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Chest, superficial</td>
<td>49 (3.1)</td>
<td>40 (3.1)</td>
<td>4 (3.1)</td>
<td>5 (4.0)</td>
<td>NS</td>
</tr>
<tr>
<td>Chest, deep</td>
<td>36 (2.3)</td>
<td>32 (2.5)</td>
<td>1 (0.8)</td>
<td>3 (2.4)</td>
<td>NS</td>
</tr>
<tr>
<td>Leg, superficial</td>
<td>65 (4.6)</td>
<td>56 (4.3)</td>
<td>0</td>
<td>9 (7.1)</td>
<td>NS</td>
</tr>
<tr>
<td>Leg, deep</td>
<td>32 (2.2)</td>
<td>28 (2.0)</td>
<td>0</td>
<td>6 (4.8)</td>
<td>.045</td>
</tr>
<tr>
<td>Days to detection, mean no. (range)</td>
<td>21.9 (3–176)</td>
<td>21.6 (3–176)</td>
<td>16.4 (9–31)</td>
<td>22.2 (6–65)</td>
<td>NS</td>
</tr>
</tbody>
</table>

NOTE. CABG = coronary artery bypass graft; NA = not applicable.

(10 of 16) with multiple infections had both chest and leg involvement. Development of multiple infections was associated with female sex (11 of 16, vs. 57 of 147 with single infections; \( P = .021 \)), diabetes (11 of 16 vs. 63 of 147; \( P = .048 \)), and a lengthy procedure (durations >300 minutes, 75% vs. 44.9%; \( P = .022 \)).

Incisional Site Characteristics

Purulent drainage and erythema were the most common manifestations of chest and leg infections, respectively (table 2). Chest infections were more likely than leg infections to be associated with purulent drainage (67.1% vs. 49.5%; \( P = .029 \)) and fever (23.5% vs. 13.4%; \( P = .002 \)). Leg infections were more likely to be associated with erythema (61.9% vs. 38.8%; \( P = .009 \)) and pain (34.0% vs. 18.8%; \( P = .019 \)). At diagnosis, 144 wound infections (79.1%) had at least one of the following signs or symptoms: purulent drainage, erythema, pain, fever, or (in chest infections) sternal instability; however, only 15 (8.2%) had the triad of drainage, erythema, and fever. There was no significant difference between the chest and leg infections with regard to the time to detection of infection.

Table 2. Comparison of signs and symptoms of wound infection, as related to site (chest vs. leg).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Chest site (n = 85)</th>
<th>Leg site (n = 97)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sign or symptom, in no. (%) of infections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purulent drainage</td>
<td>57 (67.1)</td>
<td>48 (49.5)</td>
<td>.029</td>
</tr>
<tr>
<td>Erythema</td>
<td>33 (38.8)</td>
<td>60 (61.9)</td>
<td>.009</td>
</tr>
<tr>
<td>Sternal instability</td>
<td>22 (25.9)</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Fever</td>
<td>20 (23.5)</td>
<td>13 (13.4)</td>
<td>.002</td>
</tr>
<tr>
<td>Pain</td>
<td>16 (18.8)</td>
<td>33 (34.0)</td>
<td>.002</td>
</tr>
<tr>
<td>Days to detection, mean no. (range)</td>
<td>19.2 (3–176)</td>
<td>24.1 (3–125)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Microbiology Results

Wound cultures were performed in 83.5% of cases of infection, and 82.2% were positive. Pure cultures most commonly yielded *Staphylococcus aureus* (32.9%), coagulase-negative staphylococci (27.4%), and Enterobacteriaceae (26.0%) (table 3). Polymicrobial infections involved a similar spectrum of pathogens and frequently involved both gram-positive and gram-negative organisms (62.3%) or a yeast species and a bacterium (13.2%). Almost one-quarter of polymicrobial culture specimens were obtained intraoperatively and likely represented true polymicrobial infection, but the remainder were obtained at the bedside via wound aspiration, with a higher risk of contamination. Methicillin resistance was documented in 37.1% of 35 *S. aureus* isolates. Pure culture specimens were obtained more commonly from chest wounds than from leg wounds (45 of 85 vs. 28 of 97; \( P = .002 \)) (table 3). Among pure culture specimens, coagulase-negative staphylococci and *S. aureus* were more commonly isolated from chest wound specimens (35.6% and 33.3%, respectively), whereas Enterobacteriaceae were more commonly isolated from leg wound specimens (35.7%). Overall, including pure and polymicrobial cultures, gram-negative pathogens were more commonly isolated from leg wounds vs. chest wounds (57 of 116 vs. 21 of 83; \( P = .001 \)).

Outcome Analysis

Operative reexploration for debridement occurred in 34 (20.9%) of the 163 patients with wound infections, including 30 with deep chest infections, 3 with superficial chest infections, and 1 with a deep leg infection. Recreploration for debridement was associated with the following factors: chest infection (33 of 78 vs. 1 of 85; \( P < .001 \)), prior reexploration for hemorrhage (9 of 20 vs. 25 of 143; \( P = .005 \)), and smoking (22 of 81 vs. 12 of 82; \( P = .049 \)). Flap surgery followed reexploration in 20 patients (12.3%), including 18 cases of
Table 3. Microbiology of wound cultures.

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Total</th>
<th>Chest</th>
<th>Leg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In pure culture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>73 (100)</td>
<td>45 (100)</td>
<td>28 (100)</td>
</tr>
<tr>
<td>Coagulase-negative staphylococci</td>
<td>24 (32.9)</td>
<td>15 (33.3)</td>
<td>9 (32.1)</td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td>19 (26.0)</td>
<td>9 (20.0)</td>
<td>10 (35.7)</td>
</tr>
<tr>
<td>Yeast species</td>
<td>4 (5.5)</td>
<td>3 (6.7)</td>
<td>1 (3.6)</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>3 (4.1)</td>
<td>0</td>
<td>3 (10.7)</td>
</tr>
<tr>
<td>Enterococcus species</td>
<td>2 (2.7)</td>
<td>1 (2.2)</td>
<td>1 (3.6)</td>
</tr>
<tr>
<td>Other species</td>
<td>1 (1.4)</td>
<td>1 (2.2)</td>
<td>0</td>
</tr>
<tr>
<td>In polymicrobial culture</td>
<td>126 (100)</td>
<td>38 (100)</td>
<td>88 (100)</td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td>36 (28.6)</td>
<td>7 (18.4)</td>
<td>29 (33.0)</td>
</tr>
<tr>
<td>Coagulase-negative staphylococci</td>
<td>20 (15.9)</td>
<td>12 (31.6)</td>
<td>8 (9.1)</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>18 (14.3)</td>
<td>4 (10.5)</td>
<td>14 (15.9)</td>
</tr>
<tr>
<td>Enterococcus species</td>
<td>16 (12.7)</td>
<td>4 (10.5)</td>
<td>12 (13.6)</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>14 (11.1)</td>
<td>1 (2.6)</td>
<td>13 (14.8)</td>
</tr>
<tr>
<td>Yeast species</td>
<td>7 (5.6)</td>
<td>3 (7.9)</td>
<td>4 (4.5)</td>
</tr>
<tr>
<td>Other species</td>
<td>15 (11.9)</td>
<td>7 (18.4)</td>
<td>8 (9.1)</td>
</tr>
</tbody>
</table>

Deep chest infection and 1 each of superficial chest and deep leg infection. Flap surgery was associated with chest infection (19 of 78 vs. 1 of 85; \( P < .001 \)) and obesity (9 of 39 vs. 11 of 124; \( P = .018 \)). Seven patients (4.3%) died, and wound infections contributed directly to the fatal outcome of five (four deep chest and one deep leg infection). Death was associated with reexploration for hemorrhage (4 of 20 vs. 3 of 143; \( P = .005 \)). The mean length of stay was 34.9 days (range, 6–283 days) overall and was similar for chest infections and leg infections (37.0 days and 30.0 days, respectively). Patients with deep chest infections had worse outcomes compared to those for other infected patients, including more frequent reexploration and flap surgery (31 of 36 vs. 5 of 127; \( P < .001 \)), and the mortality among them was greater (4 of 36 vs. 3 of 127; \( P = .043 \)).

Discussion

We identified a wound infection rate of 11.7% during 30 months of active surveillance of cardiothoracic surgery patients. The recency of surveillance suggests that our results reflect the infection risk at our institution in the modern era of cardiothoracic surgery. Our rates may reflect the risks at similar tertiary care institutions but are not necessarily applicable to nonreferral centers, given the potential differences in the patient populations. Because of the increased pressure for early discharge and the incomplete nature of follow-up, our wound infection rate may still underestimate the true risk [1, 2, 4, 5, 23]. Implementation of formal postdischarge surveillance will be required to establish the true risk of wound infection in cardiothoracic surgery and its impact on patient morbidity and mortality [5, 23].

Through active surveillance, we recognized that untimely antibiotic prophylaxis and unnecessary chest hair shaving were common in the cardiothoracic surgery department. Since the time of our study, we have initiated infusion of prophylactic antibiotics by anesthesiologists in the holding area prior to surgery, and this has increased the percentage of patients receiving timely prophylaxis to nearly 95%. We also have eliminated routine shaving of chests prior to surgery, but clipping is used if necessary. Prospective evaluation of both of these interventions will be needed to demonstrate efficacy in reducing wound infections.

Investigators of prior series defined deep chest infection rates of 0.5%–5.0% but failed to analyze the rates of superficial chest infection and superficial and deep leg infection [5–12, 23–31]. Kaiser et al. documented the impact of both chest and leg wound infections on patients’ outcome and hospital charges in 1987 [47], and the CDC has focused additional attention on site-specific rates [21]. Investigators of series of superficial and deep infections have reported rates similar to ours [14, 17, 45]. Active surveillance, utilization of standard definitions, and reduction of the influence of surgeons’ self-reporting bias may increase the reported rates of wound infections [1, 2, 8, 11, 13, 18, 19]. Greater comorbidity, acuity of illness, and/or case complexity in cardiothoracic surgery departments at tertiary care centers may also contribute to higher rates [8, 13, 16].

Despite the increasing complexity of CABG vs. valve vs. combined CABG/valve surgery, we noted consistent rates of superficial chest (3.1%–4.0%) and deep chest (0.8%–2.5%) infections among the three procedures, as noted in other series [6, 7, 9, 12]. However, following saphenous vein harvesting, leg infection complicated combined CABG/valve surgery more frequently than did CABG surgery, accounting for the difference in total infection rates (18.3% vs. 11.2%) between the two procedures. The greater mean age of patients undergoing combined CABG/valve surgery may be partially responsible. In addition, the extended mean duration of combined CABG/valve surgery may have increased the risk of intraoperative contamination.

The pathogenesis of chest and leg wound infections is not fully understood and may be distinct for each site [13, 41, 42]. We and others have identified gram-negative infections (particularly those due to Enterobacteriaceae) more frequently involving the leg [13, 17, 42]. Assuming intraoperative wound contamination is a prerequisite for the majority of infections at either site, it is possible that the patient’s fecal flora represent the primary pathogens for the development of leg infections because of greater intraoperative contamination of the leg wound [13, 17, 42]. This suggests that additional preoperative strategies for the prevention of leg infections may be necessary, including a longer leg-skin antibacterial scrub, use of alternative skin antibacterial agents, and perhaps gastrointestinal decontamination.

Diagnosis of wound infection following cardiothoracic surgery remains difficult and requires increased clinical suspicion.
during the first 14 days postoperatively, when most infections present [6, 8, 9, 13, 48]. It may be difficult to distinguish the signs of an infected wound from those of a poorly healing, noninfected wound. We found the combination of drainage, erythema, and fever to be uncommon, and infections may be missed if clinicians rely on the presence of these three signs. Widespread utilization of the NNIS criteria may improve detection of wound infections and allow for improved interhospital comparisons of infection rates through standardization [21].

The occurrence of wound infections due to coagulase-negative staphylococci, gram-negative organisms, and fungi may be increasing in cardiothoracic surgery [6–10, 13, 32, 41–43, 49]. We noted coagulase-negative staphylococci in 35.6% of the pure chest-specimen cultures, gram-negative organisms in 35.7% of the pure leg-specimen cultures, and fungi in 5.5% of the pure cultures overall. Infection at either site may involve gram-positive, gram-negative, or mixed (albeit contaminating) pathogens, so broad empirical antibiotic therapy must be considered for both sites, pending culture data [5–8, 13]. Antifungal therapy should be considered when patients are unresponsive to standard antibiotic regimens [7, 9, 13, 32, 49].

In our series combined chest and leg infections were associated with similarly prolonged hospital stays, in comparison with the average stay in 1993 of 9.3 days for uncomplicated cardiothoracic surgery, a finding emphasizing that both contribute significantly to excessive morbidity following such surgery. The mortality associated with deep chest infection (11.1%) in our series compares favorably with recent series noting 10%–40% mortality [5–10, 12, 13, 28]. Overall, we noted low mortality (4.3%) among patients with wound infections, despite the high frequency of comorbid conditions and delayed diagnosis, as well as the extensive nature of deep chest infections. Infection-related mortality was not limited to patients with deep chest involvement, as a deep leg wound infection contributed to one patient’s death. With prospective payment patterns, wound infections result in higher hospital costs, with net losses overall [5, 14, 15, 50]. Thus, prevention of both chest and leg wound infections should be a priority in cardiothoracic surgery.

Prospective studies in cardiothoracic surgery are needed to validate the efficacy of generic infection-control strategies (including reporting of infection rates to surgeons) and more specific interventions (such as timely antibiotic prophylaxis and elimination of chest-hair shaving). In addition, case-control investigations of wound infections at both chest and leg sites will be required to discriminate risks factors for each and to develop site-specific risk indices for future prevention efforts. Finally, documentation of resource utilization associated with all wound infections in cardiothoracic surgery will help focus attention on these complications.

References


