Outcomes in Patients With Cardiovascular Implantable Electronic Devices and Bacteremia Caused by Gram-Positive Cocci Other Than *Staphylococcus Aureus*

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**Background**—Infection is a serious complication of cardiovascular implantable electronic device (CIED) placement and requires device removal for attempted cure.

**Methods and Results**—We studied the rate, risk factors, and outcomes of CIED infection in 74 consecutive patients with bacteremia caused by Gram-positive cocci (GPC) other than *Staphylococcus aureus* between 2001 and 2007. CIED infection was defined as the presence of signs of infection at the generator site, lead vegetations seen on echocardiography, or microbiological growth from device cultures. Twenty-two (30%) of 74 patients with non--*S aureus* GPC bacteremia had CIED infections. Coagulase-negative staphylococci (CoNS) accounted for 73% of CIED infections. The rate of CIED infection in patients with CoNS bacteremia was almost 2-fold that of non-CoNS GPC bacteremia (36% versus 20%, \(P = 0.13\)). The number of leads, the presence of abandoned leads, and prior generator replacement were associated with CIED infection. Among 33 patients without identifiable CIED infection at initial evaluation who did not undergo device removal, 5 (15%) had relapsing bacteremia within 12 weeks of completing antibiotic therapy. CoNS accounted for all relapses, and none had evidence of CIED infection at relapse.

**Conclusions**—Patients with a CIED and bacteremia caused by GPC other than *S aureus* frequently had evidence of underlying CIED infection on clinical evaluation that included transesophageal echocardiography. This was particularly true among those with CoNS bacteremia. No evidence of underlying CIED infections was identified in the subgroup of patients who did not have manifestations of CIED infection on initial evaluation but subsequently had relapsing bacteremia caused by CoNS. (Circ Arrhythm Electrophysiol. 2010;3:639-645.)

**Key Words:** Permanent pacemaker ■ implantable cardioverter-defibrillator ■ infection ■ Gram-positive coccus ■ coagulase-negative staphylococci

Cardiovascular implantable electronic devices (CIED), including permanent pacemaker and implantable cardioverter defibrillator (ICD) use, is continuously growing partly because of an expanding number of indications for these devices.1-4 Recent epidemiological investigations indicate a disproportionate increase in the rate of CIED infections compared with the rate of device placement.5-7 Infection is a potentially life-threatening complication of CIED placement, and scientific statements from the American Heart Association (AHA) and the Heart Rhythm Society (HRS) both recommend complete device and lead removal in patients with definite CIED infection.8,9

**Clinical Perspective on p 645**

The likelihood of bloodstream infection serving as a manifestation of underlying CIED infection is variable and partly depends on the microbiological cause of bacteremia. In patients with *Staphylococcus aureus* bacteremia, the reported rate of underlying CIED infection has been as high as 45%.10,11 In contrast, only 6% of the patients presenting with Gram-negative bacteremia had underlying CIED infection in one retrospective survey.12 However, the incidence and risk factors associated with CIED infection in patients with bacteremia caused by Gram-positive cocci (GPC) other than *S aureus* is not known and has been identified as a focus of much-needed investigation.8 In addition, the optimal treatment of patients with CIED and bacteremia caused by GPC other than *S aureus* and no other evidence of CIED infection needs further elucidation.

The primary aims of this study were to define the rate and associated risk factors of CIED infection in patients with bacteremia caused by GPC other than *S aureus*. We also

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Preliminary analyses of these data were presented at the Scientific Sessions of the American Heart Association Meeting, November 16, 2009, in Orlando, Florida (abstract published in Circulation. 2009;120:8648–8649).

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studied the outcomes of patients with bacteremia caused by these organisms and no other evidence of CIED infection at initial presentation who did not undergo CIED removal.

**Methods**

**Study Population**

Seventy-four consecutive patients with CIED and bacteremia caused by Gram-positive cocci other than *S. aureus* who presented to Mayo Clinic, Rochester between 2001 and 2007 were identified retrospectively. Patients were identified by searching the Mayo Clinic microbiology laboratory records, the prospectively maintained CIED implantation data base, and hospital discharge ICD codes. Blood cultures were considered to be contaminated and excluded as cases of bacteremia if (1) coagulase-negative staphylococci (CoNS), *Micrococcus* species, enterococci, or viridans group streptococci were identified in only 1 set of cultures or (2) cultures from central venous or arterial catheters were positive in the absence of simultaneous positive cultures from a peripheral blood sample. The Mayo Clinic Institutional Review Board approved the study, and all patients consented to the use of their medical records for research purposes.

**Definitions**

CIED infection was defined as previously published, by the presence of (1) local signs of inflammation at the generator site, such as erythema, warmth, fluctuance, wound dehiscence, erosion, tenderness, or purulent drainage, or (2) lead vegetations detected by echocardiography, or (3) the fulfillment of modified Duke criteria for endocarditis. Echocardiographic findings suggestive of CIED or valvular endocarditis were defined as the presence of an oscillating intracardiac mass on a cardiac valve or supporting structures (in the path of regurgitant jets) or CIED leads in the absence of an alternative anatomic explanation, or visualization of a cardiac abscess, or new dehiscence of a prosthetic valve. CIED infection was microbiologically confirmed if cultures of tissue samples or swabs taken from the generator pocket and/or lead were positive for the same organism that was isolated in blood cultures. The diagnosis of CIED infection was rejected if a patient had no evidence of infection at the time of initial bacteremia, did not undergo system removal, and did not have relapsing infection during a 12-week follow-up period.

Relapsing bacteremia was defined as bacteremia caused by the same organism (based on microbiological identification and antimicrobial susceptibility testing) subsequent to complete clinical resolution of an initial episode of bacteremia after completion of planned treatment duration. Bacteremia was classified as nosocomial, health care-associated, or community-acquired, as previously defined.

**Statistical Analysis**

Continuous variables are summarized as median and range and compared between groups using the Wilcoxon rank sum test. Categorical variables are presented as percentages and compared between groups using the Fisher exact test. A 2-tailed *P*<0.05 was considered statistically significant. The probability of CIED infection associated with risk factors identified during univariate analysis was expressed as odds ratio (95% confidence interval). Time-to-relapse was calculated from the completion of antibiotic therapy to the time of first documented relapse. Patients who had not relapsed at the time of their last follow-up were censored at that time. The cumulative probability of relapsing bacteremia was estimated using the Kaplan-Meier method. All statistical analyses were performed using JMP (Version 7, SAS Institute Inc, Cary, NC).

**Results**

The clinical characteristics of 74 patients with a CIED and bacteremia caused by GPC other than *S. aureus* are presented in Table 1. The treatment and outcome of the 74 patients are presented in Figure 1. The median age of the cohort was 69 years (range, 20 to 91), and 56 (76%) were men. Fifty-one (69%) patients had a pacemaker and 23 (31%) had an ICD. Device implantation was performed at Mayo Clinic in 50% of patients and 71 (96%) patients had a generator implanted in the chest. Three patients had a generator implanted in the abdominal wall. Median (interquartile range) interval from device implantation to bacteremia was 945 days (interquartile range, 242 to 1743). A device-related procedure, including initial implantation, generator change, lead repositioning, or device upgrade was performed <3 months before the bacteremia in 9 (15%) patients.

The causative organism was CoNS in 44 patients and non-CoNS GPC in 30 patients (Figure 2). The non-CoNS GPC included *Enterococcus* species (n=16), β-hemolytic streptococci (n=5), viridans group streptococci (n=4), *Streptococcus pneumoniae* (n=3), *Pediococcus* species (n=1), and *Lactococcus gravisae* (n=1). Infection was nosocomial or health care–associated in 69% of patients. The source of bacteremia was the CIED generator pocket in 9 patients (12%). Other sources included indwelling central venous catheters (n=30), skin or soft tissue infection (n=9), pneumonia (n=5), urinary tract infection (n=2), intraoral infection (n=2), and intra-abdominal infection (n=1). No source was identified in 11 patients.

Twenty-two (30%) patients met the criteria for CIED infection. Echocardiography was performed in 59 (80%) patients; transthoracic (TTE) in 16, transesophageal (TEE) in 27 and both TTE and TEE in 16. Lead vegetations were identified in 15 (68.1%) of 22 patients with CIED infection. Ten patients with lead vegetations had CoNS and the remainder had non-CoNS GPC infection. Concurrent lead and valvular endocarditis was noted in 3 patients and isolated valvular endocarditis in 5 others. Of the 16 patients who underwent TTE and TEE, lead endocarditis was demonstrated with both procedures in 2 patients and only with the TEE in 3 others. The diagnosis was established based on the presence of findings of pocket infection in 6, modified Duke criteria in 10, and both pocket infection and Duke criteria in 6. The diagnosis was confirmed microbiologically in 14 patients. Of the 8 who did not have microbiological confirmation of CIED infection, 2 had evidence of pocket infection, 5 met modified Duke criteria, and 1 had both. Microbiological confirmation was not available because the device was not removed in 4 patients, culture of an explanted device was not performed in 3 patients, and 1 patient was lost to follow-up.

**Risk Factor Analysis**

The clinical and microbiological characteristics of patients with and without CIED infection are presented in Tables 1 and 2, respectively. Figure 1 displays the distribution of causes of bacteremia in the 2 groups. The rates of CIED infection were similar in bacteremic patients with pacemaker and ICD (31% versus 26%, *P*=0.7). No statistically significant differences were noted in the interval between the most recent device procedure and bacteremia in patients with and without CIED infection. The majority (95%) of CIED infection occurred ≥3 months after the most recent device-related procedure. Device characteristics associated with increased odds of CIED infection included number of implanted leads (odds ratio [OR] per lead, 4.9; range, 1 to 23.2), presence of abandoned leads (OR, 17.3; range, 3.3 to 90.0), and history of...
generator replacement at the same site as the current device (OR, 4.5; range, 0.5 to 38.5).

Patients with CIED infection and bacteremia presented with indolent symptoms for a longer period of time and had fewer systemic symptoms such as fever and hypotension. Whereas bacteremia in patients with renal failure was less likely to be associated with CIED infection, other patient characteristics such as the presence of prosthetic heart valve, coronary artery disease, heart failure, diabetes mellitus, malignancy, exposure to immunosuppressive agents, and chronic skin diseases did not differ significantly between the groups. Bacteremia was nosocomial or health care–acquired in the majority of (n/1100513) patients with CIED infection. Bacteremia secondary to an infected central venous catheter was less likely to be associated with CIED infection compared with other sources of bacteremia (17% versus 42%, P = 0.03).

Sixteen (36%) of 44 patients with CoNS bacteremia and 6 (20%) of 30 patients with non-CoNS bacteremia had CIED infection (P = 0.13). CoNS accounted for 73% of CIED infections. The clinical characteristics associated with CIED infection in patients with CoNS bacteremia are presented in Table 3.

### Treatment and Outcome

Among the cohort of 22 patients with evidence of CIED infection, the device was explanted at initial presentation in 12 patients. Five patients with evidence of lead endocarditis or generator pocket infection or both underwent device explantation after relapse of bacteremia, in which initial treatment consisted of antibiotic therapy alone. High operative risk precluded device explantation in 4 patients. Two of the 4 patients died in hospital as a result of infection despite appropriate antibiotic therapy, and the remaining 2 were prescribed long-term suppressive antibiotic therapy. One patient in whom device extraction was recommended was lost to follow-up before definitive treatment.

Device explantation was performed in 8 patients with no clinical evidence of CIED infection, based on modified Duke criteria and absence of pocket infection: 3 had valvular infective endocarditis, 1 had concurrent explantation of infected left ventricular assist device (LVAD), 2 had recurrent bacteremia of unknown primary focus, and 2 had bacteremia from a known non-CIED source. None of these 8 patients had microbiological...
evidence of CIED infection based on cultures of explanted material. The CIED was not explanted in 44 patients with bacteremia and no other clinical evidence of CIED infection.

Percutaneous or surgical device extraction was performed in 25 patients. Percutaneous extraction was attempted in 22 patients. Of these, 20 patients had successful complete percutaneous removal of device and leads and 2 had partial extraction with retained leads. Techniques used for percutaneous extraction included manual traction ($n=3$), locking stylet ($n=8$), and laser sheath ($n=11$). Complications occurred in 2 patients after percutaneous extraction including hypotension and bleeding at the device site. Successful surgical device extraction was performed in 3 patients as a primary procedure and in 1 patient after an unsuccessful attempt at percutaneous extraction. After device explantation, only 12 (48%) patients required reimplantation of CIED, which was performed at a median of 11 days after the resolution of bacteremia.

All patients were treated with intravenous and/or oral antibiotics for a median of 18 days (range, 2 to 70). Total duration of antibiotic therapy was longer in patients with CIED infection (34 days; range, 2 to 70) compared with patients without CIED infection (16 days; range, 2 to 49; $P=0.008$). Four (18%) patients with CIED infection died in-hospital, 3 as a direct consequence of the infection and 1 of an unrelated cause. Death occurred in 8 (15%) patients with no evidence of CIED infection.

**Figure 1.** Treatment and outcome of patients with CIED and GPC bacteremia other than $S$ aureus.

**Figure 2.** Distribution of microbiological etiology of bacteremia in patients with and without CIED infection.
The major findings of the study include the following: (1) S aureus is the predominant pathogen responsible for CIED infection.16,17 Significant, the largest published cohort to date. This investigation is pertinent because non–S aureus GPC are among the most common causes of bloodstream infection, and CoNS are the predominant pathogens responsible for CIED infection.16,17 Moreover, cardiac valve involvement was noted in patients with CIED and bacteremia caused by GPC other than S aureus.9 However, published data that examine outcomes in patients with CIED and bacteremia caused by GPC other than S aureus have been scant.

We observed a relatively high rate (30%) of CIED infection in patients with bacteremia caused by GPC other than S aureus. Among the 22 patients who had CIED infection in the current investigation, only 9 had evidence of generator site infection. Moreover, cardiac valve involvement was noted in relapses occurred in patients with CoNS bacteremia and none with no clinical evidence of CIED infection who did not undergo CIED explantation. However, none of these patients had demonstrable CIED infection at the time of relapse. The recognition of CIED infection in patients with bacteremia is pivotal in their optimal treatment. Consensus statements from the AHA and HRS both recommend complete removal of CIED in patients with definite evidence of CIED infection and in patients with either occult staphylococcal9 or GPC9 bacteremia without definite CIED infection. These recommendations are based on an observed 36% to 45% CIED infection rate and high mortality in the absence of CIED explantation in patients with S aureus bacteremia.10,11,16 However, published data that examine outcomes in patients with CIED and bacteremia caused by GPC other than S aureus have been scant.

Relapse of bacteremia within 12 weeks of completion of antibiotic therapy occurred in 5 (15%) of 33 patients without initial evidence of CIED infection who did not undergo device extraction and survived to discharge. Figure 3 presents the Kaplan-Meier curve for relapse-free survival in patients without CIED infection who survived to discharge. All relapses occurred in patients with CoNS bacteremia and none had definite CIED infection at the time of the relapse. Relapse was attributed to persistent infection of a central venous catheter and LVAD, respectively, in 2 patients. They were treated with infected catheter removal in the former case and long-term antibiotic suppression in the latter case. A third patient did not have an identifiable source of infection and was treated successfully with a repeat course of antibiotics alone. A fourth patient had an infected LVAD as the source of bacteremia, and the last patient died before identification of a source of relapsing bacteremia.

### Discussion

The current study characterizes the clinical features and outcomes of 74 patients with bacteremia caused by GPC other than S aureus and prior placement of CIED and is the largest published cohort to date. This investigation is pertinent because non–S aureus GPC are among the most common causes of bloodstream infection, and CoNS are the predominant pathogens responsible for CIED infection.16,17

The major findings of the study include the following: (1) 30% of patients with bacteremia caused by GPC other than S aureus had CIED infection; (2) CoNS accounted for 73% of CIED infections; and (3) bacteremia relapsed in 15% of patients with no clinical evidence of CIED infection who did not undergo CIED explantation. However, none of these patients had demonstrable CIED infection at the time of relapse.

| Table 2. Comparison of Characteristics of Non–Staphylococcus aureus GPC Bacteremia in Patients With and Without CIED Infection |
|---------------|-------------|-------------|------------------|---|
| Characteristics | All Patients | CIED Infection | No CIED Infection | P  |
| CoNS* bacteremia | 44 (59%) | 16 (73%) | 28 (54%) | 0.13 |
| Non-CoNS bacteremia | 30 (41%) | 6 (27%) | 24 (46%) |  |
| Duration of bacteremia, d; median (range) | 1 (1–7) | 2.5 (1–9) | 1 (1–17) | 0.35 |
| Time to culture positivity, d; median (range) | 1 (1–3) | 1 (1–3) | 1 (1–2) | 0.004 |
| Methicillin susceptibility | 38 (53%) | 12 (55%) | 26 (52%) | 0.84 |
| Source of blood stream infection | Central venous catheter | 30 (41%) | 5 (23%) | 25 (48%) | 0.03 |
| CIED generator pocket | 9 (12%) | 9 (41%) | 0 (0%) |  |
| Skin or soft tissue infection | 7 (9%) | 3 (14%) | 4 (8%) |  |
| Other | 17 (23%) | 2 (9%) | 15 (29%) |  |
| Unknown | 11 (15%) | 3 (14%) | 8 (15%) |  |
| Acquisition of blood stream infection | Nosocomial/health care–associated | 51 (69%) | 13 (59%) | 38 (73%) | 0.17 |
| Community-acquired | 23 (31%) | 9 (41%) | 14 (27%) |  |

| Table 3. Risk Factors Associated With CIED Infection in Patients Presenting With CoNS Bacteremia |
|---------------|-------------|-------------|------------------|---|
| Clinical Characteristics | All CoNS Bacteremia | CIED Infection | No CIED Infection | P  |
| Permanent pacemaker | 30 (68%) | 12 (75%) | 18 (64%) | 0.46 |
| ICD | 14 (32%) | 4 (25%) | 10 (36%) |  |
| No. of leads | 2 (1–5) | 2 (2–5) | 2 (1–3) | 0.003 |
| Presence of abandoned leads | 10 (23%) | 8 (50%) | 2 (7%) | 0.002 |
| No. of CIED manipulations* | 0 (0–5) | 1 (0–5) | 0 (0–3) | 0.01 |
| Previous generator at current device site | 12 (30%) | 9 (60%) | 3 (12%) | 0.003 |
| Chronic renal failure | 22 (50%) | 2 (13%) | 20 (71%) | 0.0002 |
| Central venous catheter | 25 (57%) | 5 (31%) | 20 (71%) | 0.01 |
| Atrial fibrillation | 23 (52%) | 4 (25%) | 19 (68%) | 0.006 |
| Acquisition of blood stream infection | Nosocomial infection | 15 (34%) | 1 (6%) | 14 (50%) |  |
| Health-care–associated infection | 17 (39%) | 7 (44%) | 10 (36%) |  |
| Community-acquired infection | 12 (27%) | 8 (50%) | 4 (14%) |  |
| Suspected source of blood stream infection | Central venous catheter | 25 (57%) | 4 (25%) | 21 (75%) | 0.0002 |
| Generator site infection | 9 (20%) | 9 (56%) | 0 (0%) |  |
| Other | 10 (23%) | 3 (19%) | 7 (25%) |  |

*Device manipulation included generator change, lead repositioning, and device upgrade.
14% of patients with CIED infection and prompted a longer course of antibiotic therapy. Hence, a thorough evaluation for device infection, including transesophageal echocardiography, is warranted in all patients with bacteremia caused by Gram-positive cocci. There were noteworthy differences in CIED infection rates based on causative organism. Among patients with CoNS bacteremia, the CIED infection rate was 36%, in contrast to 20% in those with non-CoNS GPC bacteremia. However, the observed difference in infection rates between the 2 groups did not reach statistical significance because of the relatively small sample size. The CIED infection rate in patients with CoNS bacteremia was similar to that of patients with S aureus bacteremia (35.5%) previously seen at our institution. Although the majority of CoNS infections were health care–associated, patients with community-acquired CoNS bacteremia had a strikingly high CIED infection rate of 67%. Hence, CIED infection should be considered in all patients with staphylococcal bacteremia, regardless of coagulase designation.

Although the relatively small size of the cohort did not permit a robust multivariable analysis to be performed, the associated risk factors identified on univariate analysis deserve comment. The increased risk of device infection associated with an increasing number of leads is consistent with findings from an earlier case-control study (OR, 5.4) conducted at our institution. This is of particular relevance as the indications for placement of multiple leads such as cardiac resynchronization therapy expand rapidly. The presence of abandoned leads was also associated with increased CIED infection rate. Nonetheless, we have previously shown that lead abandonment does not adversely affect CIED function. The generally favorable outcome without routine extraction of abandoned leads suggests close observation may be preferable in this population. The increased risk of infection with multiple device procedures such as generator change in the current study is consistent with the findings of previous studies. Results from the REPLACE registry showed 1.3% and 0.8% risks of infection in the first 6 months after generator replacement with and without lead revision, respectively. Interestingly, the presence of renal failure and central venous catheter in patients with CoNS bacteremia was not associated with increased risk of infection, in contrast to increased risk of CIED infection in renal failure noted by others.

Despite careful evaluation that includes transesophageal echocardiography, there is often lingering concern for occult CIED infection among patients who have bacteremia with no other evidence of CIED infection and who do not undergo complete device removal. In the current study of bacteremia caused by GPC other than S aureus, 15% of patients without other evidence of CIED infection on initial presentation developed relapsing bacteremia within 12 weeks of antibiotic completion. All episodes of relapsing bacteremia were due to CoNS, and none had clinical evidence of CIED infection at relapse. Patients who did not undergo device extraction had a mortality rate of 19% compared with 12% for those who underwent device extraction (P=0.5). These findings suggest that routine device removal in the absence of clinical evidence of CIED infection is not required for patients with bacteremia due to GPC other than S aureus. In light of these findings, the AHA and HRS recommendations for device removal in cases with “occult” GPC bacteremia may need reevaluation. Because our investigation included a limited number of patients with bacteremia, currently, it seems prudent to recommend that these patients be followed closely within 12 weeks of antibiotic completion to detect evidence of early relapsing infection that could involve the CIED.

This study has several limitations inherent to observational retrospective studies including selection, referral, and ascertainment bias. Our institution is a tertiary referral center, and 22% of patients were referred from elsewhere. The use of standard definitions and objective data to identify CIED infection might minimize ascertainment bias. Because of the retrospective nature of the study, not all patients received the same diagnostic evaluation, and we might have underestimated the rate of CIED infection. However, this is less likely because of the low relapse rate observed in patients thought to have no CIED infection. Because half of the patients had devices implanted at other institutions, information pertaining to implantation techniques and antibiotic prophylaxis were not available. However, these may be less relevant in this cohort because of the occurrence of predominantly late infections.

**Conclusions**

This study demonstrates that patients with bacteremia caused by GPC other than S aureus have a relatively high rate of CIED infection. All patients with GPC bacteremia and CIED should be thoroughly investigated for evidence of CIED infection. The higher prevalence of CIED infection in patients with CoNS bacteremia as compared with those with non-CoNS GPC bacteremia is consistent with the proclivity of staphylococcal species to cause device infections due to unique virulence factors. In contrast to patients with S aureus bacteremia, a more deliberate approach with close observation in the absence of clinical evidence of CIED infection can be undertaken in patients with non-S aureus GPC bacteremia.
Disclosures

Dr Friedman’s disclosures include honoraria/consultant: Medtronic, Guidant, and Astra Zeneca; sponsored research: Medtronic, Astra Zeneca via Beth Israel, Guidant, St Jude, and Bard; intellectual property rights: Bard EP, Hewlett Packard, and Medical Positioning, Inc; Dr Hayes: honoraria: Medtronic, Guidant, St Jude Medical, ELA Medical, and Biotronik; sponsored research: Medtronic, Guidant, St Jude Medical; medical advisory board: Guidant; steering committee member: Medtronic; Dr Baddour: royalty payments: UpToDate; editorship: Massachusetts Medical Society (Journal Watch Infectious Diseases); ACP/PIER editorial consultant; and Dr Sohail: honoraria/consultant: TyRx Pharma, Inc.

References


CLINICAL PERSPECTIVE

Infection of cardiovascular implantable electronic devices (CIED) is a serious complication that often requires device removal for cure. Staphylococcus aureus bacteremia in the presence of a CIED often indicates CIED infection, but the frequency of CIED infection when bacteremia occurs with other Gram-positive cocci is not defined. This retrospective study found that in patients who had a CIED and bacteremia with GPC that were not Staphylococcus aureus, 30% had evidence that the infection involved the CIED pocket or leads. Coagulase-negative staphylococcus was most common and associated with a greater likelihood of CIED infection than bacteremia with non-staphylococcal Gram-positive cocci. Relapse of bacteremia in patients without identifiable CIED infection at initial evaluation, who did not undergo device removal, was uncommon (15%) within 12 weeks of completing antibiotic therapy and relapse was not associated with evidence of CIED infection. These findings indicate that all CIED patients with Gram-positive cocci bacteremia should be thoroughly investigated for evidence of CIED infection. For those without clinical evidence of CIED infection and without Staphylococcus aureus bacteremia, close observation during antibiotic therapy without CIED removal is a reasonable initial approach.
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