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Heart Rhythm Disorders

Management and Outcome of Permanent Pacemaker and Implantable Cardioverter-Defibrillator Infections

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Objectives
We describe the management and outcome of permanent pacemaker (PPM) and implantable cardioverter-defibrillator (ICD) infections in a large cohort of patients seen at a tertiary care facility with expertise in device lead extraction.

Background
Infection is a serious complication of PPM and ICD implantation. Optimal care of patients with these cardiac device infections (CDI) is not well defined.

Methods
A retrospective review of all patients with CDI admitted to Mayo Clinic Rochester between January 1, 1991, and December 31, 2003, was conducted. Demographic and clinical data were collected, and descriptive analysis was performed.

Results
A total of 189 patients met the criteria for CDI (138 PPM, 51 ICD). The median age of the patients was 71.2 years. Generator pocket infection (69%) and device-related endocarditis (23%) were the most common clinical presentations. Coagulase-negative staphylococci and Staphylococcus aureus, in 42% and 29% of cases, respectively, were the leading pathogens for CDI. Most patients (98%) underwent complete device removal. Duration of antibiotic therapy after device removal was based on clinical presentation and causative organism (median duration of 18 days for pocket infection vs. 28 days for endocarditis; 28 days for S. aureus infection vs. 14 days for coagulase-negative staphylococci infection \( p < 0.001 \)). Median follow-up after hospital discharge was 175 days. Ninety-six percent of patients were cured with both complete device removal and antibiotic administration.

Conclusions
Cure of CDI is achievable in the large majority of patients treated with an aggressive approach of combined antimicrobial treatment and complete device removal. Based on findings of our large retrospective institutional survey and previously published data, we submit proposed management guidelines of CDI. (J Am Coll Cardiol 2007;49:1851–9) © 2007 by the American College of Cardiology Foundation

With an increasing number of indications for use of permanent pacemakers (PPM) and implantable cardioverter-defibrillators (ICD), there has been an accelerated rate of device implantation (1,2). According to one estimate in the U.S., there was a 42% increase in the implantation rate of cardiac devices among Medicare beneficiaries from 1990 to 1999 (3). This was associated with a 124% increase in the rate of cardiac device infection (CDI) among the study population.

Management of CDI is a difficult challenge for both cardiology and infectious diseases specialists. Reported incidence rates of CDI range from 0.13% to 19.9% and 0.0% to 0.8% for PPMs and ICDs, respectively (4–9). A CDI can present with a pulse-generator pocket infection or bloodstream infection (BSI) with or without device-related endocarditis. A CDI is complicated by increased morbidity, mortality, and financial cost (10). Reported mortality rates...
of cardiac device-related endocarditis range from 31% to 66% if the infected device is not removed, and 18% or less with a combined management approach with complete device removal and antimicrobial therapy (11,12).

Follow-up. Patients who presented with CDI and underwent device replacement procedure as part of their CDI treatment at Mayo Clinic Rochester had the option of being followed up at our institution or by their local health care providers. Of the 182 patients who survived index hospitalization for CDI, 142 patients (78%) chose follow-up at our institution, whereas 40 (22%) patients had subsequent care by their referring physician after discharge from Mayo Clinic. Median follow-up duration for cases of CDI was 175 days (mean 657 days).

Statistical evaluation. The Fisher exact test was used to test for differences in proportions for categorical data, and the Wilcoxon rank-sum test was used to test for differences in medians for continuous data. All p values were 2-sided with a level of ≤0.05 considered statistically significant. No adjustments for multiple comparisons were made. All analyses were performed using SAS version 8.2 software (SAS Institute Inc., Cary, North Carolina).

Results

Baseline characteristics. A total of 189 cases of CDI met the case definition and were included in the study. Demographic and clinical characteristics of study subjects are summarized in Table 1. The median age of patients was 71.2 years (range 17 to 95 years). Seventy-eight percent were male. Devices included 138 PPMs and 51 ICDs. Most patients (75%) had dual-chamber devices. Fifty-eight (31%) patients had their cardiac devices implanted at Mayo Clinic Rochester and 131 (69%) had device placement at another institution. Transvenous lead placement (93%) was the most commonly used lead insertion technique. The pulse generator was placed in the pectoral area in 172 (91%) patients and in the abdominal wall in 17 (9%) patients. Indications for initial device placement included heart block (38%), sinus node dysfunction (27%), and ventricular arrhythmias (21%). A CDI occurred after initial device implantation in 79 (42%) patients and after a revision (i.e., system upgrade, lead revision, or generator exchange, and so on) in 110 (58%).

Clinical presentation. Median time from device implantation to infection was 415 days for PPM and 125 days for ICDs (p = 0.009). Eighty-six (46%) patients initially presented to Mayo Clinic Rochester, and 103 (54%) were referred to Mayo Clinic Rochester because of lack of available expertise for lead extraction at the referring facility. Pocket infection, with (17%) or without (52%) BSI, was the most common clinical presentation, followed by device-related endocarditis (23%). Most patients had localized inflammatory signs at the pocket site (Table 2). Systemic signs of sepsis were present in less than one-half of the cases. Ten (3%) cases presented with erosion of lead or device generator, without accompanying inflammatory signs at the generator pocket site.

Microbiology. Coagulase-negative staphylococci (CoNS, 42%) and Staphylococcus aureus (29%) were the most common causes of CDI, followed by gram-negative bacilli (9%), including Klebsiella pneumoniae, Serratia marcescens, Pseudo-
monas aeruginosa, Stenotrophomonas maltophilia, Acinetobacter xylosoxidans, Acinetobacter baumannii, Citrobacter koseri, Morganella morganii, Hemophilus influenzae, and Moraxella catarrhalis (Fig. 1). Two patients had fungal (Candida albicans and Aspergillus fumigatus) infection. Polymicrobial infection was present in 7% of cases. Fourteen (7%) patients had localized inflammatory signs at generator pocket or erosion of device/lead but pocket cultures were negative. Purulent material was encountered (intraoperative) within the pulse-generator pocket in 151 (80%) of the cases (11% of these patients had no inflammatory signs at the generator pocket on physical examination). Seventy-five percent of the above cases had positive cultures from the generator pocket. Blood cultures were positive in only 76 (40%) of all cases.

### Complications of device infection

Complications of CDI included septic arthritis (n = 6), vertebral osteomyelitis (n = 2), sternal osteomyelitis (n = 2), femoral osteomyelitis (n = 1), lung abscesses (n = 5), splenic abscess (n = 1), and symptomatic heart failure (n = 52).

### Table 1

Demographic and Clinical Characteristics of Patients With CDI Who Were Treated at Mayo Clinic Rochester Between 1991 and 2003 (n = 189)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs), median (range)</td>
<td>71 (17–95)</td>
</tr>
<tr>
<td>Gender, male</td>
<td>148 (78%)</td>
</tr>
<tr>
<td>Device</td>
<td></td>
</tr>
<tr>
<td>PPM</td>
<td>138 (73%)</td>
</tr>
<tr>
<td>ICD</td>
<td>51 (27%)</td>
</tr>
<tr>
<td>Chambers</td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>44 (23%)</td>
</tr>
<tr>
<td>Dual</td>
<td>142 (75%)</td>
</tr>
<tr>
<td>Lead placement</td>
<td></td>
</tr>
<tr>
<td>Transvenous</td>
<td>176 (93%)</td>
</tr>
<tr>
<td>Epicardial</td>
<td>5 (3%)</td>
</tr>
<tr>
<td>Both</td>
<td>8 (4%)</td>
</tr>
<tr>
<td>Indication</td>
<td></td>
</tr>
<tr>
<td>Heart block</td>
<td>71 (38%)</td>
</tr>
<tr>
<td>Sinus node dysfunction</td>
<td>51 (27%)</td>
</tr>
<tr>
<td>Ventricular tachycardia/fibrillation</td>
<td>39 (21%)</td>
</tr>
<tr>
<td>Other</td>
<td>28 (14%)</td>
</tr>
<tr>
<td>Last procedure before CDI</td>
<td></td>
</tr>
<tr>
<td>De novo implantation</td>
<td>79 (42%)</td>
</tr>
<tr>
<td>System revision/upgrade</td>
<td>41 (22%)</td>
</tr>
<tr>
<td>Lead revision/insertion</td>
<td>19 (10%)</td>
</tr>
<tr>
<td>Generator replacement</td>
<td>49 (26%)</td>
</tr>
<tr>
<td>Time from implant/last intervention to infection, median days (mean)</td>
<td></td>
</tr>
<tr>
<td>PPM</td>
<td>415 (920)</td>
</tr>
<tr>
<td>ICD</td>
<td>125 (399)</td>
</tr>
<tr>
<td>Comorbid conditions</td>
<td></td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>114 (60%)</td>
</tr>
<tr>
<td>Heart failure</td>
<td>96 (51%)</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>67 (35%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>46 (24%)</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>34 (18%)</td>
</tr>
<tr>
<td>Malignancy</td>
<td>24 (13%)</td>
</tr>
<tr>
<td>Clinical presentation</td>
<td></td>
</tr>
<tr>
<td>Pocket infection</td>
<td>99 (52%)</td>
</tr>
<tr>
<td>Pocket infection with bacteremia</td>
<td>32 (17%)</td>
</tr>
<tr>
<td>Device-related endocarditis</td>
<td>44 (23%)</td>
</tr>
<tr>
<td>Bacteremia without localizing signs at pocket</td>
<td>21 (11%)</td>
</tr>
<tr>
<td>Generator or lead erosion</td>
<td>10 (5%)</td>
</tr>
</tbody>
</table>

CDI = cardiac device infection; ESR = erythrocyte sedimentation rate; HCT = hematocrit; WBC = white blood cell count.

### Table 2

Clinical Presentation of Patients With CDI (n = 189)

<table>
<thead>
<tr>
<th>Presenting Signs/Symptoms</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythema</td>
<td>128 (68)</td>
</tr>
<tr>
<td>Pain</td>
<td>93 (49)</td>
</tr>
<tr>
<td>Swelling</td>
<td>127 (67)</td>
</tr>
<tr>
<td>Warmth</td>
<td>71 (38)</td>
</tr>
<tr>
<td>Tenderness</td>
<td>86 (46)</td>
</tr>
<tr>
<td>Drainage</td>
<td>65 (34)</td>
</tr>
<tr>
<td>Skin ulceration</td>
<td>59 (31)</td>
</tr>
<tr>
<td>Generator/lead erosion</td>
<td>48 (25)</td>
</tr>
<tr>
<td>Intraoperative purulence at generator pocket</td>
<td>151 (80)</td>
</tr>
</tbody>
</table>

CDI = cardiac device infection; ESR = erythrocyte sedimentation rate; HCT = hematocrit; WBC = white blood cell count.
brain abscess (n = 1), liver abscess (n = 1), and perinephric abscess (n = 1). Twenty-two (11.6%) patients had thrombosis of a vein where leads were in place (subclavian vein or superior vena cava), and in 6 of these cases, they presented with symptomatic pulmonary embolism. The majority of patients (n = 147, 78%) had an echocardiogram (transsthoracic or transesophageal) performed, and 44 (23%) had either lead and/or valvular vegetations. The diameter of vegetations ranged from 0.3 to 7.0 cm in the longest dimension. It is noteworthy that none of these patients developed clinical manifestations of pulmonary embolism as a complication of percutaneous lead extraction.

**Explantation of infected devices.** The cardiac device was explanted in 182 (96%) patients at the time of initial presentation. Three (2%) other patients suffered relapsing CDI and had explantation after failure of conservative (medical) treatment. A cardiac device was not explanted in 4 patients because of high operative risk (advanced age and decompensated heart failure with ejection fraction ≤20%). The entire device system was explanted in 178 (94%) patients, whereas lead extraction was unsuccessful in 7 (4%) cases. Most patients (90%) underwent percutaneous lead extraction with use of manual traction (15%), locking stylet (34%), or laser sheath (41%). Nineteen patients (10%) had lead extraction via median sternotomy.

**Complications of lead extraction.** Twenty patients suffered complications of percutaneous lead extraction (3 manual traction, 7 locking stylet, and 10 cases with laser sheaths), which included damage to the tricuspid valve (n = 3) that required valve annuloplasty in 2 patients, subclavian vein laceration (n = 3), hemothorax (n = 4), pocket hematoma (n = 3), fracture of lead tip requiring surgical intervention (n = 6), and massive hemorrhage that required surgical intervention (n = 5) and resulted in the death of 1 patient. Surgical removal of epicardial leads was complicated by massive hemorrhage (n = 2) that was lethal in 1 patient, postoperative cardiac arrest requiring intensive care unit stay (n = 1), subclavian vein laceration (n = 1), and ventriculotomy requiring operative repair (n = 1). Complications during lead extraction were more common in patients with history of multiple device-related procedures (13 of 87, 14.9%) compared with those with initial implants (7 of 77, 9.1%). However, this difference was not statistically significant (p = 0.25).

**Antimicrobial treatment.** All patients received antimicrobials after removal or debridement of infected device system. Most patients received at least 2 weeks of antibiotics after removal of an infected device (Fig. 2). Median duration of antibiotic treatment was significantly longer in patients with *S. aureus* infection as compared to those with CoNS (28 days vs. 14 days, p < 0.001). Patients with device-related endocarditis (valvular or lead vegetation) and BSI received a median of 28 days of antibiotics after device removal. Cases with ICD infection had a longer duration of antibiotics (median 22 days) as compared to those with PPM infection (median 16 days), but this difference was not statistically
significant (p = 0.27). Most patients (97%) received a combination of intravenous and oral antibiotics. Only 3% were treated with oral antibiotics alone. Adverse effects of antibiotic treatment included diarrhea (8%), nephrotoxicity (5%), neutropenia (2%), Clostridium difficile colitis (1%), and oral candidiasis (1%).

**Reimplantation of a new device.** All patients were assessed for ongoing need of a cardiac device after extraction of an infected system. Reimplantation of a new device was considered necessary in only 127 (67%) of the cases. Median time from explantation to reimplantation was significantly longer for patients with BSI compared with nonbacteremic cases (13 days vs. 7 days, p < 0.0001). A new system was placed as early as 3 days in cases of negative blood cultures (Fig. 2). The median time from explantation to reimplantation in patients with CoNS was 7 days compared with a delay of 12 days in cases of *S. aureus* infection (p = 0.09). In cases in which a new device system was implanted, most patients (94%) had transvenous lead insertion with implantation of a generator on the opposite side of the infected pocket. Epicardial electrodes were placed in 7 (5%) patients.

**Generator or lead erosion.** Among our study subjects with CDI, 10 patients presented with generator or lead erosion only. Despite the absence of local inflammatory signs at the pocket site, purulent material in the pulse-generator pocket was noted intraoperatively in 3 (30%) of these cases, and 9 (90%) had positive cultures from an intraoperative swab of the pocket. The causative micro-organism for CDI in this group of patients included common skin flora such as CoNS (n = 4), *S. aureus* (n = 3), and *Propionibacterium* spp. (n = 1), whereas 1 patient had polymicrobial infection with CoNS, *Propionibacterium* spp., and *Corynebacterium* spp. All patients had explanation of the infected device at the initial presentation (complete hardware successfully removed in 9 cases, whereas percutaneous lead extraction was unsuccessful in 1 case). Median time from removal of an infected device to insertion of a new system was 3 days. Among cases (n = 7) with no intraoperative evidence of purulence in the generator pocket, 4 (57%) had a new system placed on the same day when the infected device was removed. All patients were cured and none had infection relapse at their last follow-up visit (mean duration 78 weeks).

**Outcome.** The average duration of hospitalization for CDI was 17 days (median 13 days). Seven patients died during index hospitalization for CDI. Of the remaining 182 cases, follow-up data were available for 142 cases (40 patients were followed up elsewhere). Most patients (135, 95%) remained free of infection, after the initial treatment, at the last follow-up (median follow-up duration 175 days; mean 657 days). Two patients had persistent pocket infection caused by retained hardware. Five cases presented with relapse of infection. Clinical characteristics, microbiology, management, and outcome of these 5 cases are summarized in **Table 3.** Two of these patients were subsequently cured with complete removal of the infected device.
There were 9 in-hospital deaths, 7 during index hospitalization and 2 in patients who were subsequently hospitalized for relapse of infection. Five of these patients had device-related endocarditis (4 with staphylococci and 1 with *Aspergillus fumigatus*). Staphylococcal BSI with sepsis (n = 5) was the most common cause of death. Two patients died secondary to complications of device extraction surgery. One patient died of ventilator-associated pneumonia during an intensive care unit stay after device removal. One severely immunocompromised patient with device-related fungal endocarditis and metastatic abscesses died.

Seven patients had partial device explantation at initial presentation. Two were lost to follow-up after the index hospitalization (both cases had abandoned epicardial leads from previous devices, and the currently infected devices had transvenous leads that were removed along with generators). One patient died of surgical complications during a second attempt at complete hardware removal. Of the remaining 4 patients, 2 had a relapse (Table 3, cases 2 and 3). The other 2 patients remained infection-free despite only partial device removal. Both had negative blood cultures and no evidence of endocarditis on echocardiography. Percutaneous lead extraction was attempted but was unsuccessful in first patient with pocket infection. Transvenous lead removal was not attempted in the second case because of absence of inflammatory changes during generator pocket exploration. In both cases, there was no evidence of infection at their last follow-up visit (5 months in the case of pocket infection and 4 years in the case of generator erosion only).

### Discussion

Despite improvements in the design and implantation techniques, infection of the cardiac devices remains a serious problem. The current study is one of the largest reported series of CDI in the United States and the only one to propose management guidelines.

#### Clinical presentation and microbiology.

There was considerable variation in time from device implantation to onset of infection in our survey. Median time from implantation to infection was shorter for ICDs (125 days) than for PPMs (414 days). This time difference between the 2 groups may in part be caused by an increased proportion of *S. aureus* infection in patients with an ICD (35%) as compared to those with PPM (26%). Patients with PPM infection were more likely to have CoNS isolated (46%) from blood or pocket cultures than those with an ICD (31%).

Most patients with CDI present with only localized inflammatory signs at the generator pocket (Table 2), and a lack of systemic signs should not sway clinicians away from a suspicion of CDI (19). Nonspecific laboratory abnormalities such as leukocytosis, anemia, and high sedimentation rate were present in less than one-half of the cases in the current study. Staphylococcal species account for more than two-thirds of CDI cases in most published series (11–13,19,22,23,29–35) and were predominant in the present investigation (Fig. 1). Therefore, empiric antibiotics for suspected CDI should include coverage for staphylococci while awaiting microbiology results.

#### Conservative treatment versus complete device removal.

Some investigators have advocated conservative treatment with antibiotics and generator pocket debridement without hardware removal (26–28). Most previously published studies, however, have shown unacceptably high failure rates with conservative treatment (11–13,19,22,23,29–35).

The Heart Rhythm Society guidelines state that extraction of an entire lead may not be necessary if the lead can be cut through a sterile incision, totally separate from an infected pocket (36). However, the intracardiac portion of a lead may be colonized in cases in which CDI findings are limited to the pulse-generator pocket only (13,25,37), and there is a high risk of treatment failure with a lead-retention approach as recommended by the Heart Rhythm Society (25,34,38–41). In the current study, 5 patients had CDI relapse (2.6%), and 3 of them had only partial explantation of the device (generator only) at initial presentation. The other 2 patients had a temporary pacing wire as a bridge between explantation of an infected device and reimplantation of a new device. Use of the temporary pacing wires has been identified as a risk factor for subsequent CDI in 2 recent studies (42,43). Based on the above findings, we recommend complete hardware removal to achieve CDI cure; this mirrors the recommendations of the American Heart Association (4).

#### Percutaneous versus surgical lead extraction.

Extraction of cardiac device leads is not without risk (16,31,40). Despite advances in techniques for percutaneous lead extraction (44), there is still considerable morbidity and mortality associated with this procedure. In our study, 20 patients (11%) had complications of percutaneous lead extraction that included damage to cardiac valves, venous lacerations, bleeding complications, and lead tip fracture that required surgical intervention. Some investigators have expressed concern about transvenous lead removal when lead vegetation size is >1 cm because of the risk of pulmonary embolization of lead vegetation fragments (12,45–47). No patient had a clinically significant pulmonary embolism in our series despite the presence of vegetation sizes that ranged from 0.3 to 7.0 cm in the longest dimension. Others have reported similar experiences (22,23,48,49). Lead removal by cardiomyotomy (50,51) has been advocated to prevent symptomatic pulmonary embolism but, as shown in the current case series, this approach can be complicated by serious adverse events. Five patients suffered massive hemorrhages postoperatively, and 1 died in our series.

#### Duration of antimicrobial treatment.

The duration of antimicrobial treatment for CDI depended on the clinical presentation and the causative agent. In a large case series from the Cleveland Clinic Foundation (19), the median duration of antibiotic treatment in CDI cases with pocket infection and those with bacteremia was 26 days and 41 days, respectively. However, in our practice, cases of CDI with only pocket infection in patients with an ICD (35%) as compared to those with PPM (26%).
infection were treated with 10 to 14 days of antimicrobials and those with BSI for 4 weeks after device removal. Similarly, patients with cardiac device-related endocarditis limited to the right heart can be treated with 4 weeks of antibiotics instead of the 6-week treatment course that has been advocated by some (12,13,19). Infection by certain microorganisms may require longer antimicrobial treatment for complete eradication of a CDI. In our study, cases of CDI attributable to *S. aureus* had significantly longer treatment after device explantation as compared to those with CoNS infection (28 days vs. 14 days, \( p < 0.001 \)). An *S. aureus* CDI is also associated with a higher mortality rate as compared with that caused by other pathogens. In our study, there were 9 in-hospital deaths (crude mortality rate 4.7%), and 5 had *S. aureus* identified in blood cultures.

**Timing and need of a replacement device.** Timing of reimplantation of a new device system after extraction of

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**Figure 3**  
**Mayo Clinic Algorithm of Cardiac Device Infection Management**

(A) Approach to management of adults with PPM/ICD infection (also see Table 4). This algorithm applies only to the patients with complete device explantation.  
*Duration of antibiotics should be counted from the day of device explantation. (B) Guidelines for reimplantation of new device in patients with PPM/ICD infection (see also Table 4). AHA = American Heart Association; TEE = transesophageal echocardiography; other abbreviations as in Figure 1.
an infected device remains a subject of debate and is influenced by the causative agent and clinical presentation of CDI. Median time from explantation to reimplantation of a new device was significantly longer for patients with BSI as compared to those with negative blood cultures (13 days vs. 7 days, p < 0.0001) in the current investigation. There was no statistically significant difference in time from explant to reimplant in patients with CoNS infection (median 7 days) as compared to those with S. aureus infection (median 12 days, p = 0.09). Although some investigators (13) have suggested delaying reimplantation of new device for 10 to 14 days in cases of pocket infection (without BSI) and up to 6 weeks in bacteremic patients, our data suggest that devices can be safely reimplanted once the pocket has been adequately debrided and blood cultures are negative. These data are consistent with previously published reports (19). Moreover, maintaining a transvenous temporary device increases the risk of subsequent CDI (43,52) and cannot be used indefinitely.

The need for placement of a new device system should be carefully assessed in all patients with CDI because an appreciable number of patients may not require a subsequent cardiac device. Discontinuation of electrophysiologic device use after removal of an infected system has been reported in 13% to 52% of cases (11,19,30,53). In our study, reimplantation of a new device was not required in one-third of patients.

Proposed Mayo Clinic guidelines for management of CDI. Based on the findings of our retrospective analysis and review of published literature (1–53), we propose guidelines for CDI (Figs. 3A and 3B, Table 4) to assist clinicians in patient management. These recommendations are not meant to replace individual patient management, however, and consultation with available specialists is advocated.

Study limitations. Our investigation has several limitations. First, retrospective studies have inherent limitations, such as potential selection and recall biases. Second, Mayo Clinic Rochester is a tertiary referral center with referral bias, as was shown in the current survey. Patients who are referred to a specialized cardiovascular center may be sicker and have more complex cardiac devices than the general population. Third, the majority of our cohort was white (91%), and this reflected both local population demographics and the referral population. Despite these limitations, data presented herein provide critical information to clinicians who manage CDI.

Conclusions. A CDI is an important and serious complication of device use. Because of the expected continued increase in the number of cases of CDI and the current lack of prospective, randomized trial data to assist in defining optimal treatment, we present proposed guidelines to assist clinicians in the management of CDI.

### REFERENCES


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**Table 4** Mayo Clinic Guidelines for the Diagnosis and Management of Cardiac Device Infections

1. All patients should have at least 2 sets of blood cultures drawn at initial evaluation.
2. Generator tissue Gram stain and culture and lead tip culture should be obtained.
3. Patients who either have positive blood cultures or have negative blood cultures but had recent antibiotics before obtaining blood cultures should have a transesophageal echocardiogram (TEE) to assess for device-related endocarditis.
4. Sensitivity of TTE is low and is not recommended to evaluate for device-related endocarditis.
5. Patients with negative blood cultures and recent prior antibiotics and valve vegetations on TEE should be managed in consultation with an infectious diseases expert.
6. All patients with device infection should undergo complete device removal, regardless of clinical presentation.
7. A large (>1 cm) lead vegetation is not a stand-alone indication for surgical lead removal.
8. Blood cultures should be repeated in all patients after device explantation. Patients with persistently positive blood cultures should be treated for at least 4 weeks with antimicrobials even if TEE is negative for vegetations or other evidence of infection.
9. Duration of antimicrobial therapy should also be extended to ≥4 weeks in patients with complicated infection (endocarditis, septic venous thrombosis, osteomyelitis, metastatic seeding).
10. Adequate debridement and control of infection should be achieved at all sites before reimplantation of a new device.
11. Reevaluation for continued need of the device should be performed before new device placement.
12. If an infected cardiac device cannot be removed, then long-term suppressive antibiotic therapy should be administered after completing an initial course of treatment and securing a clinical response to therapy. Infectious diseases expert opinion should be sought.


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