Journal of the American Heart Association

ORIGINAL RESEARCH

Analysis of Outcomes in 8304 Patients Undergoing Lead Extraction for Infection

Ryan G. Aleong, MD; Matthew M. Zipse, MD; Christine Tompkins, MD; Muhammad Aftab, MD; Paul Varosy, MD; William Sauer, MD; David Kao, MD

BACKGROUND: Patients undergoing lead extraction for infected devices have worse outcomes compared with those with noninfected devices. We assessed predictors of in-hospital mortality and procedure-related major adverse events (MAEs) in a large cohort undergoing lead extraction.

METHODS AND RESULTS: Deidentified hospital records procedure from 7 states between 1994 and 2013 were aggregated and *International Classification of Disease, Ninth Revision* (*ICD-9*) procedure codes were used to identify hospital records reporting lead extraction. MAEs included death, cardiac tamponade, hemothorax, and need for emergent cardiac surgery. Predictors of in-hospital MAEs for infected compared with noninfected leads were identified using multivariate regression. Associations between outcomes and specific microbe were also assessed. In total, 57 220 discharges specified lead extraction. Infected leads accounted for the minority of total lead extractions compared with fractured leads (16.1 versus 59.8%, 25.7% not reported). There were 3298 MAEs (5.8%) including 980 deaths (1.7%). Multivariate predictors of MAE included black race, atrial fibrillation, anemia, heart failure, and admission via either hospital transfer or emergency department versus home (all $P<0.001$). Infected leads were associated with an increased risk of death (4.6% versus 0.9%, $P<0.001$) compared with leads with fracture only. Among patients with microbial data, staphylococcal infection was most common, whereas streptococcal infection was associated with the worst outcomes.

CONCLUSIONS: Patients undergoing extraction of infected leads have higher in-hospital mortality and adverse events compared with noninfected leads. Streptococcus, anemia, and heart failure are predictors of adverse outcomes.

Key Words: lead extraction ■ cardiac implantable electrophysiological device infection ■ infection

As the number of cardiac implantable electrophysiological devices (CIEDs) has increased, the number of CIED infections has also increased.[1] Patients who develop a CIED infection have been shown to have increased mortality compared with those without CIED infections, which has been demonstrated in single-center cohorts.[2,3] It is well recognized that patients undergoing lead extraction for CIED infections have worse outcomes compared with those undergoing lead extraction for noninfection indications, but the risk factors for adverse outcomes exclusively in patients with infection have not been well characterized. Risk stratifying patients among the cohort of those who undergo lead extraction may help with patient counseling and periprocedurally planning. The goal of the current analysis was to examine the outcomes and risk factors for adverse outcomes in a large administrative database of patients undergoing lead extraction because of infection. As a secondary analysis, bacterial speciation was available for a subset of patients for further risk stratification. Identification of risk factors for adverse outcomes may help clinicians risk stratify patients who are undergoing lead extraction for an infected CIED.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable

Correspondence to: Ryan G. Aleong, MD, Section of Cardiac Electrophysiology, University of Colorado Hospital, 12401 East 17th Avenue, B136, Aurora, CO 80045. E-mail: ryan.aleong@ucdenver.edu

For Disclosures, see page 8.

JAHA is available at: www.ahajournals.org/journal/jaha

CLINICAL PERSPECTIVE

What Is New?

- We screened a large group of patients who had undergone lead extraction for infection and identified risk factors for major adverse events and death.
- In a subset of patients, microbial data were available and identified that streptococcal infection was associated with a greater degree of adverse outcomes compared with other infections.

What Are the Clinical Implications?

- These data should allow practitioners to risk stratify their patients with infected cardiac implantable electrophysiological devices and emphasize referral to experienced extraction centers.

Nonstandard Abbreviations and Acronyms

CIED	cardiac implantable electrophysiological devices
DM	diabetes mellitus
ED	emergency department
HF	heart failure
ICD	implantable cardioverter defibrillator
MAE	major adverse events
OR	odds ratio
PPM	permanent pacemaker

request. This study was a retrospective analysis of a deidentified database and, thus, the research was exempt from institutional review board review under 45 CFR 46.101(b).

Data Extraction

Deidentified administrative hospital records were obtained from state agencies in California, New Hampshire, New Jersey, Vermont, New York, West Virginia, and Colorado for the years 1994 to 2013. The data were harmonized and screened for admissions with the diagnosis lead extraction (*International Classification of Disease, Ninth Revision, Clinical Modification* [*ICD-9-CM*] code 37.75–77). From the cases of lead extraction, cases were further sorted into 3 groups with lead fracture, lead infection, and lead fracture + infection (*International Classification of Disease, Ninth Revision* [*ICD-9*] codes). Data dictionaries and *ICD-9-CM* codes were used to quantify demographics, comorbidities, and outcomes. Data were aggregated and harmonized using MySQL Server version 5.6.15 (Oracle Corporation).

Statistical Analysis

The primary end point was a major adverse event (MAE), defined as a composite of death, postprocedure cardiac complication, postprocedure hemorrhage, cardiac tamponade, pericardiocentesis, hemopericardium, hemothorax, or emergent cardiac surgery in accordance with the Heart Rhythm 2009 Guidelines on Lead Extraction.[4] Rates of MAEs and their components were compared between lead fractures, lead infections, and lead fracture + infections using chi-square test for categorical variables and Kruskal–Wallis test for continuous variables. Univariate and multivariate binomial mixed effects models were then created to assess the association between MAE and patient group (adjusted for covariates of interest). The primary fixed effect term was indication for lead extraction (lead fracture, infection, or fracture + infection) and secondary fixed effects terms included age, sex, race, atrial fibrillation, anemia, hypertension, diabetes mellitus, heart failure (HF), source of admission, and year of hospitalization. A random effect term was included for the reported hospital.[5] Mixed effects analyses were conducted using the *glmer* function from the *lme4* packages of the R statistical package (version 3.0.2, The R Foundation for Statistical Computing). $P<0.05$ was considered significant.

RESULTS

A total of 57 220 hospital records were identified. Infection was reported in 9196 (16.1%) of lead extractions compared with fractured leads, which were present in 34 240 (59.8%) of lead extractions. Both infection and fracture were reported simultaneously in 948 (1.7%) and the indication for lead extraction was unknown in 14 732 (25.7%) of hospitalizations.

The baseline demographics are listed in Table 1 comparing lead extraction in patients who had their extraction for lead fracture, lead infection, or both. Patients undergoing lead extraction for infection were more likely to be younger than 70 years, men, and nonwhite. In addition, atrial fibrillation, diabetes mellitus, and HF were more often associated with extraction for lead infection. With regard to the source of the patient and whether patients were admitted electively versus transferred from a different hospital or the emergency department, those with infected CIEDs were more likely to be transferred from a different hospital. In contrast, patients with lead fractures were more often admitted from the emergency department. All patient demographics and the source of the patient were similar in the fracture + infection and the infection groups.

MAEs were reported in 3298 of 53 922 (5.8%) hospitalizations. Patients with lead infections and lead

Table 1. Baseline Demographics of Patients Undergoing Lead Extraction for Lead Fracture, Lead Infection, and Lead Infection + Fracture

Characteristic	Fracture, 33 292 (58.2)	Infection, 8248 (14.4)	Infection + Fracture, 948 (1.7)	Other/Unknown, 14 732 (25.7)	All (N=57 2020)
Age, y*					
<18	360 (1.1)	51 (0.6)	5 (0.5)	234 (1.6)	650 (1.1)
8 to 29	280 (0.8)	82 (1.0)	12 (1.3)	175 (1.2)	549 (1.0)
30 to 39	452 (1.4)	157 (1.9)	14 (1.5)	259 (1.8)	882 (1.5)
40 to 49	964 (2.9)	349 (4.2)	27 (2.8)	530 (3.6)	1870 (3.3)
50 to 59	2196 (6.6)	767 (9.3)	64 (6.8)	1165 (7.9)	4192 (7.3)
60 to 69	4714 (14.2)	1263 (15.3)	109 (11.5)	2171 (14.7)	8257 (14.4)
>70	21 800 (65.5)	4146 (50.3)	530 (55.9)	8704 (59.1)	35 180 (61.5)
NA	2526 (7.6)	1433 (17.4)	187 (19.7)	1494 (10.1)	5640 (9.9)
Sex*					
Men	15 942 (47.9)	4462 (54.1)	462 (48.7)	7376 (50.1)	28 242 (49.4)
Women	14 498 (43.5)	2148 (26.0)	272 (28.7)	5688 (38.6)	22 606 (39.5)
NA	2852 (8.6)	1683 (19.9)	214 (22.6)	1668 (11.3)	6372 (11.1)
Race*					
White	21 368 (63.9)	4125 (50.5)	488 (51.5)	8897 (60.4)	34 799 (60.8)
Black	3424 (10.3)	1016 (12.3)	78 (8.2)	1431 (9.7)	5949 (10.4)
Hispanic	1925 (5.8)	499 (6.0)	61 (6.4)	866 (5.9)	3351 (5.9)
Other	1124 (3.4)	300 (3.6)	25 (2.6)	577 (3.9)	2026 (3.5)
NA	5530 (16.6)	2308 (28.0)	396 (31.2)	2961 (20.1)	11 095 (19.4)
Comorbidities					
AF*	9910 (29.8)	2635 (31.9)	301 (31.8)	4857 (33.0)	17 703 (30.9)
Anemia*	3139 (9.4)	1846 (22.4)	196 (20.7)	1861 (12.6)	7042 (12.3)
DM*	6960 (20.9)	2221 (26.9)	244 (25.7)	3218 (21.8)	12 643 (22.1)
HF*	10 179 (30.6)	3415 (41.4)	367 (38.7)	6338 (42.3)	20 189 (35.3)
Hypertension*	14 638 (44.0)	3206 (38.9)	374 (39.5)	5783 (39.3)	24 001 (41.9)
Source*					
Home	20 426 (61.4)	4235 (51.3)	481 (50.7)	9905 (67.2)	35 047 (61.2)
Transfer	1618 (4.9)	1656 (20.1)	155 (16.4)	966 (6.6)	4395 (7.7)
ED	10 780 (32.4)	2261 (27.4)	305 (32.2)	3625 (24.6)	16 971 (29.7)
NA	468 (1.4)	96 (1.2)	7 (0.7)	236 (1.6)	807 (1.4)
Lead type*					
PPM only	29 650 (89.1)	5096 (63.8)	794 (83.8)	8770 (59.5)	44 310 (77.4)
ICD only	3092 (9.3)	409 (5.0)	127 (13.4)	843 (5.7)	4471 (7.8)
PPM + ICD	550 (1.7)	89 (1.1)	27 (2.8)	210 (1.4)	876 (1.5)
NA	0 (0.0)	2654 (32.2)	0 (0.0)	4909 (33.3)	7563 (13.2)

Values are expressed as number (percentage). AF indicates atrial fibrillation; DM, diabetes mellitus; ED, emergency department; HF, heart failure; ICD, implanted cardioverter-defibrillator; NA, not available; and PPM, permanent pacemaker.

*P<0.001.

fracture + infection had higher rates of MAEs including a higher rate of death, hemorrhage, and transfusion compared with the lead fracture only arm (Table 2). The rate of in-hospital MAEs was more than 2 times as high in the infection and infection + fracture arms compared with the lead fracture only arm (fracture versus infection versus infection + fracture: 1364 [4.1%] versus 756 [9.2%] versus 99 [10.4%], *P*<0.001). With regard to in-hospital death, the rate of in-hospital death was markedly higher in the infection and infection + fracture groups compared with the fracture only group (fracture versus infection versus infection + fracture: 314 [0.9%] versus 381 [4.6%] versus 33 [3.5%], *P*<0.001). While there was no difference in the rate of major pericardial complications, there was a higher rate of urgent cardiac surgery both in the infection and the fracture + infection groups compared with the fracture only group (fracture versus infection versus infection + fracture: 300 [0.9%] versus 141 [1.7%] versus 27 [2.8%], *P*<0.001).

Table 2. Patient Outcomes by Indication for Extraction

Outcome	Fracture, 33 292 (58.2)	Infection, 8248 (14.4)	Infection + Fracture, 948 (1.7)	Other/Unknown, 14 732 (25.7)	All (N=57 220)
MAE*	1364 (4.1)	756 (9.2)	99 (10.4)	1079 (7.4)	3298 (5.8)
Death*	314 (0.9)	381 (4.6)	33 (3.5)	252 (1.7)	980 (1.7)
Cardiac complication*	512 (1.5)	140 (1.7)	20 (2.1)	412 (2.8)	1084 (1.9)
Pericardial complication*	293 (0.7)	52 (0.6)	11 (1.2)	190 (1.3)	547 (1.0)
Hemorrhage*	237 (0.7)	171 (2.1)	23 (2.4)	275 (1.9)	706 (1.2)
Hemothorax	10 (0.0)	1 (0.0)	0 (0.0)	8 (0.1)	19 (0.0)
Transfusion*	1346 (4.0)	1127 (13.7)	108 (11.4)	1040 (7.1)	3621 (6.3)
Emergent surgery*	300 (0.9)	141 (1.7)	27 (2.8)	242 (1.6)	710 (1.2)

Values are expressed as number (percentage). Major adverse event (MAE) indicates composite of all-cause death, postprocedure cardiac complication, postprocedure hemorrhage, cardiac tamponade, performance of pericardiocentesis, hemopericardium, hemothorax, or emergent cardiac surgery; pericardial complication; composite of tamponade; hemopericardium; or pericardiocentesis.

*$P<0.001$.

Univariate predictors of MAE are presented in Table 3. Age, race, atrial fibrillation, anemia, HF, hypertension, and lead type were among the univariate predictors of MAE. Odds ratios (ORs) and 95% CIs for multivariable predictors of MAE and all-cause death are shown in Figure—Panel A and B, respectively. Factors significantly associated with increased risk of MAE were presence of lead infection (OR, 1.67 [95% CI, 1.47–1.90]) and lead fracture + infection (OR, 2.02 [95% CI, 1.56–2.62]) versus no infection ($P<0.001$ for both), age younger than 70 years (OR, 1.13; 95% CI, 1.04–1.34 [$P=0.04$]), nonwhite race (OR, 1.18; 95% CI, 1.04–1.34 [$P=0.009$]), atrial fibrillation (OR, 1.46; 95% CI, 1.32–1.63 [$P<0.001$]), anemia (OR, 2.39; 95% CI, 2.11–2.71 [$P<0.001$]), HF (OR, 1.68; 95% CI, 1.52–1.85 [$P<0.001$]), and admission via hospital transfer (OR, 2.57; 95% CI, 2.18–3.02) or emergency department (OR, 1.45; 95% CI, 1.30–1.63) versus home ($P<0.001$ for both). Presence of diabetes mellitus (OR, 0.75; 95% CI, 0.66–0.82 [$P<0.001$]) and hypertension (OR, 0.73; 95% CI, 0.66–0.82 [$P<0.001$]) were associated with reduced risk of MAEs. Factors associated with an increased risk of death included lead infection only (OR, 4.41; 95% CI, 3.61–5.38) and lead fracture + infection (OR, 2.78; 95% CI, 1.80–4.32) versus fracture only ($P<0.001$ for both), age 70 years and older (OR, 1.37; 95% CI, 1.10–1.71 [$P=0.005$]), anemia (OR, 1.58; 95% CI, 1.27–1.96 [$P<0.001$]), HF (OR, 3.09; 95% CI, 2.55–3.75 [$P<0.001$]), and admission via hospital transfer (OR, 3.44; 95% CI, 2.56–4.61), or emergency department (OR, 3.01; 95% CI, 2.43–3.72 [$P<0.001$ for both]). Hypertension was associated with a lower risk of death (OR, 0.41; 95% CI, 0.33–0.51 [$P<0.001$]). Risk of MAE increased marginally over time (OR, 1.01 per year; 95% CI, 1.01–1.01 [$P<0.001$]), whereas risk of death decreased over time (OR, 0.96 per year; 95% CI, 0.94–0.99 [$P=0.002$]). There were no significant differences in either MAE or death in any state versus the reference state of California.

Bacterial Culture Data

In a subset of 3179 patients with lead infections, bacterial culture data were available as shown in Table 4. When considering all patients with lead infection, staphylococcal infections were the most common (26.2%) followed by Gram-negative rods and streptococcal infections. Among patients who reported at least 1 microbe (n=3179), staphylococcal infections alone represented 75.8%, Gram-negative rod only infections represented 12.0%, streptococcal infections only represented 5.8%, and anaerobic infections only represented 0.8%. Patients with at least 2 microbes reported comprised 5.5% of those with culture data. Streptococcal infections were associated with the worst outcomes including the highest rates of MAE, death, hemorrhage, cardiac perforation, and the need for cardiac surgery. Antibiotic resistance data and specific speciation data were not available.

DISCUSSION

In this large administrative database that consisted of >57 000 patients with lead extraction over a 19-year period, CIED infection was associated with a higher rate of MAEs and death compared with lead fractures. This result was consistent when comparing the lead fracture group with those who had lead extraction for infection group as well as those who had lead extraction for infection + fracture group. Atrial fibrillation, anemia, and HF were risk factors for adverse outcomes in CIED infections in multivariate analysis. In addition, patients who had defibrillators extracted as well as patients who had nonelective procedures also had a higher risk of MAEs and death in the multivariate analysis.

Outcomes of patients who undergo lead extraction for CIED infections have been shown to be worse compared with patients who undergo lead extraction for

Table 3. Characteristics of Patients With MAE, No. (%)

Characteristic	MAE–	MAE+	Total
	53 922 (94.2)	3298 (5.8)	57 220
Age, y*			
<18	585 (1.1)	65 (2.0)	650 (1.1)
18 to 29	516 (1.0)	33 (1.0)	549 (1.0)
30 to 39	817 (1.5)	65 (2.0)	882 (1.5)
40 to 49	1747 (3.2)	123 (3.7)	1870 (3.3)
50 to 59	3921 (7.3)	271 (8.2)	4192 (7.3)
60 to 69	7718 (14.3)	539 (16.3)	8257 (14.4)
>70	33 372 (61.9)	1808 (54.8%)	35 180 (61.5)
NA	5246 (9.7)	394 (11.9)	5640 (9.9)
Sex			
Men	26 651 (49.4)	1591 (48.2)	28 242 (49.4)
Women	21 395 (39.7)	1211 (36.7)	22 606 (39.5)
NA	5876 (10.9)	496 (15.0)	6372 (11.1)
Race*			
White	33 059 (61.3)	1740 (52.8)	34 799 (60.8)
Black	5520 (10.2)	429 (13.0)	5949 (10.4)
Hispanic	3169 (5.9)	182 (5.5)	3351 (5.9)
Other	1876 (3.5)	150 (4.5)	2026 (3.5)
NA	10 298 (19.1)	797 (24.2)	11 095 (19.4)
Comorbidities			
AF*	16 400 (30.4)	1303 (39.5)	17 703 (30.9)
Anemia*	6059 (11.2)	983 (29.8)	7042 (12.3)
DM	11 909 (22.1)	734 (22.3)	12 643 (22.1)
HF*	18 436 (34.2)	1753 (53.2)	20 189 (35.3)
Hypertension*	22 967 (42.6)	1034 (31.4)	24 001 (41.9)
Lead type*			
PPM only	42 270 (78.4)	2040 (61.9)	44 310 (77.4)
ICD only	4152 (7.7)	319 (9.7)	4471 (7.8)
Both PPM and ICD	810 (1.5)	66 (2.0)	876 (1.5)
NA	6690 (12.4)	873 (26.5)	7563 (13.2)
Indication*			
Mechanical	31 928 (59.2)	1364 (41.4)	33 444 (58.4)
Infection	7492 (13.9)	756 (22.9)	7954 (13.9)
Infection + mechanical	849 (1.6)	99 (3.0)	796 (1.4)
NA	13 653 (25.3)	1079 (32.7)	15 026 (26.3)
Source of admission*			
Home	33 424 (62.0)	1623 (49.2)	35 047 (61.2)
Transfer	3848 (7.1)	547 (16.6)	4395 (7.7)
ED	15 867 (29.4)	1104 (33.5)	16 971 (29.7)
NA	783 (1.5)	24 (0.7)	807 (1.4)

Values are expressed as number (percentage). AF indicates atrial fibrillation; DM, diabetes mellitus; ED, emergency department; HF, heart failure; ICD, implantable cardioverter-defibrillator; MAE, major adverse event; NA, not available; and PPM, permanent pacemaker.

*P<0.001.

noninfectious indications, such as lead fracture. The higher rate of MAEs and mortality in patients with CIED infections compared with other noninfectious indications for lead extraction has mostly been reported in single-center reports.[2,3,6,7] Larger cohorts include that reported by Guha et al[8] who analyzed the rate of CIED infections in 561 741 patients with end-stage renal disease in the United States Renal Data System and found that black race and HF were associated with increased risk for CIED infection and the risk of death

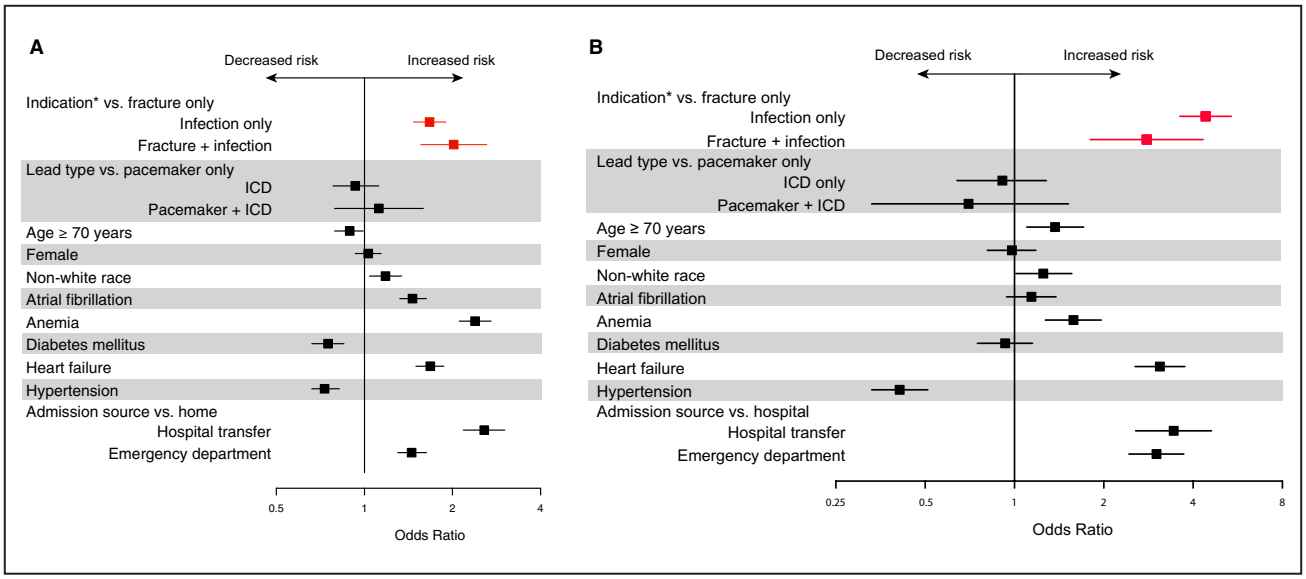

Figure. Multivariate analysis of the risk of (A) major adverse event (MAE) and (B) death according to clinical variable. *Indication for extraction. ICD indicates implantable cardioverter-defibrillator.

was higher in those with a CIED infection. Patients with a CIED infection who had an extraction had improved survival compared with those with a CIED infection who did not have an extraction. Similarly, data from the National Hospital Discharge Survey demonstrated increased mortality associated with CIED infections.[1] Determining the cause of increased mortality in patients with lead extraction with CIED infections is not clear. Tarakji et al[2] demonstrated increased 1-year mortality in patients with more invasive infections (positive endovascular infections compared with pocket infections), which may lead to other adverse sequelae, such as pulmonary emboli and multisystem organ failure. CIED infections are associated with comorbidities that increase mortality, such as end-stage renal disease and HF, which may not allow for patients to compensate and recover following a lead extraction for CIED infection. In addition, the timing of lead extraction in patients in the cohort we analyzed with CIED infections is unknown but increased mortality has been described when extraction is delayed.[9] In this cohort, patients who had lead extraction for CIED infection had more comorbidities compared with those with CIED lead fractures, but there was also a higher rate of need for cardiac surgery in the CIED infection cohort, which may suggest that there are other undefined procedural factors that may increase the risk of cardiac laceration during lead extraction in patients with CIED infection. Delays to lead extraction for CIED infection may also occur as a result of several reasons including

Table 4. Outcomes in Patients Presenting With Lead Infection With Bacterial Culture Result

	Staphylococcal Infection Only	Streptococcal Infection Only	GNR Only	Anaerobic Only	Polymicrobial	Other/NA
	2411 (26.2)	185 (2.0)	381 (4.1)	27 (0.3)	175 (1.9)	6017 (65.4)
MAE*	149 (6.2)	26 (14.1)	28 (7.3)	0 (0.0)	15 (9.5)	636 (10.6)
Death†	40 (1.7)	10 (5.4)	8 (2.1)	0 (0.0)	5 (3.2)	351 (5.8)
Cardiac complication	42 (1.7)	7 (3.8)	4 (1.0)	0 (0.0)	3 (1.7)	104 (1.7)
Pericardial complication	13 (0.5)	3 (1.6)	4 (1.0)	0 (0.0)	2 (1.3)	42 (0.7)
Hemorrhage	41 (1.7)	8 (4.3)	8 (2.1)	1 (2.3)	5 (3.2)	131 (2.2)
Hemothorax	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Transfusion*	278 (11.5)	45 (24.3)	46 (12.1)	1 (3.7)	38 (21.7)	827 (13.7)
Urgent surgery	39 (1.6)	5 (2.7)	7 (1.8)	0 (0.0)	4 (2.5)	113 (1.9)

Values are expressed as number (percentage). GNR indicates Gram-negative rod; NA, not available. Major adverse event (MAE) indicates Composite of all-cause death, postprocedure cardiac complication, postprocedure hemorrhage, cardiac tamponade, performance of pericardiocentesis, hemopericardium, hemothorax, or emergent cardiac surgery; pericardial complication, Composite of tamponade, hemopericardium, or pericardiocentesis.

*$P<0.001$.

†$P=0.006$.

delay in diagnosis, lack of facilities and/or personnel to perform the procedure, and severity of presentation, especially if patients present with bacteremia or sepsis, which may increase the risk of lead extraction in CIED-infected patients.

The findings reported in this study have many similarities to other larger data sets that have reported on risk factors for adverse events during lead extraction but with some notable exceptions. HF has previously been associated with an increased risk of adverse outcomes in lead extraction for CIED infection as has end-stage renal disease and diabetes mellitus,[10] which were not associated with adverse outcome CIED infection in our multivariate analysis. While anemia and atrial fibrillation have not previously been reported with an increased risk of adverse outcome in CIED infection, both of these factors may be associated with anticoagulation and an increased risk of periprocedural bleeding.[2,11,12] Other patient-related factors associated with MAEs in CIED infection included younger age and male sex, which may reflect increased lead fibrosis leading to increasing periprocedural complications. It is not possible to ascertain whether current measures known to decrease the risks of lead extraction, such as the superior vena cava occlusion balloon, might have decreased the mortality associated with lead extraction.

We observed that patients with streptococcal infections had the highest rate of MAEs and mortality compared with all other infections, including staphylococcal infections. We were not able to differentiate between *Staphylococcal aureus* infections and coagulase-negative staphylococcal infections; however, even with combining both groups, streptococcal infections were still associated with worse outcomes. It should be noted that in our cohort, streptococcal infections comprised a relatively small group of patients compared with staphylococcal infections. Our finding of a high mortality rate in patients with streptococcal infections is consistent with the findings from the Mayo Clinic, which also showed a high mortality rate in the few patients with streptococcal infections (3/6 patients died in hospital).[13] Our findings that staphylococcal infections are most common were also consistent with other single and multicenter study findings, although the current study describing microbiological data is the largest to date.[14,15] It should be noted that bacterial culture data were not available for all patients and this subset of patients may not be representative of the entire cohort.

LIMITATIONS

This study has the same limitations of other claims-based studies, which include lack of granularity, misclassification, unidentified confounders, and missing data. The lack of granularity leads to difficulty in discerning the exact indication for lead extraction as well as the methods used for lead extraction (eg, manual traction, laser-assisted sheath, location of the procedure). Data from this database did not have information on lead extraction operator (electrophysiologist versus surgeon), procedural location (electrophysiology laboratory versus operating room), or indication for possible cardiac surgery and hospital volume, all of which could affect hospital outcomes. There is also no information on failed lead extraction procedures when the entire lead could not be removed. There was a high number of patients who had lead extraction for lead fractures as compared with lead infections, which may have been because of lead advisories that took place during this time period and the potential for heterogeneity in the noninfected cohort of patients. Comparisons between patients with CIED who did undergo lead extraction versus those who did not could help differentiate outcomes based on whether lead extraction was performed. However, the presence of lead infection without lead extraction could not be performed because of limitations of *ICD-9* codes. Bacterial speciation data were only available from a subset of patients, and the reasons for reporting of speciation in some patients and not others could not be determined. Therefore, the generalizability of results related to specific bacterial species is uncertain especially with regard to outcomes among patients with streptococcal infections. However, it should be noted that administrative data have been used in outcomes-related cardiovascular research to risk patients undergoing cardiac catheterization and for HF hospitalizations.

CONCLUSIONS

Lead extraction for infected pacemakers and defibrillators is associated with a higher risk of adverse events compared with lead extraction for a noninfected indication. Furthermore, the risk of adverse events was higher among patients with streptococcal infections. These data and other previously reported data should not dissuade practitioners from referring patients for lead extraction for device infections as device extraction in patients has been shown to have better outcomes compared with patients who do not have removal of their infected transvenous device.[4,16] Rather, these data should allow practitioners to risk stratify their patients and emphasize that referral to experienced extraction centers is paramount.

ARTICLE INFORMATION

Received November 10, 2018; accepted February 5, 2020.

Affiliations

From the Section of Cardiac Electrophysiology, University of Colorado Hospital, Aurora, CO (R.G.A., M.M.Z., C.T., P.V., W.S., D.K.); Department of Surgery, Division of Cardiothoracic Surgery, University of Colorado, Denver, CO (M.A.).

Disclosures

None.

REFERENCES

1. Voigt A, Shalaby A, Saba S. Rising rates of cardiac rhythm management device infections in the United States: 1996 through 2003. *J Am Coll Cardiol*. 2006;48:590–591.
2. Tarakji KG, Wazni OM, Harb S, Hsu A, Saliba W, Wilkoff BL. Risk factors for 1-year mortality among patients with cardiac implantable electronic device infection undergoing transvenous lead extraction: the impact of the infection type and the presence of vegetation on survival. *Europace*. 2014;16:1490–1495.
3. Maytin M, Jones SO, Epstein LM. Long-term mortality after transvenous lead extraction. *Circ Arrhythm Electrophysiol*. 2012;5:252–257.
4. Wilkoff BL, Love CJ, Byrd CL, Bongiorni MG, Carrillo RG, Crossley GH, Epstein LM, Friedman RA, Kennergren CEH, Mitkowski P, et al. Transvenous lead extraction: heart rhythm society expert consensus on facilities, training, indications, and patient management. *Heart Rhythm*. 2009;6:1085–1104.
5. Houchens RCB, Steiner C. Hierarchical Modeling using HCUP Data HCUP Methods Series Report # 2007-01 Online. US Agency for Healthcare Research and Quality. October 1, 2007. Available at: http://wwwhcup-usahrqgov/reports/methodsjsp.
6. Habib A, Le KY, Baddour LM, Friedman PA, Hayes DL, Lohse CM, Wilson WR, Steckelberg JM, Sohail MR; Mayo Cardiovascular Infections Study G. Predictors of mortality in patients with cardiovascular implantable electronic device infections. *Am J Cardiol*. 2013;111:874–879.
7. Deckx S, Marynissen T, Rega F, Ector J, Nuyens D, Heidbuchel H, Willems R. Predictors of 30-day and 1-year mortality after transvenous lead extraction: a single-centre experience. *Europace*. 2014;16:1218–1225.
8. Guha A, Maddox WR, Colombo R, Nahman NS Jr, Kintziger KW, Waller JL, Diamond M, Murphy M, Kheda M, Litwin SE, et al. Cardiac implantable electronic device infection in patients with end stage renal disease. *Heart Rhythm*. 2015;12:2395–2401.
9. Le KY, Sohail MR, Friedman PA, Uslan DZ, Cha SS, Hayes DL, Wilson WR, Steckelberg JM, Baddour LM; Mayo Cardiovascular Infections Study G. Impact of timing of device removal on mortality in patients with cardiovascular implantable electronic device infections. *Heart Rhythm*. 2011;8:1678–1685.
10. Polyzos KA, Konstantelias AA, Falagas ME. Risk factors for cardiac implantable electronic device infection: a systematic review and meta-analysis. *Europace*. 2015;17:767–777.
11. Sohail MR, Hussain S, Le KY, Dib C, Lohse CM, Friedman PA, Hayes DL, Uslan DZ, Wilson WR, Steckelberg JM, et al. Risk factors associated with early- versus late-onset implantable cardioverter-defibrillator infections. *J Interv Card Electrophysiol*. 2011;31:171–183.
12. Al-Khatib SM, Lucas FL, Jollis JG, Malenka DJ, Wennberg DE. The relation between patients' outcomes and the volume of cardioverter-defibrillator implantation procedures performed by physicians treating Medicare beneficiaries. *J Am Coll Cardiol*. 2005;46:1536–1540.
13. Madhavan M, Sohail MR, Friedman PA, Hayes DL, Steckelberg JM, Wilson WR, Baddour LM; Mayo Cardiovascular Infections Study G. Outcomes in patients with cardiovascular implantable electronic devices and bacteremia caused by Gram-positive cocci other than Staphylococcus aureus. *Circ Arrhythm Electrophysiol*. 2010;3:639–645.
14. Uslan DZ, Sohail MR, St Sauver JL, Friedman PA, Hayes DL, Stoner SM, Wilson WR, Steckelberg JM, Baddour LM. Permanent pacemaker and implantable cardioverter defibrillator infection: a population-based study. *Arch Intern Med*. 2007;167:669–675.
15. Chamis AL, Peterson GE, Cabell CH, Corey GR, Sorrentino RA, Greenfield RA, Ryan T, Reller LB, Fowler VG Jr. Staphylococcus aureus bacteremia in patients with permanent pacemakers or implantable cardioverter-defibrillators. *Circulation*. 2001;104:1029–1033.
16. Viganego F, O'Donoghue S, Eldadah Z, Shah MH, Rastogi M, Mazel JA, Platia EV. Effect of early diagnosis and treatment with percutaneous lead extraction on survival in patients with cardiac device infections. *Am J Cardiol*. 2012;109:1466–1471.