THE TREATMENT OF PATIENTS WITH INFECTED IMPLANTABLE CARDIOVERTER-DEFIBRILLATOR SYSTEMS

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Objective: The purpose of this study was to evaluate the treatment of patients with infected implantable cardioverter-defibrillator systems. **Methods:** Retrospective analysis was done of the cases of 21 patients treated for implantable cardioverter-defibrillator infection during an 11-year period. **Results:** Of 723 cardioverter-defibrillator implantations (550 primary implants, 173 replacements), nine (1.2%) were complicated by early postoperative device-related infections. Late infections developed in two patients 19 and 22 months, respectively, after implantation. Ten other patients were transferred to our institution for treatment of cardioverter-defibrillator infection. The time from implantation to overt infection was 2.2 ± 1.3 months, excluding the two late infections. The responsible organisms were *Staphylococcus aureus* (9), *Staphylococcus epidermidis* (6), *Streptococcus hemolyticus* (1), gram-negative bacteria (3), *Candida albicans* (1), and *Corynebacterium* (1). All patients were treated with intravenous antibiotic drugs. Total system removal was done in 15 patients and partial removal in 2; in 4, the cardioverter-defibrillator system was not explanted. There were no perioperative deaths. A new implantable cardioverter-defibrillator system was reimplanted in 7 patients after 2 to 6 weeks of antibiotic therapy. Ten patients were treated without reimplantation (2 arrhythmia operation, 8 antiarrhythmic drugs). Four patients (3 patients without explantation and 1 with partial system removal) were treated with maintenance long-term antibiotic therapy. During a mean follow-up of 21 ± 2.8 months, no patient had clinical recurrence of infection. One patient treated with antiarrhythmic drugs without system reimplantation died suddenly. **Conclusions:** Infections that involve implantable cardioverter-defibrillator systems can be safely managed by removing the entire system with reimplantation after intravenous antibiotic therapy. In selected patients in whom the risk for system explantation is high and anticipated life expectancy is short, long-term antibiotic therapy to suppress low-virulence infections may represent an acceptable alternative. (J Thorac Cardiovasc Surg 1997;113:121-9)

The development of the automatic implantable cardioverter-defibrillator (ICD) in the early 1980s represented a major advance in the treatment of life-threatening ventricular arrhythmias.¹ The

treatment of patients who receive these devices may pose several difficult clinical problems, and of these the treatment of ICD-system infection remains one of the most important. The recent availability of nonthoracotomy lead systems, coupled with generators capable of delivering biphasic shocks, has simplified device implantation substantially. Because an increasing number of device implantations is likely to be done by nonsurgically trained cardiac electrophysiologists^{2,3} rather than with the current combined surgeon/electrophysiologist approach, the prevalence of device infection may transiently change. It is timely therefore to review the prevalence and treatment of ICD infections not only as a guide for management, but also to put in perspective the standards that implanting cardiac electrophysi-

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Table I. Patient clinical characteristics

	Age and sex	Disease	Arrhythmic	LVEF (%)	DM	Operation	Primary implant
Group A							
1.	45F	RHD/MI	SMVT	20	—	—	Yes (rev)
2.	71M	CAD	SMVT	40	+	CABG	Yes
3.	76M	CAD	CA	20	—	—	Yes
4.	69M	CAD	VF	43	—	CABG	No
5.	57M	CAD	VF	34	—	CABG	Yes
6.	79M	CAD	SMVT	35	—	—	Yes
7.	58M	CAD	SMVT	43	—	CABG	Yes
8.	33M	DCM	VF	73	—	—	Yes
9.	68M	CAD	SMVT	18	—	CABG	Yes
10.	83M	CAD	SMVT	23	—	CABG	Yes
11.	62M	DCM	VF	25	—	—	No
Group B							
12.	47M	VHD	VF	52	—	AVR	Yes (rev)
13.	46M	CAD	SMVT	28	—	—	Yes
14.	67F	VHD	VF	34	—	MVR	Yes (rev)
15.	74M	CAD	SMVT	43	+	—	Yes
16.	60M	CAD	SMVT	30	+	—	Yes
17.	69M	CAD	CA	45	—	CABG	Yes
18.	69M	CAD	VF	25	—	CABG	Yes (rev)
19.	56M	CAD	VF	35	+	—	Yes
20.	76M	CAD	CA/SMVT	36	—	—	Yes
21.	49M	CAD	CA/SMVT	23	+	CABG	Yes

AVR, Aortic valve replacement; CA, cardiac arrest; CABG, coronary artery bypass grafting; CAD, coronary artery disease; DM, diabetes mellitus; DCM, dilated cardiomyopathy; LVEF, left ventricular ejection fraction; MI, myocardial infarction; MVR, mitral valve replacement; Rev, system revised; RHD, rheumatic heart disease; SMVT, sustained monomorphic ventricular tachycardia; VF, ventricular fibrillation; VHD, valvular heart disease.

ologists must set for themselves. This study examines retrospectively the experience of treating device-related infection in a single center with an 11-year experience of ICD implantation with a joint surgeon/electrophysiologist approach.

Methods

Patient population. The study population comprised 21 patients with infected ICD systems treated at the Massachusetts General Hospital between June 1983 and May 1994. These 21 patients were divided into two groups: group A comprised 11 patients with infected ICD systems whose primary implantation or most recent generator change was done at the Massachusetts General Hospital, and group B comprised 10 patients in whom the primary implantation was done at an outside institution but who were transferred to our institution for treatment of device-related infection.

Group A patients were drawn from the 556 patients who underwent implantation of 723 ICDs at our institution for the treatment of spontaneous sustained ventricular tachycardia or fibrillation or of inducible, sustained ventricular tachycardia in patients with organic heart disease with syncope and

nonsustained ventricular tachycardia. Five hundred fifty procedures were primary implantations and 173 were generator changes. Among the 550 primary implantations, 354 patients had an attempted nonthoracotomy insertion. Among these 196 patients, a complete nonthoracotomy lead system with or without a subcutaneous patch could be implanted in 156 (80%), whereas 40 required thoracotomy and a combination of transvenous defibrillation coil electrodes with epicardial patch electrodes.

Infection was suspected when there were local symptoms such as erythema, tenderness, swelling, or purulent drainage from the thoracic or abdominal site. When there was swelling and erythema without spontaneous drainage, culture material was obtained by aspiration from the ICD pocket. In all cases, Gram's stains and aerobic and anaerobic bacterial and fungal cultures were obtained. A positive culture was required to make the diagnosis of ICD infection, and no patient underwent device explantation without a positive culture of blood, exudate, or aspirate. The clinical characteristics of the two groups are summarized in Table I.

For those patients in whom the ICD was implanted at our institution, the implantation proce-

Fig. 1. Timing of ICD infection as function of ICD implant number (*X axis*) and year of implantation. First implant of each year is depicted by *hatched vertical lines*, that is, number of implants until next vertical line equals implants for that year. *Triangles* represent individual infections at our institution.

ture evolved with changing technology. During the initial phase encompassing the early years, all devices were implanted by thoracotomy with extra-pericardial or epicardial placement of defibrillation patch electrodes and transvenous bipolar rate-sensing leads. An additional superior vena caval coil electrode was implanted transvenously in those patients who received either a single left ventricular patch electrode or a two-patch epicardial system with high defibrillation thresholds. ICD implantation was done as a two-stage procedure. The rate-sensing lead and the superior vena caval coil electrode were implanted in the pacemaker laboratory with closure of the infraclavicular pocket. The epicardial patch electrode was implanted later on the same day in the operating room with simultaneous tunneling of the sensing electrode from the infraclavicular to the abdominal pocket. With the advent of nonthoracotomy lead systems, implantation remained a two-step procedure. The transvenous defibrillation leads were first implanted in the pacemaker laboratory with the use of local anesthesia. The pulse generator unit and any additional subcutaneous or epicardial patch electrodes, as dictated by results of defibrillation threshold testing, were implanted later on the same day in the operating room. Routine intravenous antibiotic prophylaxis was used in all patients for both primary implantation and generator change. Early in the experience,

Table II. *Nonthoracotomy approach infections*

	Total No. of patients	Infections	
		No.	%
Group A (<i>n</i> = 3)			
Attempted NTL	196	3	1.5
Successful NTL	156	2	1.3
Lead only	67	2	
SQ patch	89	0	
Epicardial patch	40	1	2.5
Group B (<i>n</i> = 1)			
One patient with a single transvenous lead and SQ patch			

NTL, Nonthoracotomy lead system; SQ, subcutaneous.

vancomycin (500 mg every 6 hours) alone was given before operation and for 48 to 72 hours after operation. Subsequently intravenous cefazolin (1 gm every 8 hours) was added to the regimen, to broaden the spectrum of antibiotic prophylaxis on the one hand and to reinforce prophylaxis against the *Staphylococcus* species on the other.

All patients were followed up at 2- to 3-month intervals either at the ICD clinic of the Massachusetts General Hospital (176 patients) or by their referring cardiologist.

Results

Prevalence of infection

Group A. Eleven of 723 implantation procedures at the Massachusetts General Hospital (1.5%) were

Fig. 2. Time from implantation or revision to ICD infection.

Table III. Infecting organisms

Patient	Organism	Blood cultures	Cons. Rx	Intrathoracic	Duration of Abx Rx (wk)	Follow-up (mo)
1.	<i>Escherichia coli</i>	Neg	No	No	4	30
2.	<i>Morganella</i>					
	<i>Proteus vulgaris</i>	Neg	No	No	2.5	51
	<i>Enterobacter cloacae</i>					
3.	<i>Staph. epidermidis</i>	Neg	No	No	4	5
4.	<i>Strep. B group</i>	Pos	Yes	Unknown	Long-term	32
5.	<i>Staph. aureus</i>	Pos	No	No	2.5	48
6.	<i>Staph. aureus</i>	Neg	RV lead in situ	Yes	Long-term	6
7.	<i>Staph. aureus</i>	Pos	Failed	Yes	4	54
8.	<i>Staph. epidermidis</i>	Neg	No	No	3	41
9.	<i>Klebsiella pneumoniae</i>	Neg	Yes	Unknown	2	5
10.	<i>Staph. aureus</i>	Pos	No	No	4	5
11.	<i>Staph. epidermidis</i>	Neg	Yes	Unknown	Long-term	1
12.	<i>Staph. epidermidis</i>	Neg	Failed	Yes	4	30
13.	<i>Staph. aureus</i>	Pos	Failed	Yes	6	24
14.	<i>Staph. aureus</i>	Neg	No	Yes	4	14
15.	<i>Staph. epidermidis</i>	Pos	No	No	2	26
16.	<i>Staph. aureus</i>	Neg	No	Yes	6	14
17.	<i>Staph. aureus</i>	Pos	Failed	Yes	4	12
18.	<i>Candida albicans</i>	Neg	Yes	Unknown	Long-term	11
19.	<i>Staph. aureus</i>	Neg	Failed	Yes	4	7
20.	<i>Corynebacterium</i>	Neg	No	No	2	5
21.	<i>Staph. epidermidis</i>	Neg	Failed	Yes	6	28

Abx Rx, Antibiotic treatment; Cons. Rx, attempted conservative treatment; Neg, negative; Pos, positive; RV, right ventricular; *Staph.*, *Staphylococcus*; *Strep.*, *Streptococcus*.

complicated by device infection. Nine of these infections occurred within 6 months of the implantation procedure giving an early postprocedure infection rate of 1.2%; there was an additional 0.3% late infection rate (2 patients at 19 and 22 months,

respectively). One hundred eighty-seven patients had more than one generator implantation, giving a per-patient infection rate of 2.0%.

The infection rate was not significantly different for primary implants versus generator replacements:

Fig. 3. Overall management of infection. (1), Patient who had also received long-term antibiotic therapy; (1)*, patient who received short-term antibiotic therapy only.

1.6% (9/550) and 1.2% (2/173), respectively. Likewise, the infection rate in those 196 patients who underwent an attempted nonthoracotomy system implantation was no different from the rate in those who underwent a planned thoracotomy implantation (Table II). Fig. 1 shows the prevalence of infection as a function of time and implantation experience. The prevalence of infection in the first 100 patients from 1983 to 1988 was only 1%. Over the ensuing years and experience, the prevalence of infection has remained relatively constant.

Group B. Because these patients were drawn from an unknown overall population from multiple institutions, no comment can be made on the prevalence of infection in this group.

Presentation. The time from implantation to overt infection was 2.2 ± 1.3 months, excluding the two late (19 months and 22 months) infections (Fig. 2). The most common presenting site was the generator pocket in 13 patients, infraclavicular wound in 2, subcutaneous patch in 1, epicardial patch in 1, and sternal wound in 1. Overall 18 (86%) patients had culture evidence of ICD generator pocket infection, even when this was not the site of presentation; only 10 patients (48%) had systemic symptoms of infection with positive blood cultures in 7 (Table III). Septicemia, including septic shock in a patient receiving steroids, without initial signs of local infection, was the primary presentation in 3 (14%) of the 21 patients.

Organisms. The organisms responsible for infection are listed in Table III. The majority of infec-

tions were caused by *Staphylococcus* (70%) and occurred early after implantation (Fig. 2). In 2 patients, however, late *S. aureus* infection developed 19 and 22 months after implantation, respectively. Five of the 9 patients who had *S. aureus* infection had positive blood cultures.

Three patients had gram-negative infection, and in two of these more than one organism was isolated (*Escherichia coli* and *Morganella* species, *Proteus vulgaris*, and *Enterobacter cloacae*). In three patients a potential source of primary infection other than the ICD was provided by staphylococcal pneumonia (2) and a gram-negative urinary tract infection (1).

Management. The overall management strategy in the 21 patients is shown in Fig. 3.

System removal. During the initial experience with management of ICD infections, attempts to treat conservatively two patients with *S. aureus* infection were unsuccessful. Subsequently the conservative approach in patients with *S. aureus* infections was abandoned, and all such patients were subsequently treated aggressively with high-dose intravenous antibiotics and complete system removal when feasible (Fig. 4). The one exception was a 78-year-old frail patient who was judged a poor risk candidate for cardiopulmonary bypass to remove the right ventricular lead, which could not be extracted via the infraclavicular wound. This lead was therefore left in and all other hardware was removed. Of those patients transferred from other institutions, an initial conservative approach had

Fig. 4. Numbers of patients who underwent complete or partial system removal and responsible organisms.

been attempted unsuccessfully in four patients before transfer.

Among the 17 patients in whom complete system removal was done, the initial implantation had been by median sternotomy (6), left lateral thoracotomy (4), subxiphoid (4), and nonthoracotomy approaches (3) (Table IV). Removal of these systems involved median sternotomy (4), bilateral thoracotomies (4), and unilateral thoracotomy (6). Four patients with transvenous defibrillation electrodes had infections: two with the single CPI Endotak (Cardiac Pacemakers, Inc., St. Paul, Minn.) lead and two with the dual-lead Medtronic Transvene system (Medtronic, Inc., Minneapolis, Minn.), which has an active fixation screw-in right ventricular electrode. Three of these infections occurred early after implantation (≤ 6 months), and the transvenous leads with or without the subcutaneous patch electrodes were easily removed. The screw-in right ventricular lead could not be extracted in one patient in whom late infection developed and was therefore cut in the infraclavicular region and left in situ as mentioned previously.

Two patients had prosthetic mechanical valves and two patients had dual-chamber permanent pacemakers at the time the ICD system infection became clinically apparent (Table I). Despite evidence of intrathoracic infection in two patients and septic shock in a third patient with a permanent

pacemaker, the prosthetic valves and permanent pacemakers were not removed at the time of ICD explant. This decision was aided by transesophageal echocardiography findings, which did not show any evidence of vegetations or a paraprosthetic valve leak in the patient with an aortic valve prosthesis. Late reinfection did not occur in these four patients.

All patients received high-dose intravenous antibiotic drugs for 2 to 6 weeks guided by the sensitivity of the organism. The duration of treatment was influenced by the time from diagnosis to system removal and the virulence of the infection. When complete system removal was achieved, long-term antibiotic therapy was never necessary.

Long-term antibiotic therapy without system removal. In addition to the single patient described herein who had *S. aureus* infection and partial system removal, four other patients with relatively low-virulence infections or poor clinical status were treated conservatively without ICD system removal. All were treated with high-dose intravenous antibiotics, and four patients subsequently received maintenance long-term oral antibiotic therapy. The responsible organisms in these four patients were *Staphylococcus epidermidis*, *Candida albicans*, group B *Streptococcus hemolyticus*, and *Klebsiella pneumoniae*.

System reimplantation. Of the 17 patients who underwent system removal, 7 underwent new system

Table IV. ICD infection: surgical treatment strategy

	Initial implant	Previous revision	RSL	Patches (No.) and transvenous leads	Removal	Reimplantation	Alternative therapy
Group A							
1.	LL thorac.	Yes	Endo	Epi (2)	LL thorac.	No	Aneurysmect.
2.	Med. stern.	No	Epi	Epi (2)	Bilat. thorac.	No	Amiodarone
3.	NTL only	No	Endo	Endotak system only	NTL	NTL	
4.	Med. stern.	No	Endo	Epi (1) + SVC coil	N/A	N/A	
5.	Med. stern.	No	Epi	Epi (1) + SVC coil	LL thorac.	N/A	Amiodarone
6.	LL thorac.	No	Endo	Epi (1) + Transvene system	LL thorac. + Subx	N/A	Amiodarone
7.	Med. stern.	No	Endo	Epi (2)	Bilat. thorac.	N/A	BB + class I drugs
8.	LL thorac.	No	Endo	Epi (2)	LL thorac.	Subx	
9.	Med. stern.	No	Endo	Epi (2)	N/A	N/A	
10.	NTL only	No	Endo	Transvene system only	NTL	N/A	Class I drugs
11.	Subx	No	Endo	Epi (1) + SVC coil	N/A	N/A	
Group B							
12.	Med. stern.	Yes	Epi	Epi (2) + SVC coil	LL thorac.	NTL + Subx	
13.	Subx	No	Endo	Epi (1) + SVC coil	Med. stern.	No	Aneurysmect.
14.	Med. stern.	Yes	Epi	Epi (3)	Bilat. thorac.	N/A	Class I drugs
15.	Subx	No	Epi	Epi (2)	Subx + Med. stern.	NTL + LL thorac.	
16.	Subx	No	Epi	Epi (2)	Med. stern.	NTL	
17.	Med. stern.	No	Epi	Epi (2)	Bilat. thorac. (2)	N/A	Patches only
18.	Med. stern.	Yes	Epi	Epi (4) + SVC coil	N/A	N/A	
19.	Subx	No	Epi	Epi (2)	Med. stern.	N/A	Sotalol
20.	NTL	No	Endo	SQ + Endotak system	NTL	NTL	
21.	Med. stern.	No	Epi	Epi (2)	R thorac.	NTL + epi (1)	

Aneurysmect, Aneurysmectomy; *BB*, beta blocker; *bilat*, bilateral; *endo*, endocardial; *epi*, epicardial; *LL*, left lateral; *med. stern.*, median sternotomy; *NTL*, nonthoracotomy lead system; *N/A*, not applicable; *RSL*, rate-sensing lead; *SQ*, subcutaneous; *Subx*, subxiphoid; *SVC*, superior vena caval; *Thorac.*, thoracotomy.

reimplantation after 2 to 6 weeks of high-dose intravenous antibiotic therapy. Whether system reimplantation was done during the same hospitalization was determined by the seriousness of the presenting arrhythmia, the ability to control or modify the arrhythmia with antiarrhythmic drug therapy, and the state of wound healing. Four patients had the system reimplanted during the same hospitalization. Three other patients were discharged home receiving antiarrhythmic therapy and were readmitted to the hospital after 3 to 9 months for system reimplantation. Three of the seven patients received complete nonthoracotomy lead systems. Three patients required a new epicardial patch electrode: in two patients who had previously undergone left lateral thoracotomy, the subxiphoid approach was used, whereas in one patient whose initial system had been implanted by a subxiphoid approach, a left lateral thoracotomy was done. In the final patient a previous epicardial patch electrode that had not been removed was used again.

System removal without reimplantation. Ten patients underwent system removal without reimplantation. These patients received 2 to 6 weeks of antibiotic therapy. Two patients underwent map-guided left ven-

tricular aneurysmectomy. At postoperative electrophysiologic study, these two patients had no inducible ventricular arrhythmia and an ICD was not reimplanted. Another patient did not undergo system replacement, because he had no inducible ventricular arrhythmia after coronary artery bypass grafting. Seven patients either refused or were unfit to undergo system reimplantation after protracted illness. Of these seven, four were treated with long-term class III antiarrhythmic drugs (3 amiodarone, 1 sotalol) and three patients with class I antiarrhythmic drugs.

Follow-up. There was no in-hospital mortality. During a mean follow-up of 23.5 months (range 5 to 54) no patient treated with complete or partial system removal had recurrent infection. Among the four patients treated with short-term followed by long-term antibiotic therapy without system removal, none had a clinical recurrence of infection during a mean follow-up of 12.3 months (range 1 to 32).

Of the 21 patients with ICD infection, four patients died, three of progressive heart failure. One patient died suddenly 14 months after system removal while being treated with a class I antiarrhythmic drug. Among 556 group A patients follow-up data were available in 478 (86%). The mean fol-

low-up period was 41 months. Of the 478 patients, 381 (80%) were alive at the end of the follow-up period, whereas 97 (20%) had died. Twelve patients had undergone cardiac transplantation with explanation of the ICD at the time of transplantation.

Discussion

Previous studies of patients with ICDs have reported an infection rate between 2% and 11%.⁴⁻⁸ Recent reports of the use of nonthoracotomy leads suggest a lower incidence of infection with these systems,^{8,9} with one large multicenter study with short-term follow-up reporting an incidence as low as 1.2%.¹⁰ Our results from a single institution with a large implanting experience show that with use of a combined cardiac electrophysiologist/cardiac surgical approach, the incidence of device-related infection can be as low as 1.5%. The infection rate is no different for primary implantations versus generator replacements and no different for configurations that use transvenous defibrillation coils.

There has been considerable debate as to the optimal mode of treatment for infected ICD systems: some authors suggest immediate system removal with reimplantation of the same generator after debridement, followed by continuous irrigation of the generator pocket with antibiotic solution.¹¹ Our initial unsuccessful attempts to treat *S. aureus* infections conservatively led to a more radical policy of complete ICD system explantation once infection with this organism had been diagnosed. This approach has been extended to infections with potentially less virulent organisms. In support of this more aggressive approach, several of the patients transferred to our institution had unsuccessful attempts at infection control either with generator removal alone or partial system removal. Wunderly and colleagues¹² also reported similar disappointing results with four out of five failures when attempts were made to treat infection without complete system removal. Once the infection had finally been eradicated, these investigators reimplanted the original generator, which had been resterilized, without further problems. Although the North American Society of Pacing and Electrophysiology has published guidelines for the reuse of permanent pacemakers, the safety of reusing ICD generators in a similar way has not been established.

Diagnosis of pocket infection can be made by direct inspection and cultures of wound drainage or aspiration of pocket fluid. Diagnosis of whether the infection involves the defibrillating or sensing elec-

trodes and extends intrathoracically is more difficult. As a principle we assume the presence of lead/intrathoracic infection when *S. aureus* is the infecting organism. Kelly and associates¹³ have described the value of gallium-labeled leukocyte scans in the demonstration of intrathoracic spread of device-related infection. They used this technique in three patients with *S. aureus* infection to demonstrate both generator pocket and intrathoracic infection. However, neither the sensitivity nor specificity of this technique has been fully defined for patients with ICD infection.

In contrast to our relatively radical approach, other authors have suggested a more conservative approach to ICD infection. Among 12 cases of infection treated by Watkins and Taylor¹⁴ at Johns Hopkins, these authors judged that the infection was limited to the pocket alone in six patients. They removed the generator, treated with parenteral antibiotics, then reimplanted the generator on the opposite side and used the original lead system.

Although in general we favor a radical approach to device infection, the patient's overall clinical condition may prohibit this approach. We have successfully treated four patients with lower virulence infection (for example, *Candida albicans*) with long-term oral antibiotic therapy. It is unlikely that these infections have been eradicated; they are probably chronically suppressed as evidenced by the patient with *Streptococcus hemolyticus* in whom fever immediately redeveloped once penicillin therapy was stopped. In such patients the risk of system removal must be balanced against the risk of long-term antibiotic therapy or continuing infection with the risk of subacute bacterial endocarditis or other uncontrollable sepsis, as well as against the anticipated cardiac natural history.

Because the success rate of complete nonthoracotomy ICD systems has now risen from 70% to 75% to greater than 90% with the use of generators capable of delivering biphasic shocks, the issue of defibrillator replacement after successful control of infection will be less complex. In our study, a small number of patients had nonthoracotomy lead systems removed because of infection. When this occurs early, as is the rule, electrode removal is relatively simple. For system infection that develops much later, lead extraction can prove more problematic. Although it is generally believed that late extraction of screw-in electrode systems can be achieved more easily than it can with tined fixation systems, it is likely that removal of either system late

after implantation (>18 months) will be difficult. After the development of the Cook extraction system, the necessity for thoracotomy for late removal of infected pacemaker leads has been reduced to less than 10%.^{15, 16} Whether these systems will prove equally effective and safe for the removal of the currently larger transvenous defibrillation electrodes remains to be established, though preliminary results appear encouraging.¹⁷

The decision regarding device reimplantation after a prolonged period of antibiotic therapy can often be difficult both for the patient and physician. It may be argued that the actuarial survival of 95 (of a total of 1,896) recipients in the Bilitch Registry who had the systems removed (33 because of infection) was the same as that for those who never had the systems explanted.¹⁸ In our series one patient had an episode of in-hospital cardiac arrest after ICD removal, and a second patient who refused reimplantation died suddenly. Until the wider issue of the influence of ICD versus antiarrhythmic drug therapy on overall survival is resolved, we currently recommend defibrillator reimplantation, with use of a nonthoracotomy approach when feasible, unless curative map-guided endocardial resection has been done without inducible arrhythmias after operation.

We routinely use antibiotic prophylaxis for all primary ICD implantations and generator changes. Whether this reduces the incidence of infection is unproved. The use of prophylactic antibiotics for patients undergoing other surgical procedures or dental procedures is even less clearly defined, though we often recommend antibiotic prophylaxis for such procedures for 3 months after primary implantation.

Limitations. In 10 patients with ICD infection referred to our institution, a conservative approach had already failed in 4. Therefore these referred patients may be a selected group either because of infections refractory to conservative management or because of poor medical condition. Thus, considering all ICD infections in general, the effectiveness of conservative management may be better than suggested by our experience. Furthermore, although this study represents a single institution's experience, it is a retrospective study that examines a single mode of clinical practice without any randomization to different modes of management. We cannot, therefore, claim that our approach to treatment is superior to other methods. However, given this approach the in-hospital mortality from infection in this series was zero, and the short-term follow-up was favorable.

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