Should They Stay or Should They Go?
Current Controversies in Lead Extraction

Lead Extraction Is Preferred for Lead Revisions and System Upgrades

When Less Is More
Melanie Maytin, MD; Laurence M. Epstein, MD

Cardiovascular implantable electronic device (CIED) use has increased exponentially during the past decade, with >4.5 million active devices and 1 million new leads implanted annually. With expanded CIED use and indications for device therapy, observed complications have increased in parallel. The occurrence of more frequent device system revisions for complications, system upgrades, and/or lead malfunction and longer patient life expectancies have mandated a paradigm shift toward premeditated lead management strategies from implant to removal or replacement. Consequently, clinicians increasingly are faced with the challenging choice of extraction or abandonment of sterile, superfluous leads. The decision is difficult and highly controversial, with limited rigorous evidence and passionate arguments on either side.

Response by Henrikson on p 424

We contend that although decisions regarding extraction in these situations must be made on a case-by-case basis after considering multiple patient- and physician-related variables, lead extraction should be the preferred management strategy for lead revisions and system upgrades. Randomized, controlled trials of extraction versus abandonment are lacking, but the available evidence from observational, cohort, and registry studies supports the contention that the potential future benefit of lead extraction outweighs the risks of lead abandonment and that lead abandonment should be viewed as a "palliative procedure" that "just postpones the inevitable future lead extraction." In patients with venous occlusion undergoing the addition of a lead with plans to preserve the existing leads (eg, VVI to DDD implantable cardioverter defibrillator, or DDD implantable cardioverter defibrillator upgrade to BiV implantable cardioverter defibrillator), venoplasty, when possible, is the preferred approach. In many such patients, the venous obstruction is short in length and can often be easily passed with a wire and dilator. Our comments below relate to patients in whom lead abandonment is being considered.

Background

Lead extraction has undergone an explosive evolution since its inception as a rudimentary skill with limited technology and therapeutic options. Early techniques involved simple manual traction that frequently proved ineffective for chronically implanted leads and carried a high risk of myocardial avulsion, tamponade, and death. The significant morbidity and mortality associated with these early extraction techniques limited their application to life-threatening situations such as infection and sepsis. The past 30 years have witnessed significant advances in lead extraction technology, resulting in safer and more efficacious techniques and tools and thereby

The opinions expressed in this article are not necessarily those of the editors or of the American Heart Association.
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providing the skilled extractor with a well-equipped armamentarium. With the development of the discipline, we have witnessed a growth in the community of transvenous lead extraction (TLE) experts coincident with a marked decline in the incidence of procedure-related morbidity and mortality, with more recent registries at high-volume centers reporting high success rates with exceedingly low complication rates (Figure 1).\(^{24,25,31,32}\) Accordingly, this has resulted in expanded indications for TLE\(^{23}\) (Table 1), although noninfectious indications for TLE remain a controversial topic.\(^ {18,19,21,22,33,34}\)

**Figure 1.** Success, morbidity, and mortality in large series. Graphic representation of complete success as a function of time, represented by black columns. Secondary y axis represents percent morbidity (orange) and mortality (red). Timeline of extraction techniques and tools commensurate with reported trials is at the top of the figure. Values below the graph represent the number of leads (N) extracted in each study. Composite major complication (MC) and mortality (M) rate was calculated. Only studies with ≥50 leads extracted and data regarding mortality and major complications were cited. EDS indicates electrosurgical dissection sheath.

### Risks of TLE

With the introduction of locking stylets and successful intravascular countertraction techniques, TLE has grown from a rare specialty reserved for life-threatening lead conditions to an increasingly practiced and often used tool with continually expanding indications.\(^ {23}\) In fact, it is estimated that the demand for TLE has reached an annual extraction rate of 10,000 to 15,000 leads worldwide.\(^ {35}\) This growth is not only a result of expanding device indications and use but also a consequence of new tools and techniques with higher success rates and less morbidity and mortality. Simple traction was much less effective for chronically implanted electrodes and was associated with a significant risk of myocardial avulsion. The creation of the locking stylet and telescoping sheath represented significant advances in TLE, allowing for critical opposing forces of traction and countertraction and yielding a higher degree of success and safety. The introduction of the laser sheath improved extraction success rates dramatically. In PLEXES,\(^ {36}\) 301 patients with 465 pacing electrodes were randomized to nonlaser versus laser-assisted extraction. Extraction efficacy improved from 64% with traditional extraction techniques to 94% with laser-assisted extraction, although significant crossover between groups occurred.

Complication rates with TLE directly parallel operator experience. Major and minor complications are reduced by
Table 1. Indications for TLE\textsuperscript{23}

<table>
<thead>
<tr>
<th>Indication</th>
<th>Class I Procedure should be performed</th>
<th>Class IIa Reasonable to perform procedure</th>
<th>Class IIb Procedure may be considered</th>
<th>Class III Procedure should not be performed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infection</strong></td>
<td></td>
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<tr>
<td></td>
<td>1. Definite CIED infection, eg, valvular endocarditis, DRE, or sepsis (LOE: B)</td>
<td>1. Persistent occult Gram-negative bacteremia (LOE: B)</td>
<td></td>
<td>1. Superficial or incisional infection without involvement of device/leads (LOE: C)</td>
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<tr>
<td></td>
<td>2. CIED pocket infection, eg, abscess, erosion, or chronic draining sinus (LOE: B)</td>
<td></td>
<td></td>
<td>2. Chronic bacteremia due to a source other than CIED when long-term suppressive antibiotics are required (LOE: C)</td>
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<tr>
<td></td>
<td>3. Valvular endocarditis without definite lead and/or device involvement (LOE: B)</td>
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<td></td>
<td>4. Occult Gram-positive bacteremia (LOE: B)</td>
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<tr>
<td></td>
<td>1. Persistent occult Gram-negative bacteremia (LOE: B)</td>
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<tr>
<td></td>
<td>1. Superficial or incisional infection without involvement of device/leads (LOE: C)</td>
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<tr>
<td></td>
<td>2. Chronic bacteremia due to a source other than CIED when long-term suppressive antibiotics are required (LOE: C)</td>
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<tr>
<td><strong>Thrombosis or venous stenosis</strong></td>
<td>1. Clinically significant TE events associated with thrombus on lead or fragment (LOE: C)</td>
<td>1. Ipsilateral venous occlusion precluding ipsilateral implant of additional lead without contraindication to contralateral implant (LOE: C)</td>
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<td></td>
<td>2. Bilateral SCV or SVC occlusion precluding implant of needed TV lead (LOE: C)</td>
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<td></td>
<td>3. Planned stent deployment in vein with TV lead already to avoid entrapment (LOE: C)</td>
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<td></td>
<td>4. Symptomatic SVC stenosis/occlusion (LOE: C)</td>
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<td></td>
<td>5. Ipsilateral venous occlusion precluding implant of additional lead when contralateral implant contraindicated (AVF, shunt or vascular access port, mastectomy) (LOE: C)</td>
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<tr>
<td></td>
<td>1. Ipsilateral venous occlusion precluding ipsilateral implant of additional lead without contraindication to contralateral implant (LOE: C)</td>
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<tr>
<td><strong>Functional leads</strong></td>
<td>1. Life-threatening arrhythmias due to retained leads (LOE: B)</td>
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<td></td>
<td>2. Leads, due to design or failure, may pose immediate threat if left in place (LOE: B)</td>
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<tr>
<td></td>
<td>1. Leads with potential interference with CIED function (LOE: C)</td>
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<tr>
<td></td>
<td>2. Leads, due to design or failure, with potential threat if left in place (LOE: C)</td>
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<td></td>
<td>3. Abandoned leads (LOE: C)</td>
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<td></td>
<td>4. Need for MRI without alternative (LOE: C)</td>
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<td></td>
<td>5. Need for MRI conditional CIED system (LOE: C)</td>
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<tr>
<td></td>
<td>1. Redundant leads with $&lt;1$ year of life expectancy (LOE: C)</td>
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<td></td>
<td>2. Known anomalous lead placement (SCA, Ao, pleura, etc) or through a systemic atrium or ventricle.* (LOE: C)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>1. Ipsilateral venous occlusion precluding ipsilateral implant of additional lead without contraindication to contralateral implant (LOE: C)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>*Can be considered w/surgical backup</td>
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</tbody>
</table>

(Continued)
50% with increased operator experience from 20 to 120 cases to >300 cases performed.\textsuperscript{37} Large-scale, multicenter, randomized trials have confirmed the effect of experience on outcomes.\textsuperscript{32,36–39} Likewise, observational registries of experienced, high-volume extractionists have consistently demonstrated even higher success rates (>99%) with exceedingly low major complication (<1.0%) and mortality (<0.3%) rates.\textsuperscript{24,25,31}

Similar outcomes have been reported with TLE for lead revision or device system upgrade.\textsuperscript{40–43} The safety and efficacy of telescoping sheaths for lead extraction in the setting of subclavian vein thrombosis were first reported by Le Franc et al.\textsuperscript{43} They described 2 patients with defibrillator systems and thrombosis of the implant vein who required the implantation of new pacing and defibrillator electrodes. Recanalization of the implant vein was achieved without complication through TLE with the use of locking stylets and telescoping sheaths. Bracke et al.\textsuperscript{41} presented a case series of 3 patients with subclavian vein stenosis and a need for lead replacement who underwent successful laser-assisted extraction of a nonfunctional lead to gain access to the venous circulation without complications. Venous dilation and/or stenting were not needed after recanalization of the implant vein with the laser sheath. Korley and colleagues\textsuperscript{40} evaluated 20 patients undergoing TLE for upgrade from an abdominal to a pectoral system or from a single- to a dual-chamber device. Thirty leads were extracted with 96.7% complete procedural success and 100% clinical success. No deaths or perioperative cardiac or vascular perforations occurred. Another series of 18 patients with 29 extracted functional leads and 8 preserved leads with successful TLE and reestablishment of venous access was reported by Gula et al.\textsuperscript{42} No procedure-related complications were observed. The risk of extraction is similar to other well-accepted cardiovascular procedures. In a recent publication, catheter ablation for atrial fibrillation, a completely elective procedure, was associated with a major complication rate of 4.5% and a mortality rate of 0.15%.\textsuperscript{44}

Decisions regarding extraction must be made on a case-by-case basis after considering multiple patient- and physician-related variables. An invasive approach, with the potential for significant morbidity and mortality, may not be warranted in patients with a poor prognosis or for whom the risks of intervention clearly outweigh the benefits. In addition, lead extraction should be performed by those experienced in the procedure and with the necessary tools available to attain complete success and in a setting prepared and committed to the complete and safe performance of the procedure.\textsuperscript{23}

### Risks of Abandoned Leads

As aforementioned, clinicians are frequently confronted with the challenging decision of superfluous lead management. Rigorous evidence from large-scale, randomized trials is lacking, and the available reported observational and cohort

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**Table 1. Continued**

<table>
<thead>
<tr>
<th>Indication</th>
<th>Class I</th>
<th>Class IIa</th>
<th>Class IIb</th>
<th>Class III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonfunctional leads</td>
<td>Procedure should be performed</td>
<td>Procedure may be considered</td>
<td>Procedure should not be performed</td>
<td></td>
</tr>
<tr>
<td>3. Leads that interfere with CIED function (LOE: B)</td>
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<tr>
<td>4. Leads that interfere with treatment of malignancy (radiation, surgery) (LOE: C)</td>
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<tr>
<td>1. Severe chronic pain at device or lead insertion site with significant discomfort not manageable by medical or surgical techniques and without acceptable alternative (LOE: C)</td>
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<tr>
<td>2. Need for MRI without alternative (LOE: C)</td>
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<td></td>
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<tr>
<td>3. Need for MRI with alternative (LOE: C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Redundant leads with &lt;1 year life expectancy, (LOE: C)</td>
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<tr>
<td>2. Known anomalous lead placement (SA, Ao, pleura, etc) or through a systemic artery or vein* (LOE: C)</td>
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<tr>
<td>3. CIED implant would yield &gt;4 leads on 1 side or &gt;5 leads through SVC (LOE: C)</td>
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</tbody>
</table>

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Adapted from 2009 Heart Rhythm Society Expert Consensus on Transvenous Lead Extraction.\textsuperscript{23} DRE indicates device-related endocarditis; TE, thromboembolic; SV, subclavian vein; SCA, subclavian artery; Ao, aorta; TV, transvenous; LOE, level of evidence; and MRI, magnetic resonance imaging. Other abbreviations are as defined in text.

*Can be considered with surgical backup.
studies are often underpowered, generating more confusion than answers (Table 2).6,27,30,34,45–51. Recently, the preliminary results of the REPLACE registry52 have been reported. The prospective, observational study of 713 patients at 62 centers undergoing device generator change with planned lead addition or revision documented a 15.3% major complication rate with a 1.1% mortality rate at 6 months. In comparison, a 4.2% major complication rate and a 0.6% mortality rate were observed in the same registry in patients undergoing generator change without lead addition or revision.53 These results demonstrate an increased complication rate with device system upgrade with lead abandonment. The risks of system upgrade versus lead abandonment cannot be interpreted in isolation, and it is plausible that both factors contribute independent risks.

**Preserving Venous Access**

The controversy surrounding the abandonment or extraction of superfluous leads frequently centers incorrectly on the argument of maintaining venous patency. In fact, the primary benefit of removing rather than replacing a lead is preserving venous access, that is, the continued use of the implant vein to preserve contralateral or alternative venous access for future use. Although this distinction may appear to be a matter of semantics, the difference is paramount to the rationale in favor of extraction. As the number of younger individuals receiving CIED and life expectancies increase, the device-years per person will also increase along with the attendant potential risks of infection, lead malfunction, and the need for system upgrade–augmenting the likelihood of the eventual need for implantation via the contralateral venous system. Consequently, physicians performing implants are required to evaluate and implement the best lead management strategy for each individual, not only for the immediate procedure but also for future procedures, hence, the imperative to preserve venous access and not venous patency.

Within 4 to 5 days of implant, near-complete encapsulation of intravascular pacing leads with a fibrin sheath has been observed in an extensive thrombosis.54,55 Younger patients develop more vigorous fibrotic responses and more frequently develop progressive calcification.56 Several clinical studies have similarly demonstrated the common occurrence of venous stenoses and occlusion after endovascular pacing and defibrillator lead placement; however, the venous pathology is frequently asymptomatic.57–59 Similarly, asymptomatic venous thrombosis is commonly observed in patients with abandoned leads, again with little clinical significance.27,30,47,48 In contrast, little is known about the effects of lead extraction on venous patency, and attempts to study this have been confounded by ipsilateral reimplantation, making it impossible to isolate the effects of extraction.60

CIED upgrade or lead revision can be and certainly has been accomplished despite venous occlusion. The solution frequently involves venoplasty,61 unconventional ipsilateral venous entry,62–65 or contralateral venous access with tunneling or complete abandonment of the original system. Each approach is fraught with flaws. Tunneled leads can be painful both at implant and chronically and can be apt to erode.42 Moreover, contralateral implantation should not be considered a reasonable alternative to lead extraction. It is our opinion that preservation of venous access is essential to responsible lead management (Figure 2A–C). Although venoplasty and unconventional ipsilateral venous access avoid the unnecessary use of the contralateral venous system, both result in increased lead burden, have uncertain effects on lead survival, and carry potential present and future risks. Furthermore, in some cases, venoplasty of the occluded vein may not be possible. In this situation, extraction is the only option to avoid contralateral lead placement.

**Infection**

Coincident with the upsurge in CIED use, there has been a disproportional rise in CIED infection (0.8 to 19.9% of CIED patients).7,8,66 Between 2003 and 2006, the number of CIED implants increased by 12% while the number of CIED infections rose by 57%.7 Several risk factors for CIED infection have been identified, including the presence of >2 pacing leads67 and cardiac resynchronization therapy.68 Data regarding the risk of CIED infection in patients with abandoned leads have failed to demonstrate an increased risk of device-related infection but are limited by small sample size and abbreviated follow-up periods.27,30,46,48,51 In young patients with abandoned leads, Silvetti and Drago27 observed an alarming 11% incidence of CIED infection compared with a 2% incidence in all pacemaker patients, although the trial was underpowered to reach statistical significance. All patients with CIED infection required definitive treatment with lead removal. Similarly, in comparing patients with and without complications among those with abandoned pacing leads, Suga et al.47 noted a significant increase in infection and asymptomatic venous occlusion in patients with multiple leads, although the end point was driven largely by venous pathology. Similar to the experience reported by Silvetti and Drago, all patients with CIED infection underwent complete device system removal. In addition, 44% of patients with asymptomatic venous occlusion required TLE for ipsilateral venous access, whereas the remaining 56% underwent contralateral implantation for lead revision.

Untreated device-related infection is associated with mortality rates as high as 66%. Mortality is reduced to 18% in patients treated with extraction and antibiotics, and eradication of CIED infection requires complete removal of the entire system.69–71 The occurrence of device-related infection in the setting of previously abandoned leads increases both the difficulty and risk of the extraction procedure owing to the longer implant duration and lead-lead binding. Although rigorous data regarding CIED infection risk and lead abandonment per se are lacking, the risk of device-related infection with increasing lead burden and the associated mortality with incomplete treatment mandating TLE require careful
### Table 2. Risks of Lead Abandonment

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>Groups Studied</th>
<th>No. of Patients</th>
<th>No. of Leads</th>
<th>Follow-Up</th>
<th>Primary End Point</th>
<th>Comparative Results: Abandon vs Remove</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wollman et al&lt;sup&gt;45&lt;/sup&gt;</td>
<td>Retrospective cohort</td>
<td>Add HV vs replace HV</td>
<td>33 add vs 53 replace*</td>
<td>2.6 ± 0.8 vs 1.4 ± 0.7†</td>
<td>9.3 ± 2.7 vs 6.7 ± 3.8 y†</td>
<td>Event-free survival</td>
<td>(Add HV decision due to failed TLE attempt in 70%)</td>
</tr>
<tr>
<td>Wollman et al&lt;sup&gt;46&lt;/sup&gt;</td>
<td>Prospective observational</td>
<td>Add P/S</td>
<td>151</td>
<td>2.3</td>
<td>3.6 ± 2.3 y</td>
<td>Event-free survival</td>
<td>N/A (Conclude removal best given 28.5% failure rate of new P/S requiring repeat procedure)</td>
</tr>
<tr>
<td>Suga et al&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Retrospective observational</td>
<td>Patients with ≥ 1 abandoned lead</td>
<td>433</td>
<td>2.8</td>
<td>3.1 ± 2.7 y</td>
<td>Event-free survival</td>
<td>N/A (No. abandoned leads higher in those with complications)†</td>
</tr>
<tr>
<td>Furman et al&lt;sup&gt;48&lt;/sup&gt;</td>
<td>Retrospective observational</td>
<td>Patients with ≥ 1 abandoned lead</td>
<td>152</td>
<td>NA</td>
<td>4 y</td>
<td>Event-free survival</td>
<td>N/A (Fatal embolization of cut lead)</td>
</tr>
<tr>
<td>Rettig et al&lt;sup&gt;10&lt;/sup&gt;</td>
<td>Retrospective observational</td>
<td>Patients with ≥ 1 abandoned lead</td>
<td>25</td>
<td>NA</td>
<td>1.8 y</td>
<td>Event-free survival</td>
<td>N/A (11% DRE and 28% new contralateral implant but study underpowered)</td>
</tr>
<tr>
<td>Silvetti and Drago&lt;sup&gt;27&lt;/sup&gt;</td>
<td>Retrospective observational</td>
<td>Young patients with abandoned leads</td>
<td>18</td>
<td>1.1 ± 0.3 (abandoned)</td>
<td>4 y</td>
<td>Event-free survival</td>
<td>N/A (No sensing malfunction, venous thrombosis, or change in DFT)</td>
</tr>
<tr>
<td>Glikson et al&lt;sup&gt;34&lt;/sup&gt;</td>
<td>Retrospective observational</td>
<td>Abandoned HV or P/S</td>
<td>78</td>
<td>1.5 (abandoned)</td>
<td>3.1 ± 2.0 y</td>
<td>Event-free survival</td>
<td>N/A</td>
</tr>
<tr>
<td>deCock et al&lt;sup&gt;49&lt;/sup&gt;</td>
<td>Prospective observational</td>
<td>Patients with ≥ 3 leads vs age-matched dual-chamber controls</td>
<td>48</td>
<td>3.2 vs 2.0</td>
<td>7.4 ± 2.0 y</td>
<td>Clinical venous occlusion, RHF, AF, hospitalizations, and mortality</td>
<td>N/A</td>
</tr>
<tr>
<td>Bohm et al&lt;sup&gt;10&lt;/sup&gt;</td>
<td>Retrospective observational</td>
<td>Patients with ≥ 1 abandoned lead (epi/endocardial)</td>
<td>60</td>
<td>1.0 (abandoned)</td>
<td>NA</td>
<td>Event-free survival</td>
<td>N/A (20% event rate driven by migration of cut leads)</td>
</tr>
<tr>
<td>Sweeney et al&lt;sup&gt;16&lt;/sup&gt;</td>
<td>Prospective observational</td>
<td>Device upgrades: add vs replace</td>
<td>58</td>
<td>NA</td>
<td>1.1 ± 1.1 y</td>
<td>Event-free survival</td>
<td>N/A (42% vs 3% rate of major complications infectious vs non)</td>
</tr>
<tr>
<td>Parry et al&lt;sup&gt;31&lt;/sup&gt;</td>
<td>Retrospective observational</td>
<td>Patients with ≥ 1 abandoned lead (infectious vs non)</td>
<td>119</td>
<td>NA</td>
<td>NA</td>
<td>Event-free survival</td>
<td>N/A</td>
</tr>
</tbody>
</table>

HV indicates high-voltage defibrillation lead; †, no significant difference between extraction and abandonment; P/S, pace-sense lead; RHF, right heart failure; AF, atrial fibrillation; DFT, defibrillation threshold; DRE, device-related endocarditis; NA, not available; N/A, not applicable, refers to studies in which comparative analysis is not possible.

*Mean lead implant duration 7.4 ± 2.9 y in the add-HV group vs 4.1 ± 3.4 y in the replace group (P < 0.05).

†P < 0.05.
consideration of an individual’s future risk in the management decision regarding superfluous leads.

**Lead-Lead Interaction**

Lead-lead interaction between superfluous and active leads can result in the oversensing of specious signals and inappropriate inhibition of pacing with potential serious sequelae (Figure 3, A–C). Opponents of nonfunctional lead removal argue that the risk of electrical interference is avoided by eliminating contact between the active and abandoned leads and that this potential risk is not supported by available data. In fact, physical lead-lead interaction is only 1 mechanism of spurious signal generation. False signals can be created by the production of a galvanic current between 2 electrodes of different composition without physical contact between the active and abandoned electrodes. The lack of supportive data is a reflection of underpowered studies unable to detect a significant difference. Wollman et al observed a 2-fold increase in oversensing with inappropriate shocks in patients with an added as opposed to a replaced high-voltage lead. In a prior observational study of added pace-sense leads, Wollman et al found a 28.5% failure rate of the new pace-sense lead, with half of the failures attributed to oversensing. Because neither study clearly delineated the mechanism of oversensing (ie, lead fracture, T/P-wave oversensing, or lead-lead interaction), the exact incidence of lead-lead interaction is unknown. Of the patients with abandoned lead complications, 62% required reoperation for the addition of another pacemaker or high-voltage lead.

**Lead Burden and the Central Venous System**

Endovascular lead-induced venous stenosis and thrombosis are not limited to the implant veins. Although infrequent, multiple reports of superior vena cava (SVC) syndrome exist in the literature. As a result, the 2009 Heart Rhythm Society Expert Consensus on Lead Extraction has assigned a class IIa indication to lead extraction for a CIED procedure that would result in >4 leads on 1 side or 5 leads through the SVC. Symptomatic SVC syndrome requires an invasive approach with surgical or percutaneous venoplasty, frequently in association with lead extraction.

**Lead Burden and the Tricuspid Valve**

After endovascular lead implantation, fibrous adhesion of electrodes to the tricuspid valve in pathological specimens and regurgitant valve disease of varying clinical significance are observed commonly. More recently, isolated cases of severe tricuspid stenosis from excessive lead burden have been reported in patients with 4 and 5 endovascular pacing leads.

**Risk of Future Lead Extraction**

Perhaps the most important and certainly the most commonly overlooked risk of lead abandonment is the potential need for future lead extraction. As emphasized previously, the increasing incidence of CIED complications and longer patient life expectancies make the incremental likelihood of TLE in an individual lifetime significant. Moreover, TLE failure and complications are directly related to both lead implant duration and lead burden. In a prospective registry of 3500 leads extracted at 266 centers, Byrd and colleagues noted a 2-fold increase in the risk of extraction failure with every 3 years of implant duration. Roux et al found a similar association between unsuccessful TLE and lead implant
duration in addition to a higher incidence of complications in patients requiring bilateral extraction. More recently, 212 consecutive patients undergoing TLE were observed to have a 3.5-fold increase in TLE complications per additional right ventricular lead extracted and a 50% increase in the need for powered sheath assistance per year increase in implant duration of the oldest lead. These data are consistent with our own observations that lead-to-lead binding, particularly in the setting of multiple endovascular leads, is frequently more technically challenging than vessel-to-lead fibrosis. Although quantification of this potential risk is difficult, it cannot be ignored.

**Figure 3.** A–C, Inappropriate inhibition of pacing due to lead-lead interaction. A, Twelve-lead ECG with A-V sequential pacing, premature ventricular contractions, and oversensing, resulting in inappropriate inhibition of pacing output (arrows). Device interrogation demonstrated normal lead parameters. B and C, Posterior-anterior and lateral chest radiographs showing bilateral endovascular CIEDs and multiple endovascular leads.
Risk Versus Risk

The assertion that lead extraction should be the preferred management strategy for lead revisions and system upgrades mandates a comparison of the risks of extraction with the risks of lead abandonment (Figure 4). The risks of TLE are concrete, with large-scale, randomized trials and registries defining the success and complication rates, although this risk must be individualized on a case-by-case basis. The consideration of patient and lead characteristics and, perhaps most important, operator experience, must be factored into the risk assessment of extraction. Specific attention to the number of leads, implant duration, defibrillator versus pacing electrodes, and patient age must enter into the risk assessment process. In contrast, the risks of lead abandonment and, by extension, the potential risk of future TLE, are difficult to quantify. The majority of studies of abandoned leads are small registries or observational reports with a finite period of follow-up. In fact, most of these studies have follow-up times of <5 years. In contrast, in many of the extraction studies, the average implant duration was 6 to 7 years with leads as old as 32 years. Observed complications often do not reach statistical significance, not surprisingly owing to the short duration of follow-up and the small number of events that are frequently ascribed away or deemed unimportant. Moreover, most extraction experts would agree that the irreducible risks of pacemaker and/or defibrillator lead abandonment are related to the potential need for future extraction—a risk that is essentially ignored despite the frequent need for transvenous or surgical extraction in the patients with complications of abandoned leads (29% to 100% of abandoned leads with complications).27,46,47,50,51 There is not only a potential need for future extraction but also an increased risk of TLE, given the increase in lead burden, lead-lead binding, and implant duration in the time after the initial lead replacement. Thus, lead decisions at the time of system revision or upgrade must weigh the present risks of extraction with the future risks of both lead abandonment and potential lead extraction.

Risk-risk analysis must also incorporate the indication for extraction. Device system revision or upgrade in the setting of bilateral subclavian vein thrombosis, SVC occlusion, or ipsilateral venous occlusion preventing ipsilateral implantation with contraindications to contralateral implant (eg, arteriovenous fistula, vascular access port, mastectomy, etc) are defined as class I indications for TLE.23 Class IIa indications include the need for lead implantation with ipsilateral venous occlusion preventing ipsilateral implantation without contraindications to contralateral implant or lead implantation that would result in >4 leads in the implant vein or >5 leads through the SVC. Despite the compelling nature of these TLE indications, careful consideration of patient and lead characteristics as well as operator experience is integral to risk evaluation and the decision process. Superfluous leads with the potential for CIED interference and abandoned or redundant leads represent a class IIb indication for extraction and are more controversial, requiring even more scrutiny of the potential complications.

Decisions regarding lead extraction must be made on an individual case-by-case basis, integrating various patient and lead characteristics and operator-related variables. TLE with the potential for significant morbidity and mortality may not be warranted in patients with a poor prognosis or for whom the risks of intervention clearly outweigh the risks of lead abandonment. In addition, those inexperienced in the procedure should not perform lead extractions, nor should those without the necessary tools available to attain complete success or in a setting not prepared and committed to the complete and safe performance of the procedure.23

Disclosures

Dr Maytin has no conflicts of interest to disclose. Dr Epstein has received research grants from and is a consultant for Boston Scientific, Medtronic, Spectranetics, and St. Jude Medical and has equity in and served as a board member for Carrot Medical.

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Response to Melanie Maytin, MD, and Laurence M. Epstein, MD

Charles A. Henrikson, MD

I agree with my opponents that the decision to remove extraneous leads at the time of pocket manipulation is a matter of balancing the risks of lead extraction versus the risks of lead abandonment. As detailed in my review and that of my opponents, the risks of lead extraction are well known and are likely decreasing as technology and techniques mature. However, the risks of lead abandonment are largely theoretical in nature. The few data available are mostly short to medium term in follow-up and often report complications that are of unclear significance, such as asymptomatic venous occlusion. Thus, the balance of the risks turns out to be a balance of known risks versus theoretical risks. I certainly concede that there will probably be patients of mine who will need extractions in the future from whom I could have extracted years ago at the time of system revision but chose not to. These patients will have older leads and require more difficult extractions. However, for each of these patients, there will likely be dozens, if not hundreds, of my patients with abandoned leads who will never require extraction. In addition, the risks of extraction may continue to decline in the future, making future extractions more attractive and potentially safer than current extractions. All said, given the paucity of data, I believe that a conservative approach to complex lead management will result in better outcomes for patients, shielding them from known risks today while exposing them only to theoretical risks in the future.
Lead Extraction Is Preferred for Lead Revisions and System Upgrades: When Less Is More
Melanie Maytin, Charles A. Henrikson and Laurence M. Epstein

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