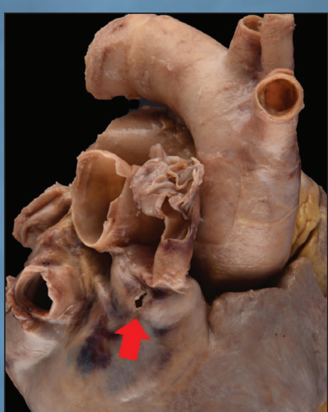
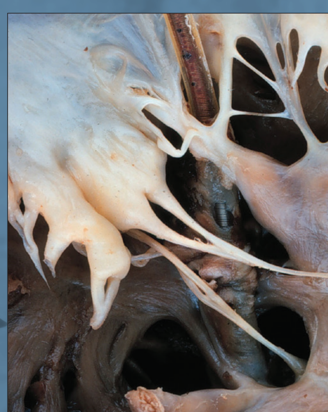
CARDIAC LEAD EXTRACTION

A Case-Based Contemporary Approach

Includes Digital Edition with Videos





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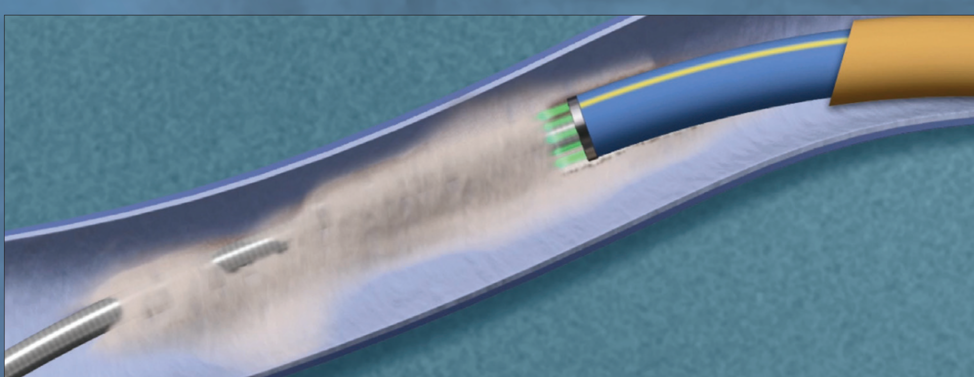

cardiotext

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A Case-Based Contemporary Approach

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cardiotext

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Forewords

Joshua M. Cooper, MD

Lead extraction is a somewhat solitary niche within our specialty of cardiac electrophysiology. The high-stakes, unpredictable nature of these procedures whittles down the number of interested trainees. The resource-heavy support system needed for a responsible lead extraction program limits the number of well-equipped and interested medical centers. The optimization of procedural safety and success compels us to concentrate the experience into as few hands as is feasible. Consequently, there tend to be a limited number of lead extractors within a medical institution (often only one) or geographic region. This scarcity results in the performance of lead extraction in a figurative silo, with personal experience being the primary guide for the incremental honing of skills.

Lead extraction is the discipline with the greatest amount of case-to-case variability, requiring the physician to continuously exercise intra-operative judgment, including the leveraging of a great breadth of approaches and tools. The seasoned extractor will invariably innovate and improvise during difficult cases, often relying on the creative application of techniques never originally intended to be used for the freeing and removal of indwelling pacemaker and ICD systems.

So how exactly is a lead extractor in isolation supposed to expand their toolbox and thereby maximize operative success? Personal experience moves at a fixed pace, limited by what that individual has seen before. This mode of learning by self-experience also requires each novel scenario to be encountered more than once for the extractor to directly benefit, assuming there were self-taught innovations during the first struggle that are worth repeating.

The ability to learn from the collective wisdom of the lead extraction community is a game-changer. Dr. Yong-Mei Cha and Dr. Siva Mulpuru fill an essential void with this text by bringing together detailed and practical expert guidance from preoperative planning through all phases and dimensions of the procedure itself, as well as 26 carefully selected case studies that span a wide range of clinical challenges. This compendium showcases a breadth of techniques and expertise that extends far beyond what any individual could achieve. The detailed visual and descriptive presentations provide a virtual "operating theater" to the reader, who is then able to draw from this exposure and apply new methods and insights without having to reinvent the wheel on their own. I wish the editors and contributing authors heartfelt congratulations on the publication of this important work, which will benefit physicians and patients alike.

Joshua M. Cooper, MD, is a Professor of Medicine at Lewis Katz School of Medicine at Temple University, and the Director of Cardiac Electrophysiology for Temple University Health System, Philadelphia, Pennsylvania.

Maria Grazia Bongiorni, MD

It is my pleasure to contribute a foreword to this case-based lead extraction book, which covers a topic often forgotten or not sufficiently explored in electrophysiology and devices books. In the last decades, procedures for lead extractions have soared. Like the authors, I was fortunate to see the birth of these techniques and to have contributed to their growth.

Having a case-based contemporary approach to and explanation of lead extraction is essential. In my experience, I have learned that the lead extraction procedure is not a "routine" procedure, but that each situation needs to be treated individually, on its own merits. Many times, I had to figure out ingenious solutions to overcome challenging situations, such as the use of the internal jugular approach. As described in this book, many solutions have been developed in the last decade to increase the efficacy and the safety of this procedure, making it accessible and workable in many centers.

Lead extraction is one of the medical areas where the need for a solution has led to continued research and resulted in many ingenious ideas. Since that time when the father of the lead extraction, Dr. Charles Byrd, first developed the system of sheaths to make an efficient and safe procedure of transvenous lead extraction, substantial progress has been made in the field. Today, transvenous lead extraction has become a widespread procedure throughout the world.

Lead extraction is a true team procedure. Each participant must keep in mind that all the steps of the lead extraction procedure are intertwined, and by working together to anticipate, manage, and prevent potential complications, the team can achieve the best potential outcome for the patient.

In summary, I highly recommend *Cardiac Lead Extraction: A Case-Based Contemporary Approach* as a superb contribution—one that benefits not only fellows or beginning trainees in the sector, but also experienced colleagues and electrophysiologists. A proper understanding of the challenges of lead extraction should reflect in procedural decisions during device implantation, removal of leads, and overall patient care.

Maria Grazia Bongiorni, MD, is Director of Cardiology and Arrhythmology Division at University Hospital in Pisa, Italy.

Kenneth A. Ellenbogen, MD

Lead extraction has become an increasingly important technique for managing patients with cardiac implantable electronic devices (CIEDs) and leads. It is estimated about 26,000+ procedures are undertaken worldwide. At first glance, this book may seem directed towards the small group of individuals who remove pacemaker and defibrillator leads from the heart. However, after reviewing this book, I think it is far more—and it will appeal to a larger and more diverse group of readers.

In eight chapters and 26 case-based studies, the authors take us from patient evaluation, to lead evaluation and performance, to preprocedural evaluation and risk stratification, to procedural tips and tricks, and finally to postprocedural management and planning. The teaching points are well summarized at the end of each chapter, and in typical Mayo Clinic fashion, the figures and videos are of excellent quality.

I tremendously enjoyed reading this book and extend my congratulations to the outstanding contributors who combined to give us a wide spectrum of cases. It would be impossible to read this monograph and not take away a number of important tips and tricks. For those who do not perform lead extraction, this is a useful book that helps one appreciate lead and device management even more. For those in training or caring for patients with devices, I could not think of a better place to learn about these important techniques for patient management and procedure performance.

This is a comprehensive book that provides everyone—from the learner to the experienced practitioner—with insights into management of the common clinical problems seen with patients with implantable devices, and especially with regard to managing and removing leads. I can highly recommend this lovely monograph.

Kenneth A. Ellenbogen, MD, is the Kimmerling Professor of Cardiology at Virginia Commonwealth University School of Medicine in Richmond, Virginia.

Video Legends

CHAPTERS

Chapter 3: Lead Extraction Imaging

Video 3.1 (A) 2D RV inflow with device lead causing impingement of the septal leaflet of the tricuspid valve. (B) Color Doppler interrogation of the RV inflow view showing severe TR. [00:03]

Video 3.2 Cine venogram demonstrating a patent subclavian vein with scar adherence to SVC coil. Prior traction on the ICD lead entrapped within scar resulted in uncoiling of the SVC coil. [00:12]

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Video 3.5 AP view cine images obtained from a 63-year-old female with pacing leads placed 16 years earlier. Imaging demonstrates very free lead movement, suggesting little lead-to-lead or vascular adherence. [00:03]

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Video 3.8 AP view cine images obtained from a 36-year-old female with pacing leads placed 8 years earlier. There is little free lead movement suggestive of a heavy scar burden with lead adherence. [00:03]

Video 3.9 RAO view cine images obtained from a 36-year-old female with pacing leads placed 8 years earlier. There is little free lead movement suggestive of a heavy scar burden with lead adherence. Classic "railroad tracking" is seen in the RAO view demonstrating lead-to-lead adherence from the subclavian to the distal SVC. [00:03]

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Video 3.11 RAO view cine images taken just prior to extraction of a dislodged nonfunctioning LV lead. Note the redundant lead loop extending into the IVC with concerns over possible adherence to the IVC. [00:01]

Video 3.12 LAO view cine images taken just prior to extraction of a dislodged nonfunctioning LV lead. Note the redundant lead loop extending into the IVC with concerns over possible adherence to the IVC. [00:03]

Video 3.13 AP view cine images taken demonstrating calcified scar along pacing leads. The red arrow points out calcium along the lead while the yellow arrow points out a heavy band of calcified scar binding the 2 leads as they exit the innominate into the SVC. These images influence tool selection (please see text). [00:03]

Video 3.14 The corresponding video taken from the patient illustrated in Figure 3.18. This ICE video demonstrates the lack of any lead SVC wall adherence. [00:59]

1 | Structural Basis for Lead Extraction Complications

Justin Z. Lee, MBBS; Samuel A. Shabtaie, MD; Samuel J. Asirvatham, MD

INTRODUCTION

Lead extraction has the highest complication and mortality rate among device-related procedures.[1] It is essential for the electrophysiologist who performs lead extraction to be familiar with the tools involved with lead extractions, the engineering aspects of the lead, and the anatomic basis of lead extraction. In that context, this chapter reviews the critical cardiac and venous anatomy that is essential for the electrophysiologist to keep in mind when performing the procedure. This chapter reviews the anatomic basis for complications that can happen during lead extraction, techniques to avoid the injury, and early recognition of complications when they occur.

VENOUS COMPLICATIONS

Superior Vena Cava

The anatomy of the superior vena cava (SVC) is of paramount importance as the most common cause of death related to lead extraction is SVC laceration.[2] The SVC is formed by the confluence of the right and left brachiocephalic veins, and it returns deoxygenated blood to the right atrium. Typical venous turns occur at the innominate–SVC junction and the SVC–right atrial junction. **Figure 1.1** shows the relationship of the SVC to the heart. It is unsupported in its more proximal portion, and therefore has no cushion when tension is applied to its wall. The parietal pericardial reflection can be visualized as well in Figure 1.1. It is closer to the atrium posteriorly and farther from the atrium anteriorly. When a laceration occurs above the pericardial reflection, this can lead to hemothorax and brisk bleeding into the mediastinum, requiring prompt recognition and emergent surgical repair to prevent the patient's rapid demise. Sole reliance on the presence of the development of pericardial effusion and hemopericardium for recognition of an SVC injury above the level of the pericardial reflection may be misleading. Of all vascular injuries during lead extraction, two-thirds were in the SVC, half of which were above the pericardial reflection and the other half below.[3] This also highlights the importance of ensuring that the SVC balloon is deployed with its tip beyond the brachiocephalic–SVC junction level.

Below the pericardial reflection, the SVC is contained within the pericardial space (see Figure 1.1). Therefore, if a perforation occurs below the pericardial reflection, this results in hemopericardium. The SVC is also closely related to the right superior pulmonary vein (RSPV), forming a posterior buttress (see Figure 1.1). Perforation at this level will lead to an RSPV-to-SVC fistula.

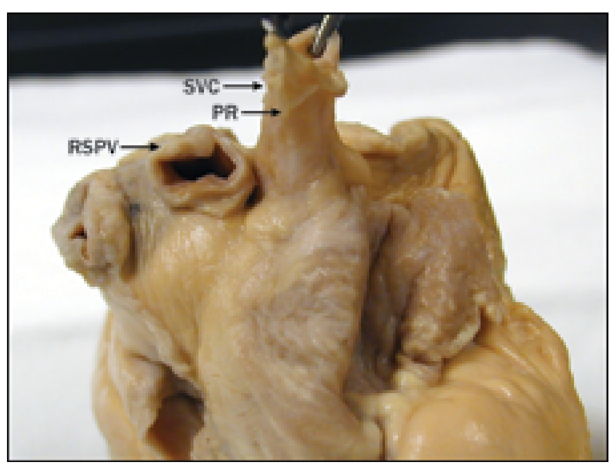

Figure 1.1 Lateral view from an autopsied heart showing the relative anatomy of the superior vena cava (SVC), pericardial reflection (PR), and the right superior pulmonary vein (RSPV).

The challenges during extraction and the frequent need for specialized laser or mechanical sheaths are adhesions and fibrosis forming around the lead. The free wall of the SVC is one of the most frequent sites for the development of adhesions and fibrosis (**Figure 1.2**).[4] When a lead is placed via the left subclavian vein, the point where lead slack is taken up is at the free wall of the SVC. With cardiac contractility, the free wall of the SVC undergoes repeated contact and abrasions from the lead, which leads to adhesions. As opposed to left-sided leads, right-sided leads will have slack taken up by the medial portion of the SVC.

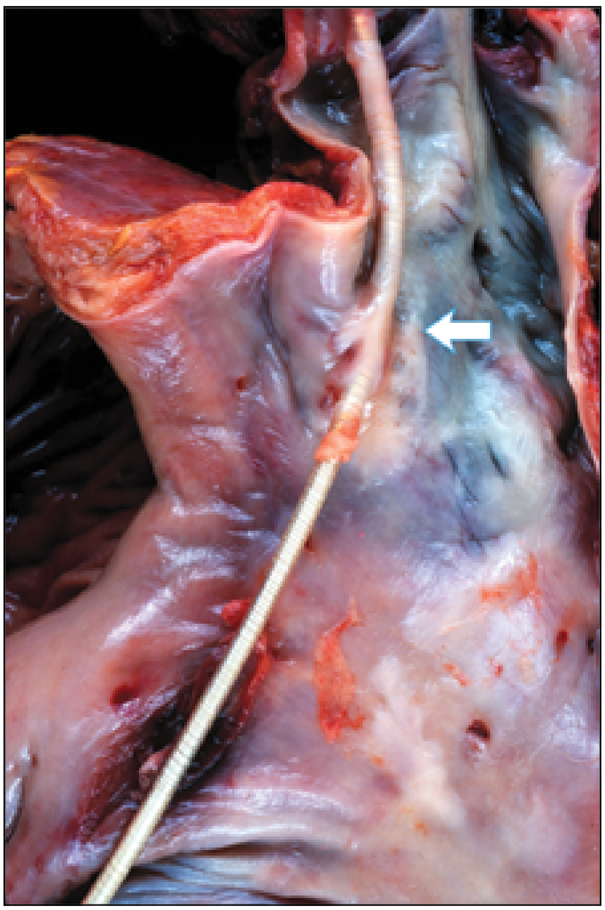

Figure 1.2 Lead adhesions (**arrow**) at the free wall of the SVC. (Anatomic image courtesy of William Edwards, MD.)

It is also worth noting that the amount of microscopic injury to venous structures following extraction may be much higher than clinically apparent. One study has shown 9.3% of extracted leads contained segments of the vein, most of which were transmural (including the adventitial layer), though only 1.1% required surgical intervention.[5] A transmural venous injury detected microscopically will not always correspond to a perforation of the SVC because of the myocardium and adipose tissue support outside the vein proper as the SVC enters the right atrium.[6]

Key Anatomic Points for the Extractionist

Superior Vena Cava

- Perforation above the pericardial reflection is catastrophic mediastinal bleeding but without pericardial effusion.
- Medial adhesions are less common likely because of aortic pulsatility in this region.
- Posterior inferior perforations may lead to fistulae with the right upper pulmonary vein.
- SVC balloons need to be sized appropriately for the larger volume extrapericardial portion.

CALCIFICATION AND LEAD-TO-LEAD INTERACTIONS

The challenges faced during lead extraction are primarily due to fibrosis and calcification, binding the leads to the surrounding tissue. Initially following lead implantation, thrombus development may occur, with subsequent fibrosis and encapsulation of a lead with a fibrin sheath within 5 days postimplantation.[7,8] As the body attempts to isolate the foreign material from the surrounding environment, acute inflammatory cells, followed by a macrophage predominate chronic inflammatory phase, ultimately results in fibroblast recruitment and proliferation, yielding a fibrotic capsule.[9,10] Binding sites have been found to contain high collagen content in addition to ongoing chronic inflammation present in leads with a long dwell time.[11]

Figure 1.3 shows that lead adhesions can also occur to a neighboring lead, resulting in lead-to-lead adherence. These make extraction challenging, especially if the adhesions and fibrosis calcify. Figure 1.3 also shows calcification between both leads. Laser energy does not penetrate calcified adhesions well, whereas mechanical sheaths and

2 Clinical Assessment

Kunal Shah, MD; Ulrika Birgersdotter-Green, MD

INTRODUCTION

Over 1 million new cardiovascular implantable electronic devices (CIEDs) are inserted yearly across the globe.[1–4] Consequently, lead management is becoming an increasingly vital component of patient care.[1] A critical component of lead management is understanding when lead extraction is necessary and indicated. In addition to understanding the guidelines, it is also imperative to incorporate the patient's profile in the overall clinical assessment. This section will address guidelines for lead extraction, clinical assessment, and shared decision making.

INDICATIONS FOR LEAD EXTRACTION

The indications for extraction can be broadly separated into infectious and noninfectious categories.

Infection-Related Indications

Infection remains the most common reason for extraction. Over 60,000 patients with CIEDs develop new infections every year worldwide, and there has been a 320% increase in hospitalizations for CIED infections from 1996 to 2006.[5–9]

The infection-related indications for extraction and subsequent device management are reviewed in the 2010 American Heart Association (AHA) Update to the CIED Infection Scientific Statement.[10] A practical algorithm from this statement is presented in **Figure 2.1**.

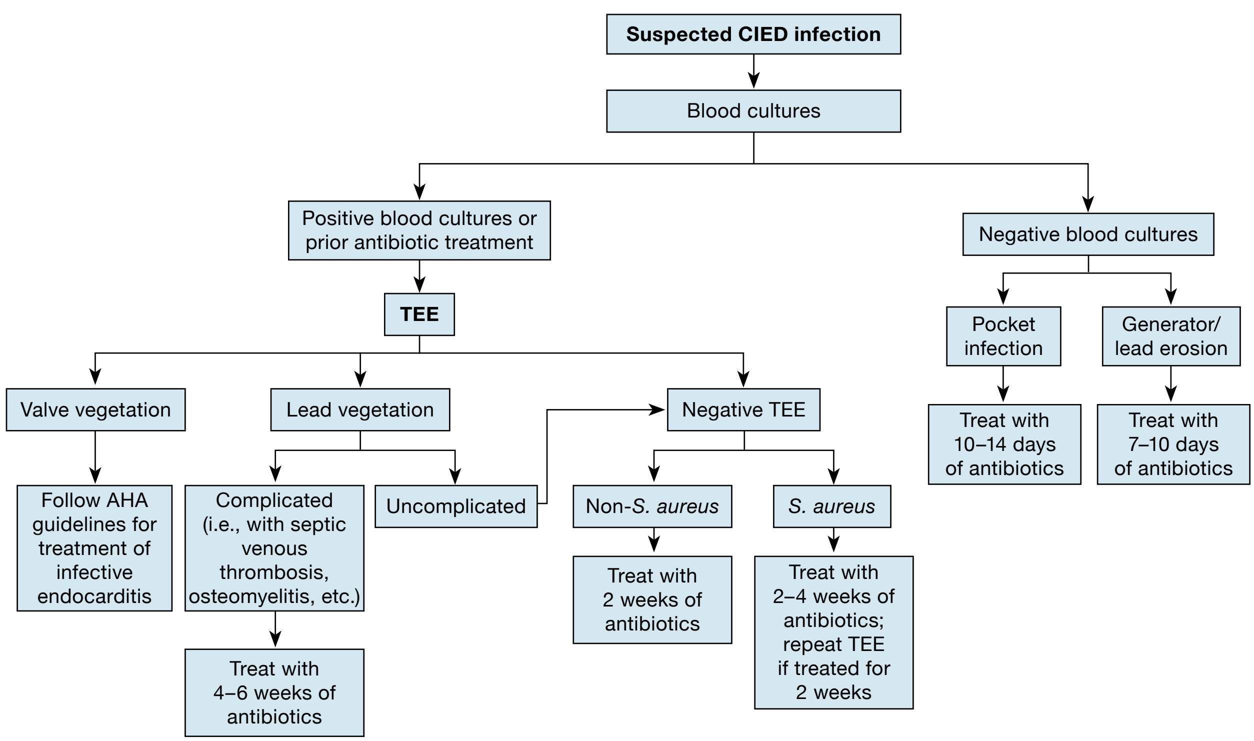

Figure 2.1 Workflow summary of how to manage suspected CIED infection.[10]

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Table 2.1 summarizes the infectious indications for lead extraction based on current Heart Rhythm Society (HRS) guidelines and is further detailed in the subsequent text.[1]

Pocket infections are the most clinically apparent CIED issue during follow-up. They necessitate complete CIED extraction but can have highly variable clinical presentations. Less than half of patients present with classic inflammatory changes such as erythema, swelling, pain, warmth, or drainage.[1,10,11] Device erosion through the skin is less common, and it mandates CIED extraction as any external exposure allows local pathogens to enter the pocket and vasculature.[1,10,11]

Clinicians should also have a high suspicion for CIED infection in any patient who presents with systemic symptoms such as fever, chills, anorexia, or malaise. However, the absence of these symptoms does not exclude CIED infection. When any CIED infection is suspected, it is imperative to obtain two sets of blood cultures, which will help guide extraction decisions, antibiotic choice, and treatment duration.[1,10]

If bacteremia is discovered in any patient with a CIED, clinicians may evaluate if CIED is the source of or involved in the infection. Specifically, if a patient has unexplained or recurrent bacteremia or fungemia, CIED extraction is recommended.[1] Infectious disease consultation ultimately guides the decision-making process of the extraction team. **Figure 2.2** summarizes workflow with various pathogen species potentially found in blood cultures; however, pathogen alone should not dictate CIED extraction decision.[1,10,12]

Another crucial component of a suspected CIED infection is the transesophageal echocardiogram (TEE). The TEE can help visualize vegetations, valvular dysfunction, and perivalvular abscesses with a high specificity.[1,14] CIED extraction is recommended if endocarditis or lead vegetations are present, regardless of pathogen species. If the diagnosis of CIED infection is in doubt, additional imaging modalities such as FDG-PET/CT or tagged white blood cell (WBC) scan may be useful.[1,15]

In summary, CIED extraction is recommended for definite system infection, endocarditis (even without device involvement), and unexplained bacteremia/fungemia[1] (see Table 2.1).

Noninfectious Related Indications

The growing need for CIED extraction in patients without infection (**Table 2.2**) largely stems from patients living longer and increased implantation of defibrillator systems.[1,7,13,16] High-voltage leads tend to fail at higher rates, and cardiac resynchronization therapy (CRT) systems involve an additional left ventricular (LV) lead, which occupies more intravenous space.[1,17]

The reasons for extraction fall into three major categories: vascular issues, intrinsic lead issues, and miscellaneous issues summarized in **Table 2.3** and detailed in the subsequent text.

Vascular Issues

Transvenous leads can cause fibrosis, stenosis, and thrombosis throughout their implanted life span.[1,17,18] Severe fibrosis and stenosis can lead to superior vena cava (SVC) syndrome. This syndrome is characterized by persistent shortness of breath, facial swelling, and migraines. Although this is only seen in approximately 0.1% of patients with CIED, when it does occur, lead extraction is indicated.[1,19,20] SVC syndrome may be amenable to

Table 2.1 Infectious indications for CIED extraction, class of recommendation (COR), and level of evidence (LOE)

Indication	COR	LOE
Infectious		
Definite CIED infection	I	B
Endocarditis (+/– device or lead involvement)	I	B
Unexplained persistent/recurrent bacteremia/fungemia	I	B

8 Surgical Management of Bleeding Complications Associated with Transvenous Lead Extraction

Bradley Genovese, MD; Travis Pollema, DO

INTRODUCTION

Transvenous lead extraction (TLE) has become an increasingly common procedure as part of the treatment algorithm for cardiac implantable electronic devices and lead management. Although it is performed with increasing frequency, it can still portend a significant morbidity or mortality risk for patients who experience vascular or cardiac injuries. The injuries can range from minor bleeding and hematomas to life-threatening, catastrophic tears or perforations of the great vessels or heart leading to tamponade and death. For this reason, it is the recommendation from the 2017 HRS expert consensus on lead management that a cardiothoracic surgeon be immediately available for surgical intervention if the principal operator is not a surgeon.[1] Vascular and cardiac injuries have been previously categorized by their size and also by their hemodynamic presentation.[2] This is clinically important for centrally located injuries, but little has been described about injuries and their management along the course of the entire lead. This chapter will describe potential injuries and their surgical repair during lead extraction cases from the lead post to the lead tip. Anatomic locations include the subclavian vein, innominate vein, superior vena cava (SVC), right atrium, tricuspid valve, right ventricle, and the coronary sinus.

POCKET/SUBCLAVIAN VEIN

Vascular injuries during the creation or exploration of the deltopectoral pocket are infrequent. They may arise from the lead tract's aggressive dissection under the clavicle or removal of a suture sleeve placed near the subclavian vein. The most common and unavoidable vascular injury at the pocket or subclavian vein level is the entrance site for the extraction tool. Both laser and mechanical tools create a venotomy of 12 Fr to 16 Fr. This tract can be easily controlled with a vicryl purse-string that can be gently tied down following the completion of the lead removal or reimplantation (**Figure 8.1**).

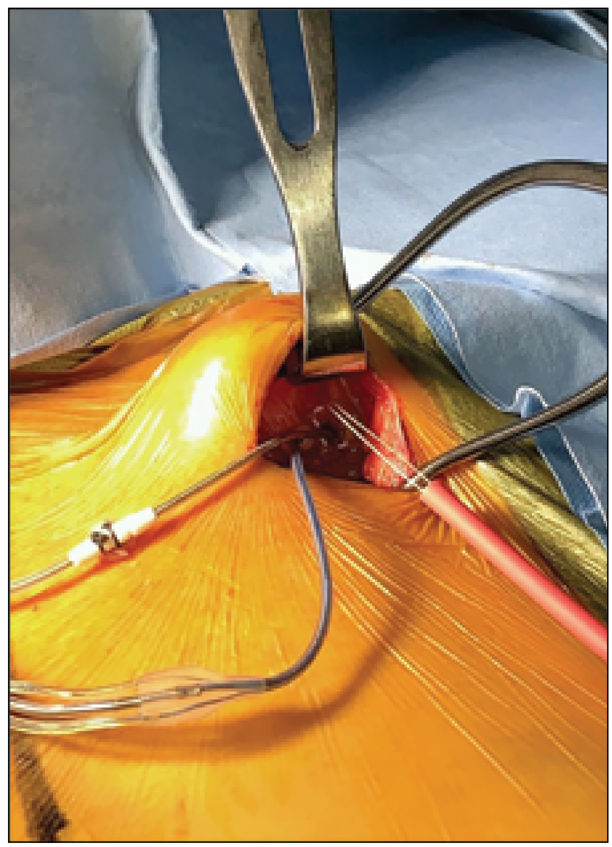

Figure 8.1 Vicryl purse-string suture around the lead track and entry site for a powered sheath.

If the subclavian vein has been inadvertently exposed, mobilization and primary repair of the anterior vessel wall may need to be performed.

This can usually be accomplished with 5-0 or 6-0 prolene sutures in a running two-layered fashion. If the injury defect is large (> 50% of vessel circumference) and primary repair is likely to cause stenosis, a patch repair can be performed with bovine pericardium or an extracellular matrix. An injury to the subclavian vein's posterior wall is uncommon but can occur during the use of a laser-powered or mechanical sheath. The patient may develop sudden hypovolemia and hypotension with new left pleural effusion on echocardiogram or fluoroscopy. Distal subclavian vein injuries are best approached through supraclavicular or infraclavicular exposure, while more proximal subclavian vein injuries can be approached via median sternotomy. Isolated injury to the subclavian artery or arteriovenous fistula is rare but has been reported and been managed with an endovascular approach.[3]

INNOMINATE VEIN

In many patients presenting for TLE, the innominate vein is found to have significant stenosis or even complete occlusion due to multiple indwelling leads or previous catheter/device interventions. These situations usually require larger caliber tools for successful extraction. Injuries to the innominate vein are likely more common than one would expect but probably under-recognized due to lack of clinical or hemodynamic significance. For nearly all of its course, the innominate vein is surrounded by soft tissue left from thymic involution. This remnant tissue acts as a defense to minimize the extent of bleeding or hematoma formation. Hemodynamic changes are also minimal with isolated innominate vein injuries since it is located outside the pericardium, and compression of surrounding structures is unlikely. Incidental innominate vein injuries are often identified during a left-arm venogram if performed following TLE. Contrast extravasation is usually present but contained. In more extensive injuries, it is not uncommon to see contrast extravasation tracked along the course of the vein toward the SVC and terminate outside the pericardium (**Figure 8.2**).

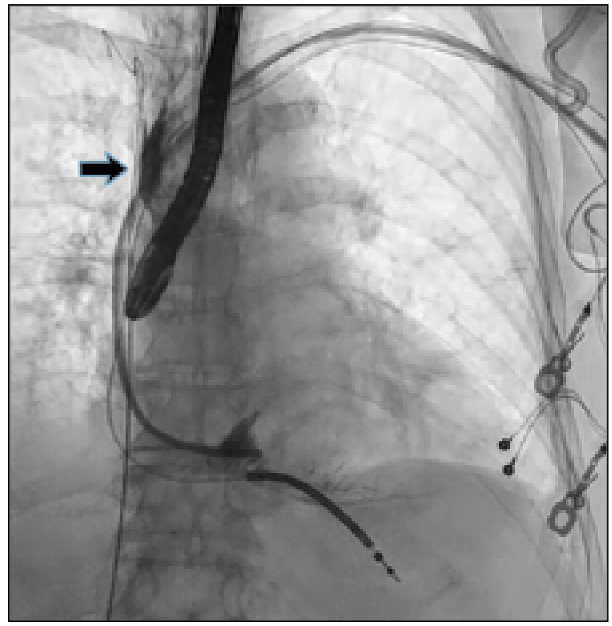

Figure 8.2 Contrast extravasation (**black arrow**) tracking along innominate vein from injury and stopped by pericardial reflection.

Isolated innominate vein injuries can be managed conservatively and are not likely to cause harm to the patient. In patients with prior stenosis or occlusion, a network of venous collaterals is expected to be present, which will minimize left arm swelling complications.

Should the patient have a concomitant venous or cardiac injury during the same TLE procedure requiring emergent sternotomy, or if an innominate vein injury is unknown or not expected, it is important to avoid opening the superior extent of the thymic remnant. Aggressive dissection in the mediastinum's superior portion can expose a self-contained hematoma that will now bleed freely. During a sternotomy for cardiac tamponade, opening the pericardium just enough to have a possible cannulation site for cardiopulmonary bypass (CPB) will avoid unwanted innominate vein bleeding. If an injury is exposed, the type of repair depends on the amount of vessel wall involved or complete disruption. Smaller partial wall injuries can be repaired by primary repair with prolene sutures in two layers. Larger partial

1 | Device Extraction from Superior Venous Access

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CLINICAL VIGNETTE

A 75-year-old male patient presented with copious orange-colored discharge from the pacemaker site. He underwent dual-chamber pacemaker implantation for sinus node dysfunction in 2008. Subsequently, he underwent a generator change after his device reached the elective replacement indicator. Five weeks after the generator change, he noticed that the pacemaker pocket's lateral edge did not heal well, and he started noticing swelling of the pocket site with discharge (**Figure 1.1**).

Figure 1.1 Redness around the incision site, swelling, orange color discharge from the pocket is noted three weeks after device surgery. Please note the scaly lateral part of the incision, which the patient subjectively felt, did not heal well.

He denied fevers, chills, and rigors. His pertinent past medical history included obesity, hypothyroidism, permanent atrial fibrillation, thyroid cancer status post-thyroidectomy, bipolar disorder, and prostate enlargement. He had a history of symptomatic left subclavian vein thrombosis after his initial pacemaker implantation procedure and was on anticoagulation for six months. The most recent device details are as follows:

Device Details

Device Component	Manufacturer/ Model	Date of Implant
Pulse generator	St. Jude Medical Assurity	04/2017
Right atrial lead	St. Jude Medical 1646 T	01/2008
Left ventricular lead	St. Jude Medical 1646 T	01/2008

The patient was in atrial fibrillation and was pacing about 71% from the right ventricle. Laboratory workup was unremarkable, and his echocardiogram revealed a structurally normal heart with an ejection fraction of 55%. There were no valvular or pacemaker lead vegetations noted on the transesophageal echocardiogram (TEE). Blood cultures remained persistently negative.

PREPROCEDURAL PLANNING

The patient was evaluated by cardiac surgery and electrophysiology teams before the procedure. Anticoagulation with rivaroxaban was stopped 2 days before the procedure. A preprocedural CT scan was also performed to understand venous anatomy for the procedure. The device was programmed to VVI at a lower rate of 50 bpm, and the pacemaker paced less than 1% of the time 48 hours before the extraction procedure.

PROCEDURAL DETAILS

A preprocedural huddle was performed with all teams in attendance. The patient was taken to the hybrid operating room and was prepped from the neck to the groin in a sterile manner. General anesthesia was administered, and a TEE probe was placed for monitoring during the procedure. Four units of blood cross-matched, packed red cells were available in the room for the procedure. Venous and arterial accesses were obtained using ultrasound guidance and modified Seldinger's technique. Dedicated arterial and venous sheaths were placed in the left femoral venous site for rapid initiation of peripheral cardiopulmonary bypass in the event of a complication. Multiple sheaths were also placed in the right common femoral vein. A 9-Fr sheath was placed in the right common femoral vein for high-volume crystalloid or blood product infusion. An 8-Fr SRO sheath (Fast Cath, Abbott) was placed in the right femoral vein over a wire with the sheath's tip in the right atrium (RA). A 12-Fr sheath was also placed in the left common femoral vein to place a stiff 0.035-inch wire. A Bridge Occlusion Balloon (Philips Medical) was placed over the stiff wire. An appropriate position was confirmed after contrast injection. A marker was placed on the shaft of the catheter. The balloon was deflated, and the catheter was pulled down to the inferior vena cava (IVC). A 7-Fr sheath was also placed in the right internal jugular vein for CVP measurement. The pocket was opened, and the leads were freed till the suture sleeves. A lot of pus and active inflammation was noted in the pocket. The sutures were cut, and the sleeves were pulled back. The leads were prepared using locking stylets (Lead Locking Device, size 1, Philips Medical). The locking stylet could not be advanced to the tip of the atrial lead (**Video 1.1**). An 11-Fr mechanical extraction sheath (TightRail, Philips Medical) was placed on the ventricular lead. It was advanced using the traction-countertraction technique, and the ventricular lead was eventually taken out of the vasculature.

The mechanical extraction sheath was also advanced on the atrial lead to the mid subclavian vein. Separation of the ring and tip electrodes was noted with traction on the pacemaker lead (**Video 1.2**). An endoscopy biopsy forceps (Radial Jaw 4 Biopsy forceps, Boston Scientific) was placed through the SR0 sheath to grab the lead proximal to the ring electrode and to apply downward traction (**Video 1.3**). The biopsy forceps prevented transmission of the force beyond the ring electrode, thereby preventing the lead's transection. The snare provided a way to apply downward traction on the lead and serve as a rail to advance sheaths from a superior access site. The mechanical extraction sheath was advanced to the biopsy forceps. As the sheath could not be advanced further, a 12-Fr laser extraction sheath (GlideLight, Philips Medical) was used. However, the tip could not be freed, and an acute angulation is seen between the long axis of the extraction sheath and the tip electrode's axis (**Video 1.4**).

As there were concerns about leaving the tip electrode in the body, we proceeded to the femoral route of extraction, which provides a favorable angle of approach to the tip electrode. The lead was cut at the pocket, and the lead was internalized in the vasculature using the biopsy forceps (**Video 1.5**). The femoral venous access site was upgraded to a 16-Fr long introducer sheath (Cook Medical) over a guidewire. A 15-mm Goose Neck snare (GN 1500, Medtronic) was used to go over the tip of the lead and engage the body of the lead at the level of the ring electrode (**Video 1.6**). The lead's proximal cut end is grabbed with the biopsy forceps placed inside the 16-Fr femoral sheath. The stretched-out conductor cable between the ring and tip electrodes can be appreciated on 3D echocardiography (**Video 1.7**). The femoral sheath was slowly advanced with traction on the lead applied through the biopsy forceps and the

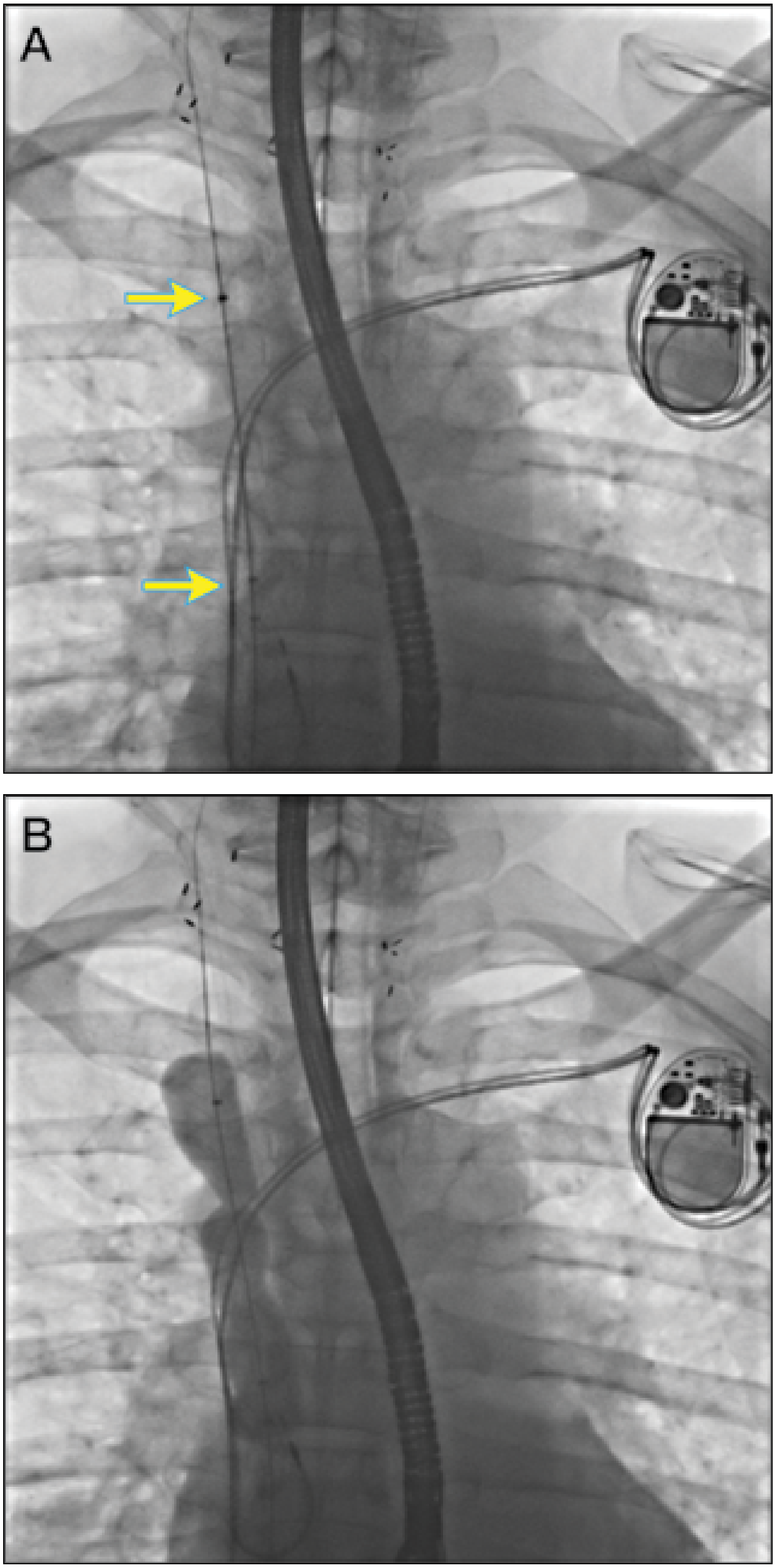

Figure 1.2 A Bridge Occlusion Balloon (Philips Medical) was placed over a stiff guidewire to cover the potential area of SVC lateral wall injury (**Panel A**). Diluted contrast is injected into the balloon to confirm adequate placement (**Panel B**). A marker (sticker) is then placed over the shaft of the catheter when the balloon is in an optimal position. The balloon is then deflated and is pulled down to the level of the IVC. The wire is left in place and serves as a rail to push the balloon up to the marker in an emergency.

snare (**Video 1.8**). Once tissue contact is made with the femoral sheath, the Goose Neck snare is released and is pulled back on to the shaft of the femoral sheath. Traction with the biopsy forceps and countertraction with the femoral sheath is applied with careful monitoring on echocardiography. A pseudopericardial effusion can be appreciated as the RA wall is pulled away from the pericardial cavity (**Video 1.9**). The lead tip was eventually freed and was taken out of the body.

All sheaths were eventually removed, and hemostasis was achieved by manual compression. TEE showed trivial pericardial effusion. As he required minimal pacing before the extraction procedure decision was made not to reimplant a pacemaker. The pocket was debrided, and a vacuum-assisted suction device was applied to the incision site.

POSTPROCEDURAL COURSE

The patient was extubated in the operating room and was transferred to the floor service. The vacuum suction device was removed on day 3, and the pocket was closed with non-absorbable sutures. As he was in permanent atrial fibrillation with controlled ventricular rates, the team opted not to reimplant the device. Pocket cultures grew mixed gram-positive organisms, and he received IV vancomycin for 2 weeks through a peripherally inserted central catheter line. Anticoagulation therapy was started with rivaroxaban after pocket closure. He was discharged from the hospital on day 5 after the extraction procedure and remained well during follow-up.

SUMMARY POINTS

- Understand the nuances of lead design and their relevance to the extraction procedure. Certain leads tend to separate between the ring and tip electrode.
- Appreciate the relationship between the lead axis and the long axis of the extraction sheath. Acute angulations can lead to unfavorable force transmission leading to increased risk of complications or lead transection.
- Familiarity with the femoral tools (snares, biopsy forceps, and deflectable catheters) is needed to seamlessly convert a superior route to femoral route of extraction.
- Pseudopericardial effusion is due to invagination of the atrial wall and creation of a false space in the pericardium. Prompt recognition prevents unnecessary interventions and also helps the operation reduce the traction on the lead.
- Device reimplantation decisions about should take into consideration of the continuing need for device therapy especially after device infection.

VIDEO LEGENDS

Video 1.1 A locking stylet was placed in the atrial lead. However, the tip of the stylet (yellow arrow) could not be passed to the lead's tip. [00:01]

Video 1.2 Separation of the ring (yellow arrow) and tip electrode (green arrow) can be appreciated when traction was applied on the lead. A conductor cable still connected the 2 electrodes. [00:01]

Video 1.3 An endoscopy biopsy forceps (Radial Jaw 4 Biopsy forceps, Boston Scientific) was used to grab the lead proximal to the ring electrode to prevent transection of the lead tip. [00:01]

Video 1.4 A 12-Fr laser sheath was advanced over the lead, and good separation between the ring electrode (yellow arrow) and the tip electrode (green arrow). Note the acute angulation between the long axis of the extraction sheath and the tip electrode's long axis. [00:02]

Video 1.5 The lead was cut in the pocket area. The body of the lead was grabbed using the biopsy forceps (pink arrow), and the proximal end (lead cut in the pocket) was internalized and was pulled down to the level of IVC. Notice the significant separation between the ring (yellow arrow) on the tip electrode (green arrow) connected by the conductor cable. [00:02]

Video 1.6 A Goose Neck snare was placed on the lead's body and was advanced to the ring electrode (yellow arrow). The cut end of the lead was grabbed by the biopsy forceps placed inside a 16-Fr sheath. The green arrow indicates the tip of the femoral sheath. The ring and the tip electrode are still connected by a conductor cable (blue arrows). [00:02]

Video 1.7 3D TEE delineates the conductor cable between the ring and tip electrode. Notice that the tip electrode was attached right below the superior vena cava (SVC)–RA junction. [00:01]

Video 1.8 The femoral sheath (yellow arrow) was slowly advanced until the tip electrode (green arrow). Notice that the angle between the femoral sheath's long axis and the pacemaker lead is favorable for preventing tip transection. The Goose Neck snare (pink arrow) is advanced as distally as possible to apply traction near the tip electrode. [00:01]

Video 1.9 As traction was applied on the lead using the biopsy forceps and countertraction was applied using the tip of the femoral sheath, an echo-free space (yellow arrow) can be appreciated on echocardiography. This echo-free space mimics the presence of a pericardial effusion (pseudopericardial effusion) and is caused by inversion of the atrial wall. An oval-shaped Goose Neck catheter (green arrow) pulled back on to the shaft of the femoral sheath can be appreciated in the video. [00:02]

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