

# Extraction of Transvenous Cardiac Implantable Electronic Devices in 2026

Transvenous lead extraction has become an essential component in the management of cardiac implantable electronic devices, particularly in the setting of device-related complications. Since the introduction of lead extraction techniques, the technology and procedural approaches have evolved considerably. Today, the majority of leads can be removed via the transvenous route with high success and safety rates. In this review, we summarize the current standards and contemporary practices in transvenous lead extraction.

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## ABSTRACT

Transvenous cardiac implantable electronic devices (CIEDs) are essential in the treatment of various cardiac arrhythmias but remain susceptible to mechanical failure and infection over time. Consequently, transvenous lead extraction has become a cornerstone in the management of device-related complications. Whereas lead removal was initially performed surgically, modern transvenous extraction techniques using mechanical rotational or laser sheaths are now well-established methods for removing leads with prolonged dwell times. In addition, femoral approaches provide an alternative route to access leads and may facilitate successful extraction in more complex cases.

### Introduction

Cardiac implantable electronic devices (CIEDs) play a crucial role in the treatment of cardiac arrhythmias, including both bradycardias and ventricular tachycardias. Over time, the management of patients with CIEDs can require the removal of previously implanted leads or generators because of infection, upgrades, or malfunction, making transvenous lead extraction (TLE) an essential and frequently performed procedure today (1). Since its introduction, TLE techniques have evolved substantially, from simple traction (“pulling” on the lead) through open surgical procedures to today’s transvenous interventions (2,3). Current practice generally follows a step-by-step procedure progressing from simple approaches to the use of specialized, advanced tools such as powered extraction sheaths and snares (*Figure 1*). This review outlines the indications, procedural fundamental principles, and clinical outcomes of TLE, including complications.

### Indications for Transvenous Lead Extraction Cardiac Implantable Electronic Device Infection (*Figure 2*)

Infections remain the most consistent and widely accepted reason for lead extraction (4,5). Microorganisms readily colonize the surfaces of implanted, non-biological materials, making the complete eradication of infections extremely difficult once contamination has occurred (6). Consequently, complete removal of all device components is generally required to successfully treat infections related to CIEDs (4,5). Failure to remove infected hardware is associated with poor clinical outcomes. In a retrospective analysis involving 416 patients with CIED-related infections, individuals treated solely with antibiotic therapy had a sevenfold increase in 30-day mortality compared to those undergoing device removal (7). Furthermore, infections have been linked to an increased risk of mortality at one year, even among patients who subsequently undergo TLE (8). In light of these findings, current clinical guidelines recommend complete system removal whenever a device-related infection is identified, regardless of whether the infection is localized or systemic.

### Venous Stenosis

Venous obstruction is another recognized consequence of transvenous leads. Reported prevalence rates range from approximately 2 to 22% (9,10). Although most patients remain asymptomatic, a subset can develop significant symptoms that necessitate intervention including lead extraction to restore venous patency (11). Venous stenosis can also complicate upgrade procedures in patients with previously implanted CIEDs. In such cases, sacrificing an existing lead during extraction may be necessary to restore venous access when obstruction is present (12).

### TLE for Nonfunctional Leads Versus Lead Abandonment

The decision to perform TLE for malfunctioning or redundant leads requires careful clinical judgment, as extraction is not always obligatory, and lead abandonment could be considered an alternative strategy (4,5). Current recommendations emphasize an individualized risk-benefit assessment when choosing between different approaches, particularly because randomized trials addressing this situation are missing. Contemporary studies suggest that the mortality risk

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associated with TLE is lower than previously reported, with rates estimated at approximately 1% (13–15). In contrast, the long-term risks associated with abandoned leads remain difficult to quantify because potential complications may arise many years after the implantation. These risks include infection, thrombosis, and the possibility of increased procedural complexity due to progression of fibrotic adhesions over time should an extraction become necessary. To date, no large randomized trials have directly compared lead abandonment with extraction; however, evidence from observational studies suggests potential disadvantages of leaving leads in situ. A registry analysis involving 6,859 patients reported that lead abandonment was associated with a higher incidence of infections compared to immediate extraction, often requiring a removal at a later stage (16). Similarly, a study of 1,386 patients undergoing TLE because of infections demonstrated that procedures were more prolonged and technically demanding in individuals with previously abandoned leads (17). However, this potential long-term benefit must be balanced against the procedural risks associated with TLE, particularly in higher-risk cases involving prolonged lead dwell time, multiple leads, or more complex lead systems (e.g., implantable cardioverter-defibrillator compared to pacemaker leads). With technological advancements of TLE tools and growing experience of operators, this indication has been increasing over time (18).

## Methods of Transvenous Lead Extraction

### General Principle of TLE

The fundamental principle of TLE is the balance between traction and countertraction to dissect adhesive tissue from the implanted lead while advancing the sheath over the lead (19) (Figures 3 and 4). Excessive traction may result in tissue avulsion, whereas advancing the sheath with inappropriate force can lead to uncontrolled or misguided vascular dissection. Optimal balance of force enables a controlled advancement of the dissecting sheath towards the lead tip,

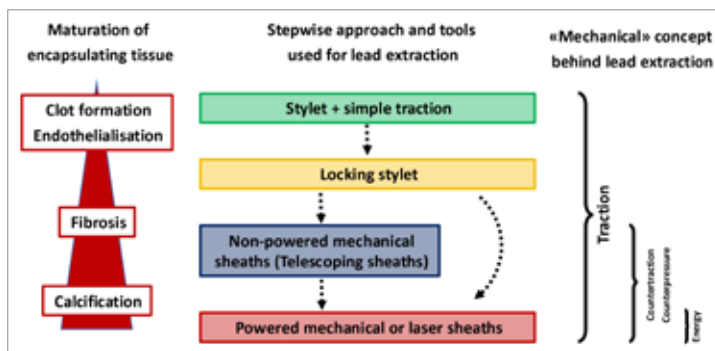


Figure 1. Stepwise approach in transvenous lead extraction from simple to more advanced techniques.

gradually freeing the lead from the encapsulating fibrotic tissue while minimizing the risk of vascular and myocardial injury.

Over time, extraction strategies have evolved from traction-only techniques to approaches combining traction with countertraction delivered through dissecting sheaths or more advanced powered tools (Figure 1). During extraction procedures, the lead functions as a guide or rail along which a dissecting sheath can be advanced. Countertraction is generated as the sheath progresses over this rail, allowing fibrotic adhesions surrounding the lead to be dissected (Figure 5). Although all types of extraction tools are usually available during the TLE procedure, not all of them are required in every case. Nowadays, a step-by-step approach is recommended, starting with simple traction techniques, gradually progressing to the use of locking stylets to enhance traction and lead stability, as well as powered extraction tools if necessary.

### Traction

The first technique used for lead extraction involves the application of direct traction to the implanted lead, which is

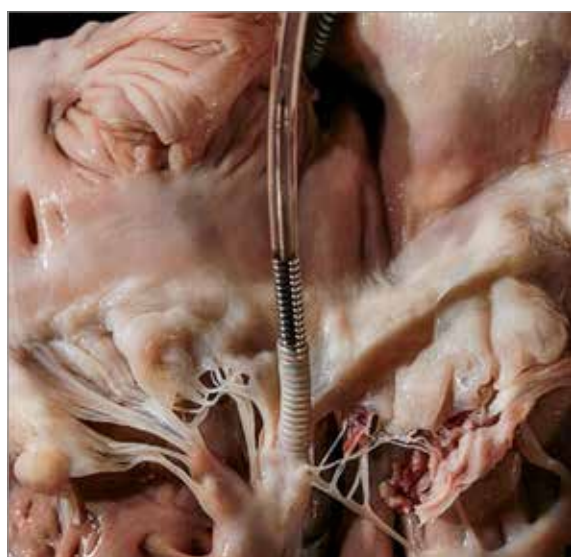


Figure 2. Adhesive tissue (arrow) surround the lead before (left) and after (right) transvenous lead extraction.



Figure 3. Various presentation of device-associated infections ranging from a device perforated through the skin (A) to severe pocket (B) and systemic (C) infections (vegetations attached to the lead, arrow).

often successful in leads with a short dwell time (less than two years). In the PROMET (Patient-related Outcomes of Mechanical Lead Extraction Techniques) study, approximately 17.8% of leads were successfully removed using traction-based methods alone (14).

#### Locking Stylets

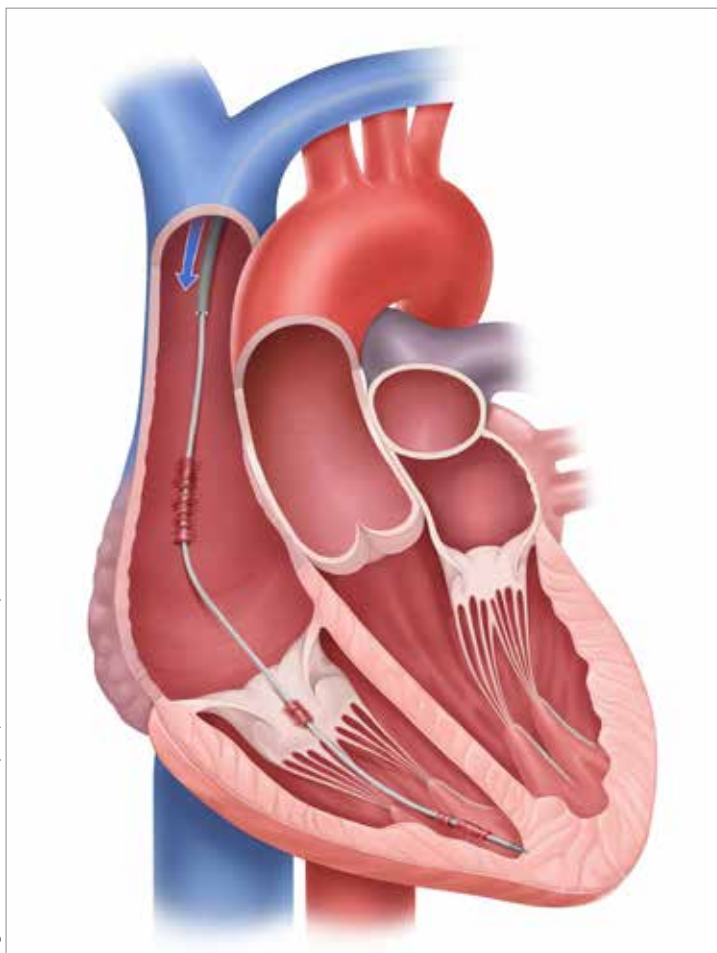
Locking stylets are specialized stylets used during TLE to improve traction and control of the lead. Inserted into the inner lumen of the pacing or defibrillator lead, the stylet is advanced to the distal end and then locked in place, creating a firm internal support along the length of the lead. This stabilization allows traction forces to be transmitted more effectively to the lead tip while reducing the risk of lead stretching or fragmentation (20). By enhancing traction, locking stylets facilitate a safer and more efficient extraction and are commonly used during an early step in the step-by-step approach to TLE procedures.

#### Dissecting Sheaths Used for Countertraction

Early dissecting sheaths were manufactured from materials such as polypropylene, polytetrafluoroethylene (Teflon™), or stainless steel, each offering distinct mechanical properties (19). These sheaths were advanced over the lead, which served as a rail. Simultaneous advancement of the sheath and application of traction on the lead created countertraction facilitating the dissection of the lead from surrounding fibrotic tissue.

#### Powered Sheaths for TLE

Rotational mechanical sheaths represent a category of powered extraction tools currently used in clinical practice (Figure 5) (14,21). These devices incorporate a stainless steel cutting tip that rotates when activated by a hand-triggered mechanism. The rotational system advances along the lead while controlled traction and countertraction are applied. The PROMET study remains the largest evaluation of rotational extraction tools, involving 2,205 patients and 3,849 targeted leads (14). The study reported a complete procedural success rate of 96.5% and a clinical success of 97%. Major complications occurred in approximately 1% of cases, with a procedural mortality of 0.4%. Notably no injuries to the superior vena cava were reported. An important observation from the PROMET study was the effectiveness



(Figure: A. Breitenstein, University Hospital Zurich, University Heart Center)

Figure 4. Illustration of a transvenous lead extraction using a powered, mechanical rotational extraction tool advancing over the lead.

of rotational tools in leads with long dwell times, with a median implantation duration exceeding eight years. These findings highlighted the ability of rotational sheaths to disrupt dense and calcified fibrotic adhesions that often develop around leads implanted long-term.

The findings from the PROMET study were subsequently supported by the RELEASE study, a prospective multicenter trial that included independent adjudication of complications (22). In this cohort of 230 patients and 460 leads, clinical success was achieved in 98.7% of cases, with a complete lead extraction success rate of 96.3%. Major complications occurred in 5.3% of procedures, and no procedural deaths were reported.

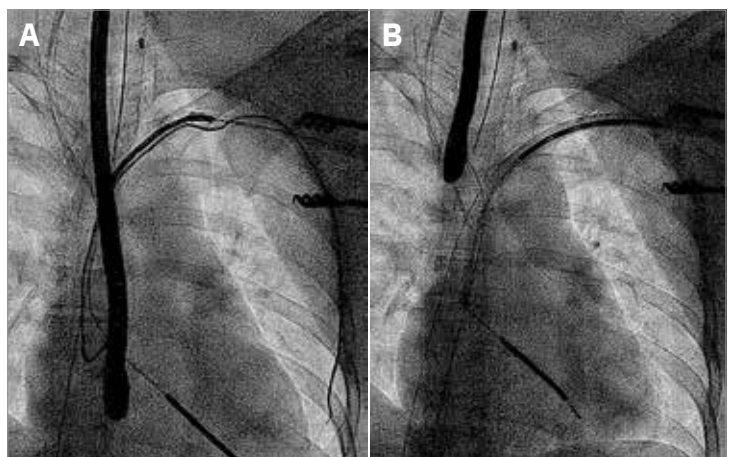
In addition to powered mechanical sheaths, energy-based technologies using laser energy can be used to dissect fibrotic adhesions surrounding implanted leads (23–25). Laser-powered extraction systems were introduced in the mid-1990s, adapting principles originally developed for percutaneous coronary interventions. The laser energy vaporizes fibrotic tissue surrounding the lead. At the cellular level, laser energy is absorbed by proteins and lipids, disrupting molecular bonds and causing tissue disintegration (26). Early clinical data suggests that laser extraction improved procedural outcomes compared to traditional mechanical approaches. The LExiCon (Lead Extraction in the Contemporary Setting) study provided insight into laser-assisted extraction in a large observational cohort of 1,449 patients and 2,405 leads (24). The analysis reported a complete extraction success rate of 96.5%, with a major complication rate of 1.4% and a procedural mortality of 1.86%.

#### **Femoral Snare Approach**

In a minority of cases, lead extraction cannot be completed using the conventional superior (subclavian) approach described above, with studies suggesting that this occurs in less than 5% of procedures (27,28). In these situations, alternative vascular access routes become necessary. In such cases, the femoral approach represents an important option, even though it has traditionally only been used as a bailout strategy when the superior approach fails. However, the femoral approach may also serve as a primary access route or can be combined with the superior approach as part of a dual-access technique, the Tandem approach (Figure 6) (29).

The femoral vein provides a large and relatively straight pathway to the heart via the inferior vena cava, which can help overcome the challenging vascular angulations sometimes encountered when extracting leads through the superior subclavian route. Its large diameter also permits the safe use of sizeable snare systems (30).

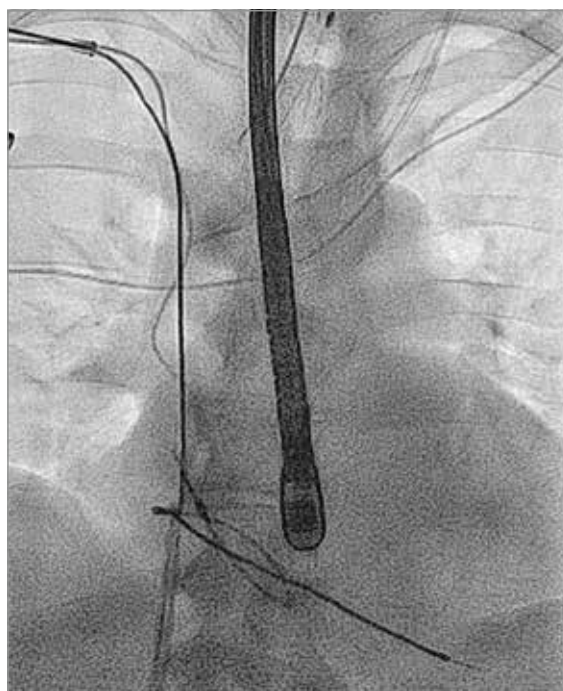
In contrast to the superior approach, procedures performed via femoral access do not have access to the proximal lead end for traction, preventing the use of locking stylets and countertraction tools. Therefore, the lead must be engaged using dedicated snaring devices. If the distal lead tip remains attached to the myocardium, usually, a so-called Needle's Eye Snare® (Cook® Medical) is required (30,31). In



*Figure 5.A and 5.B. Illustration of a transvenous lead extraction using a powered, mechanical rotational extraction tool advancing over the lead.*

contrast, when the lead tip is free-floating within the vasculature, it can usually be captured using single-loop or triple-loop snare systems.

Observational studies have demonstrated that femoral snare extraction can improve procedural success significantly when used after failure of the superior approach. In one study, the addition of femoral snare techniques increased overall procedural success rates, particularly in cases involving inaccessible intravascular leads or leads with long dwell times (32). The importance of the femoral approach



*Figure 6. Illustration of a transvenous lead extraction using a powered, mechanical rotational extraction tool advancing over the lead as well as the Tandem technique with snaring the lead at the same time from the femoral (arrow).*

as a bailout strategy has also been confirmed in larger cohorts. El-Chami and colleagues reported that in a review including 1,080 patients, femoral extraction was required in a small but significant proportion of challenging cases (27). Despite the complexity of these procedures, the technique proved both safe and effective when performed by experienced operators. If used as a primary extraction strategy, the femoral approach has demonstrated similar efficacy as the superior approach. In a series of 229 procedures, clinical success was achieved in 98.2% of cases, with major complications occurring in only 0.7% and no procedural mortality (31). The relatively linear pathway from the inferior vena cava to the right atrium reduces the risk of vascular injury and provides favorable geometry for extracting atrial and coronary sinus leads; however, removal of right ventricular leads can be more challenging because the extraction sheath must adopt a sharp angulation upon entering the ventricle.

#### **Tandem Technique**

Effective control of traction forces is critical for safe lead extraction regardless of the chosen access route. The Tandem technique utilizes simultaneous superior and inferior approaches to balance extraction forces (*Figure 6*) (29,33). With this method, the targeted lead is secured within the right atrium using a femoral snare, providing countertraction to the superior traction applied from the implantation site. By stabilizing the lead from both directions, the Tandem technique creates a more rigid rail for the advancement of dissecting sheaths and improves the ability to navigate the extraction tool through vascular angulations, particularly near the brachiocephalic vein-superior vena cava junction. The snare also transfers traction forces away from the myocardium, reducing the risk of myocardial invagination as the sheath advances.

Clinical studies have demonstrated high procedural success using this technique. In a retrospective series of 131 patients, complete extraction success was achieved in 96.2% of cases with no procedural mortality (34). This method is particularly beneficial in leads with long dwell times, where dense fibrotic encapsulation can complicate extraction.

However, once the sheath reaches the right atrium, the lead must be released from the snare to allow advancement toward the distal tip, introducing potential risk of injury to the tricuspid valve and right ventricle.

#### **Success and Complications of Transvenous Lead Extraction**

Despite the technical challenges associated with TLE, large observational series have reported relatively low complication rates and successful complete extraction rates of usually more than 95% (4,5,13,14,24,25,35). Major complications occur in approximately 1 to 1.7% of procedures, while procedural mortality ranges between 0.18 and 0.5%. These outcomes are comparable to those observed in other interventional cardiology procedures, including percutaneous

coronary intervention. Complication rates may be substantially higher in real-life circumstances due to definitions, heterogeneous patient profiles, and center experience. For example, we observed a procedure-related major complication rate of 3.7% during 350 TLEs in our own experience, while procedure-related mortality remained low at 1% (15).

Among the most serious complications of TLE is the injury of the superior vena cava. This complication can rapidly become fatal if prompt surgical repair is not performed. Even with immediate intervention, mortality rates approach 50% (36,37). Injuries of the superior vena cava most frequently occur in the central segment of the vessel, the region encountered by the dissecting sheath as it advances from the brachiocephalic vein into the superior vena cava. Because this portion of the vessel is typically located outside the pericardial sac, a rupture commonly results in a massive bleeding into the right hemithorax, leading to rapid exsanguination at rates approaching 500 ml per minute (38). Recognition of this injury may be delayed until the hemodynamic collapse occurs. In contrast, myocardial perforation occurs within the pericardial space and usually leads to a cardiac tamponade. In these cases, the hemodynamic deterioration occurs rapidly, enabling an earlier detection of the complication (37).

Another complication that may be underrecognized is the damage to the tricuspid valve (13). The risk of a tricuspid valve injury arises at the time of right ventricular lead implantation (39). Potential mechanisms include leaflet perforation, mechanical interference with valve motion, laceration, entanglement within the valve apparatus, or damage to the chordae tendineae. Over time, fibrotic adhesions may cause the lead to become tethered to the valve apparatus, further increasing the risk of a valve injury during extraction. Data regarding the incidence of tricuspid valve injury following TLE remain limited, likely reflecting the relatively recent recognition of this complication (39). In a large observational cohort of 2,631 patients, investigators assessed the effect of TLE on the severity of tricuspid regurgitation (40). They reported a worsening of tricuspid regurgitation in approximately 9.7% of patients, although only 2.5% developed a severe regurgitation. In the majority of cases (approximately 90%), no deterioration in valve function was observed.

#### **Acute Management of Complications**

When a major cardiovascular injury occurs during TLE, rapid stabilization of the patient is essential to allow time for a definitive surgical repair. Two principal strategies can be employed to achieve temporary hemodynamic control.

One initial approach involves the deployment of an endovascular occlusion balloon within the superior vena cava (37). Inflation of the balloon temporarily blocks the venous blood flow, thereby limiting hemorrhage and providing a critical window for surgical teams to identify and repair the injury. The effectiveness of this technique was evaluated in an observational study of 116 patients who sustained injuries of the superior vena cava during TLE (36). Survival rates were significantly higher among patients in whom an occlusion

balloon was used appropriately. In this group, 88.2% of patients survived compared to 56.9% of those managed without balloon deployment.

An alternative strategy for managing catastrophic vascular injuries during TLE is the initiation of percutaneous cardiopulmonary bypass (CPB) (41). A femoral-to-femoral bypass circuit can be established rapidly provided that a femoral vascular access has already been obtained. In contemporary TLE procedures, femoral access is commonly established at the beginning as part of a multi-access strategy (1). The use of CPB offers several advantages. In addition to hemorrhage control, the system can maintain systemic perfusion and organ oxygenation, thereby reducing the risk of ischemic injury to vital organs such as the brain and kidneys. Establishing CPB before surgical intervention may also facilitate a more controlled operative repair, as emergency off-pump procedures are rarely feasible.

Percutaneous CPB is particularly valuable in patients with previous sternotomy, where surgical reentry may be technically challenging due to adhesions. In many cases, injuries of the superior vena cava can be repaired through a right anterior thoracotomy performed at the second intercostal space, especially when a right-sided hemothorax is present (42).

## Conclusion

Transvenous lead extraction in 2026 is a highly effective intervention with high procedural success rates and low complication rates when performed in experienced centers. A variety of extraction tools and procedural approaches are now available, facilitating the management of both routine and complex cases. □

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