ILLUSTRATIVE APPROACH

Transvenous Lead Extraction: A Step-by-Step Approach

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Introduction

The increasing number of implanted transvenous pacemakers, implantable cardiac defibrillators (ICDs), and cardiac resynchronization therapy (CRT) over the last two decades has led to the rising need for lead extractions. Over time, these leads have to be removed due to structural defects, infections, or the need to upgrade a pre-existing system. Chronic leads may develop a dense fibrotic and sometimes calcific process within the thin-walled venous structures or the endocardial surface of the heart or tricuspid valve, which can make them difficult to extract. Given the technical complexity and risk of life-threatening complications that can arise from lead extractions, a systematic approach needs to be taken prior to performing the procedure by a multidisciplinary team.

Preprocedural set-up

In order to be successful, extractions should only be performed at hospitals that are dedicated to maintaining a sufficient procedural volume to ensure maintenance of skills for the physician and extraction team. In addition to the number of cases performed, it is essential that there be a continuous commitment by both the physician and the hospital to maintain the skills of the entire extraction team, and to monitor outcomes of both device implantation and lead extraction.1

Given the intricacy of lead extractions with the potential of life-threatening complications, a careful written consent should be obtained, including an explanation of the critical elements of the planned procedure. The patient should be aware of the hospital’s extraction volume and outcomes, as well as the physician’s experience and outcomes.

Prior to the procedure, a thorough history and physical examination should be performed to properly identify the indication for lead extraction and the patient’s comorbidities, which could affect the procedure and postoperative recovery. A chest X-ray should be performed to identify the number, location, and type of leads, as well as the lead’s fixation mechanism. A preprocedure venogram or Doppler study should be performed to determine the patency of upper limb veins, especially if a device upgrade is planned on the ipsilateral side. By knowing the type of leads, the operator can have all the appropriate tools on hand. The device should be interrogated prior to the procedure to determine if the patient is pacemaker dependent and, if so, should have a temporary transvenous wire placed prior to the extraction. The device should also be interrogated to document the original settings and parameters. Leads that are not going to be extracted can be tested to ensure the parameters pre- and post procedure are the same and that they are not damaged. Rate response and tachycardia therapies should be turned off to prevent inappropriate pacing and therapies, respectively. Consultation with an infectious disease specialist to guide antibiotic therapy should be considered if the device is infected.

Procedure

Anesthesia and intraoperative monitoring

Older leads (specifically >1 year) may not come out with simple traction and might require a more complex approach to extraction. Complex lead extraction is associated with the risk of vascular injury by traction or perforation, causing tamponade, hemothorax, arteriovenous fistula, tricuspid...
valve disruption, or possibly pulmonary embolism. Extractions should always be performed in an operating room with adequate fluoroscopy under general endotracheal anesthesia with on-site cardiothoracic surgical support. Four units of packed red blood cells should be typed and cross-matched and should be available.

Intra-operative transesophageal echocardiogram is performed by the anesthesiologist to constantly monitor for a pericardial effusion. The patient’s entire chest should be prepped and draped in a sterile fashion in preparation for emergent sternotomy.

**Vascular access and emergency contingency**

Intraoperative blood pressure should be monitored by an arterial line, and large-bore central venous access should be available to anesthesia for resuscitative purposes. An additional central venous line should be placed in the femoral vein in case the patient is pacemaker dependent and would need a temporary pacing wire or if lead extraction from the pocket is unsuccessful and the lead needs to be “snared” from the groin. Femoral arterial access should also be available for possible percutaneous bypass cannulation.

**Pacemaker pocket and lead preparation**

Good surgical technique and strict hemostasis should be adhered to at all times during pocket exploration. It is helpful to rinse or wipe blood from the operator’s hands and instruments frequently to ensure that the stylet and sheaths do not become “sticky” from blood. The pocket is opened and the leads are detached from the device. The leads should be carefully and completely dissected free from scar tissue and followed down to the insertion point under the clavicle. Self-retaining retractors and a fine sucker can aid in this dissection. The suture sleeves should be removed. It is important to avoid any injury to the leads during dissection. The pocket should be thoroughly dissected of all scar tissue, especially in the case of an infected pocket. Infected pockets should undergo a pocket revision with removal of all the infected or necrotic tissue, in conjunction with local and systemic antibiotic use. Wound vacuum-assisted (VAC) therapy can shorten the healing period by promoting granulation formation in these infected pockets. If the pocket was infected, the timing and need for device reimplantation must be determined prior to the procedure, and after the extraction the pocket should be packed with iodoform packing strips until the pocket closes by secondary intention. Reimplantation of a new device system should in these cases be done on the contralateral side. A single dose of prophylactic parenteral antibiotic is used in non-infected cases.

**Lead preparation and extraction techniques**

Extraction of leads can be performed by a variety of techniques, e.g. simple traction, traction devices, and various types of sheaths, including mechanical, laser, electrosurgical, rotating threaded tip, and telescoping sheaths. If only one lead is being extracted, a regular stylet should be placed in all the other leads to ensure that they remain stable and do not dislodge when attempting to extract the other lead. The active fixation mechanism should be retracted using a retraction wrench or curved hemostats for better traction. If the helix does not retract, the entire body of the lead can also be rotated several times to facilitate retraction. Manual traction can be attempted at this point, and if the lead does not move freely, a locking stylet (Liberator Universal Locking Stylet, Cook Medical, Bloomington, IN) can be used to aid with traction. The exposed end of the lead is secured with a Sof-Grip Hemostat (Cook Medical), and the lead is cut distal to that point, leaving approximately 15 cm of lead visible (Figure 1). The outer coating of the lead is then removed to expose the inner lumen (Figure 2). Prior to inserting the locking stylet, the inner lumen can be dilated with a dilating tool to facilitate the locking stylet placement and to remove any debris. It is important to advance the locking stylet as far distal as is possible. The risk of severing a possibly frail interpolar section of an encapsulated bipolar lead is higher if a positive lock close to the lead tip cannot be achieved. In order to avoid pulling out the core of the lead and leaving the outer insulation in place, Supramid suture (S. Jackson, Inc., Alexandria, VA) is used to fasten the insulation to the rest of the lead and is then connected to the end of the locking stylet (Figure 3). This may require two separate sutures tied together to accommodate the length of the locking stylet. Tortuous leads with sharp bends can make advancement of the locking stylet difficult. In order to counter this, the locking stylet can be advanced to the area that is tortuous, lock the stylet, straighten that portion of the lead, unlock the stylet, advance it toward the tip, and then relock the stylet. Manual traction can then be attempted again at this point. If at this point the lead still does not come out with minimal traction, mechanical sheaths or laser sheaths can be used for extraction. It is important to keep in mind that the vast majority of vascular or cardiac injuries are due to overzealous traction.

![Figure 1: Sof-Grip Hemostat clamped around cut lead.](image)
Mechanical and laser sheaths

The mechanical dilator sheath (EVOLUTION Shortie, Cook Medical) comprises a threaded barrel distal tip design. It consists of a flexible rotating sheath that separates fibrous binding sites from the leads that need extracting. This inner, exotic braided polymer sheath, shielded by an outer telescoping polymer sheath, connects to a handle, or trigger, which rotates it mechanically and allows maintenance of venous access after the lead is extracted. This is especially useful when trying to break up a tight fibrotic area around bends like the costo-clavicular space, medially positioned between the clavicle and the first rib. When using the mechanical sheath, there is a risk of dislodgment as well as damage to other leads, which makes stabilization of the other leads with stylets critical (Figure 4). After freeing the lead up from a fibrotic area, gentle manual traction can be attempted again at this point. If the lead still does not come out, the mechanical sheath can be exchanged for a laser sheath (Spectranetics CVX-300 Excimer Laser and Spectranetics Laser Sheath (SLS II), Colorado Springs, CO). The laser beam, located at the tip of the sheath, lyses via photochemolysis and photothermal ablation, small amounts of fibrotic tissue that gets pulled up against the laser area. Spectranetics guidelines are followed to select the appropriate size sheath to remove the lead in question. By not using an outer sheath, the single sheath is more flexible and easier to maneuver. After calibrating the laser sheath, the sheath is advanced over the lead, locking stylet and suture (Figure 5). In order to reduce friction between the lead and laser sheath, we sometimes use mineral oil. Four to five drops of sterile light mineral oil are placed inside the sheath from both the distal and proximal ends, lubricating the inner Teflon surface of the sheath. Excess oil is allowed to drip out after lubrication. Commercially available sterile light mineral oil is routinely used in operating rooms to lubricate surgical instruments. The stylet and...
lead are then threaded through the sheath as usual. With this technique, the lead slides with minimal friction through the laser sheath and allows the operator to reduce the force applied to the lead and sheath. With less friction to overcome, the physician can control the movement of the laser sheath with more accuracy and less traction on the tissues. The laser sheath tip is then advanced under fluoroscopic guidance, making sure that the beveled edge of the sheath is kept on the inside when approaching the brachiocephalic curve (Figure 6). The lead, in conjunction with the stylet and suture, is kept in line with the sheath and an appropriate amount of countertraction is held. Slowly rotating the sheath when advancing the laser sheath adds mechanical dilatation to the laser energy at the sheath tip. The J shape of the atrial lead can usually be straightened out as the sheath is advanced over it, before countertraction is applied. As the laser sheath nears the tip of the lead, the lead tip can usually be freed with countertraction, which involves keeping the atrial/ventricular wall aligned with the sheath while steady traction is maintained on the lead, locking stylet, and suture for up to several minutes. Patience, attention to detail, and avoidance of overzealous traction is usually rewarded with successful extraction.

Emergent surgical management of vascular or cardiac injury

Considering the frail state of many patients who require lead extraction, it is not unexpected that despite diligent technique, cardiac and vascular injury can occur. These injuries can range from minor hematomas to catastrophic bleeding and even cardiac tamponade with pending death. A significant number of patients requiring lead extraction have had prior open heart surgery. When major vascular injury occurs in these patients, an emergency redo sternotomy will have to be performed. It is thus imperative that all preparations be in place for supporting circulation and to perform emergency sternotomy. We routinely have an open heart surgical set laid out and a cardiopulmonary bypass machine set up in the room. The scrub nurse and perfusionist must be present or near the room during extraction. As mentioned before, the entire anterior chest and both groins are prepped and draped to allow for easy surgical access in the event of an emergency. We also routinely place heparin-flushed sheaths in a femoral vein and femoral artery to allow for rapid deployment of cannulas for cardiopulmonary bypass via modified Seldinger technique. We believe that emergent institution of percutaneous bypass is the safest method of managing the circulation in a patient with a major vascular or cardiac injury. After full heparinization, we employ an 18-Fr wire-reinforced long venous cannula and apply vacuum-assisted drainage to the venous reservoir. Our strategy for arterial cannulation is with a 16-Fr wire-reinforced femoral arterial cannula. Once cardiopulmonary bypass is established, we allow the patient’s systemic temperature to drift down to 35°C.

With bypass established, a midline sternotomy is performed. This allows for access to major vascular or cardiac structures that might have been injured. Common sites of injury are the innominate and subclavian veins, the superior vena cava (SVC), the right atrium, posterior right ventricle, or the coronary sinus (CS). The injuries are usually traction-induced injuries that can be repaired either by direct suturing or with biological patch repair. It is important to avoid air being sucked into the venous system via the injury defect, which might cause a venous return lock and may shut the bypass circuit down. Simple reverse Trendelenburg positioning usually avoids this complication. If the emergency occurred prior to complete extraction, we would proceed with open extraction by placing an SVC cannula and snare. In addition, we would retract the femoral venous cannula out of the atrium and snare the inferior vena cava, allowing for a right atriotomy and removal of residual leads under direct vision. Occasionally, it might be necessary to arrest the heart to free up the lead from its ventricular location.

Injury to the tricuspid valve is usually well tolerated and can be addressed on an elective surgery basis should the patient become symptomatic from tricuspid regurgitation. Sternotomy might also afford the opportunity to

Figure 6: Laser sheath being advanced under fluoroscopic guidance.
place epicardial leads such as a left ventricular (LV) lead in non-infected extraction cases.

**Tips, pitfalls, and special considerations**

If more than one lead is being extracted, always extract the lead that is newer, as it will be easier to extricate. While trying to extract one lead, the laser sheath may not be able to advance past fibrosis at such areas of the SVC or right atrium–inferior vena cava junction. At this point, it is advisable to switch to the other lead in order to break up the fibrotic adhesions that are binding the leads together (Figure 7). This back-and-forth approach while the locking stylets are in place stabilizes the lead that is not being worked on while guiding the laser sheath over the alternative lead. If this approach is also unsuccessful, upsizing the laser sheath to a 16-Fr sheath in conjunction with an outer sheath may be necessary. Despite the use of a larger laser sheath, the sheath may still not pass over the lead due to severe fibrosis and calcification, which is often seen in patients with end-stage renal disease.

When extracting leads with vegetations, we start with a 14-Fr sheath and upsize to a larger size 16-Fr sheath as needed, as the vegetation usually adheres to the lead. When extracting leads with vegetations, the physician must be cognizant of the size of the vegetation; at our institution, we remove leads with vegetations up to 3 cm in size.

Extraction of leads with fractures can be very difficult. Advancing the locking stylet in a known fractured lead, such as the Sprint Fidelis (Medtronic Inc., Minneapolis, MN) can be challenging. As the locking stylet is advanced, it may come out of the lumen at the site of the fracture and penetrate outside of the lead. This could damage the lead so that the locking stylet may not reach the end of the lead tip and decide the success or failure of the extraction. The lead should be cut and the inner lumen exposed proximal to the fracture in order to allow for advancement of the locking stylet. The Bulldog lead extender (Cook Medical) may need to be placed to add workable lead length. A mechanical or laser sheath will need to be used as well, with careful countertraction on the lead and locking stylet to keep the lead straight, in order to avoid the tip of the sheath harming or shearing the lead.

In our experience with removing traditional LV leads, these rarely present a problem unless there are adhesions to other existing leads. The LV lead can often be removed with light traction alone. The approach to removing LV leads with adhesions is otherwise identical to other leads; however, laser applications should not be performed in the CS. We have limited long-term experience in removing the Medtronic Attain Starfix lead, which has a fixation mechanism in which three expandable polyurethane lobes near the tip of the lead can be deployed for fixation. Although these lobes can be relaxed multiple times during implant, they quickly become permanently locked in position and present a significant challenge when there is a need for lead removal. A CS venogram may be helpful, but the LV lead branch is often completely occluded. Careful mechanical dilation in the CS using a soft sheath that can advance over the expanded lobes may allow for successful removal.

In the event that the lead breaks and either remains attached or becomes free-floating, retrieval via the femoral approach needs to be attempted. It is critical to have good fluoroscopy, as approaching an extraction from the groin will require viewing the lead from various angles to be able to “snare” it. We have used both the Byrd Workstation Femoral Intravascular Retrieval Set (Cook Vascular, Leechburg, PA) and the Needle’s Eye Snare (Cook Vascular) with success.

If all of these methods fail, the adhesions and/or calcifications are likely to be severe, and the extraction should be aborted. The patient will then have to undergo an open extraction.

**Conclusion**

Given the rising number of implanted transvenous pacemakers, ICDs, and CRT, transvenous lead extractions are going to be performed more frequently. To ensure success, it is imperative to have a systematic approach, given the technical complexity and risk of life-threatening complications that can arise. Old leads, calcifications, infections, and multiple leads can make the procedure more technically difficult. By following our step-by-step approach, we avoid major complications and ensure a higher success rate.

**References**