Use of Transesophageal Echocardiography to Improve the Safety of Transvenous Lead Extraction

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ABSTRACT

OBJECTIVES The aim of this study was to evaluate the utility of transesophageal echocardiography (TEE) during transvenous lead extraction (TLE) involving both conventional and laser lead removal.

BACKGROUND TLE carries a small but measurable risk of serious adverse events. Few studies have examined the potential benefit of continuous monitoring with TEE during this procedure.

METHODS Continuous TEE monitoring was performed in 100 consecutive patients (67% male; average age, 57 ± 17 years) who underwent TLE in the past 5 years. Lead extraction was attempted for 193 leads. The average time since lead implant was 78 ± 55 months (range, 1.4 to 274.4 months). Indications for extraction were device endocarditis (n = 28), lead fracture (n = 28), recalled lead (n = 21), pocket infection (n = 17), and other (n = 6).

RESULTS Complete success occurred in 181 leads (94%), partial success in 4 leads (2%), and failure in 8 leads (4%). Eighty patients required laser lead extraction (80%). Major complications included 1 right ventricular and 2 right atrial/superior vena cava lacerations, which were detected and localized within 1 to 2 min with the use of TEE and resulted in prompt surgical repair. There was 1 upper gastrointestinal bleed caused by the TEE probe. TEE prevented premature termination and unnecessary surgery in 4 patients with hypotension but no intracardiac abnormalities seen on TEE. In-hospital mortality rate was 0%. In total, TEE provided immediately useful clinical information in 7 patients (7%).

CONCLUSIONS Continuous monitoring with TEE facilitates prompt diagnosis and treatment of intracardiac damage and prevents premature termination of cases with hypotension but no abnormalities on TEE. (J Am Coll Cardiol EP 2015;1:442–8) © 2015 by the American College of Cardiology Foundation.

Transvenous lead extraction (TLE) is being performed in greater numbers of patients each year as the number of pacemakers and implantable cardioverter-defibrillators (ICDs) implanted increases. Despite relatively low major complication (0.4% to 3.4%) (1–4) and mortality (0.00% to 1.86%) rates (1,2,4), the risk of serious adverse events remains due to vascular laceration, and great care is needed to both prevent and respond to such events.

Despite the inherent risk, many lead extractions are performed in the electrophysiology laboratory with cardiothoracic surgeons “on standby” (5). One study comparing procedures performed in the electrophysiology laboratory with those performed in the operating room found no difference in complication or mortality rate between the two (6). Although current guidelines do not require that this procedure be performed in an operating room, there is a strong recommendation for immediately available cardiothoracic surgery backup on the basis of previous findings that delays in open access to the heart of more than 5 to 10 min often result in fatal outcomes (7).

There is also no clear consensus on the use of echocardiography during TLE. Current recommendations...
suggested transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE) be immediately available, but no recommendation is made for monitoring with TEE (9). This modality has previously shown benefit before and after TLE as well as being of benefit as an intra-procedural monitoring tool (1, 8). Proposed benefits include evaluation of lead vegetations before attempted TLE, investigation of causes of intraprocedural hypotension, and rapid detection and localization of cardiac defects caused by TLE itself. Although previous case reviews have examined the role of continuous TEE, predominantly in patients undergoing conventional TLE, there are few data on its utility in laser lead extraction (1, 9). Here we seek to review patients undergoing both conventional and laser TLE with continuous TEE monitoring.

METHODS

STUDY GROUP. The records of 100 consecutive patients who underwent TLE of a transvenous pacemaker or ICD leads with continuous TEE monitoring at a single university medical center between 2009 and 2014 were reviewed. In accordance with the 2009 Heart Rhythm Society Guidelines on transvenous lead extraction, pocket infection was defined as “erythema with or without purulent discharge, device erosion, fat necrosis, and/or adherence of device to the skin” (10). All other infections were considered device-related endocarditis, and, of note, all such patients had positive blood cultures.

PROCEDURE. All TLE procedures were performed in a hybrid operating room by a cardiac electrophysiologist with a cardiothoracic surgeon present during the procedure. After induction of general anesthesia by a cardiac anesthesiologist who was certified for perioperative TEE, an arterial line was placed in the radial artery, and a TEE probe was inserted in the midesophagus. A stepwise approach was used for TLE beginning with simple traction, if possible, followed by laser (Spectranetics, Colorado Springs, Colorado) or mechanical sheaths (Cook Medical, Bloomington, Indiana) with a locking stylet (Spectranetics) and a snare (Cook Medical), if required. Definitions of procedural success and major and minor complications are taken from the Heart Rhythm Society 2009 Guidelines on Lead Extraction (10).

ECHOCARDIOGRAPHIC STUDY. TEE was performed on an iE 33 Philips Echocardiography system (Kloninklijke Philips NV, Amsterdam, the Netherlands). Baseline TEE images were obtained with an X7–2t transducer (Kloninklijke Philips NV) with 2- and 3-dimensional capabilities before pocket interrogation to evaluate for pericardial and pleural effusion, tricuspid regurgitation, intracardiac mass, and other abnormal findings. Throughout the procedure, the TEE probe was left in the midesophagus, and a 4-chamber view was used for continuous monitoring. The images were monitored by experienced anesthesiologists and, in some cases, reviewed by cardiologists.

**STATISTICAL ANALYSIS.** Continuous descriptive data are presented as the average ± SD and total range. Categorical variables are expressed as the absolute value and percentage. The incidence of TEE findings is expressed as number of findings divided by the total number of patients.

RESULTS

DEMOGRAPHICS AND INDICATIONS FOR EXTRACTION. Baseline characteristics and indications for TLE are listed in Table 1. Sixty-seven patients were male, and the average age of all patients was 57 ± 17 years. In total, 193 leads were extracted from 100 patients for an average of 1.93 leads per patient. The maximal number of leads in 1 patient was 5. The average length of time since lead implantation was 78 ± 55 months (range 1.4 to 274.4 months). The most common indications for lead extraction were endocarditis and lead fracture. Other indications included pocket infection, lead recall, malfunctioning leads without fracture, dislodged leads, and patient preference.

LEAD EXTRACTION OUTCOMES. Table 2 summarizes outcomes. TLE was attempted for 193 leads with complete success in 181 leads (n = 93), partial success in 4 leads (n = 3), and failure in 8 leads (n = 4). Partial success came in the form of retained tips of 2 right atrial leads, 1 right ventricular lead, and 1 coronary sinus lead. Procedural failure in the 3 patients resulted from major complications. Eighty patients required lead extraction using a laser or mechanical sheath on at least 1 lead, whereas 20 patients had manual extraction only.

Four patients experienced major complications including laceration of the right ventricle (n = 1) or the right atrium/superior vena cava (SVC) (n = 2) and upper gastrointestinal (GI) bleeding attributed to TEE (n = 1). There were 3 minor complications consisting of transesophageal echocardiography (TEE) and transvenous lead extraction (TLE).
of new small pneumothorax, new mild tricuspid regurgitation, and dislodgment of a right atrial lead requiring extraction.

There were 8 patients who experienced significant hypotension during the procedure (systolic blood pressure <90 mm Hg). Four of these patients had no obvious cause for hypotension seen on TEE, and the procedure was allowed to continue without premature termination. Right ventricular inversion was observed in 4 of these patients, as shown in Figure 1, and allowed the operator to decrease the traction on the lead, improve blood pressure, and continue with the procedure.

The average length of hospital stay was 7.37 days (range 1 to 37 days). In-hospital mortality rate for all 100 patients was 0%.

**TEE Findings.** **Pericardial effusion.** TEE revealed baseline pericardial effusion in 14 patients, with new or worsening effusion in 4 patients. Of these 4 patients, 1 patient with new trace pericardial effusion remained hemodynamically stable and did not require intervention. The other 3 cases related to laceration of the right ventricle (n = 1) and right atrium/SVC (n = 2), as described previously. In all 3 cases, an acute loss of blood pressure was accompanied by new large pericardial effusion, prompting immediate sternotomy and surgical intervention (Table 3).

**Intracardiac mass.** Fourteen intracardiac masses were seen in 13 patients. All 14 were considered to be vegetations. One mass was smaller than 1 cm, 1 was between 1 and 2 cm, and 2 were larger than 2 cm. The other 8 masses were not measured but described as “small” in 3 cases and “large” in 1 case, with no description in 4 cases. Locations of the masses included right atrial leads (2 masses), right ventricular leads (6 masses), tricuspid valve (1 mass), and...
right atrium (5 masses). There were no cases of clinical pulmonary embolism after device extraction in these patients (Table 3).

**Tricuspid regurgitation.** Twenty-five patients had tricuspid regurgitation before lead extraction. Sixteen cases were 1+, 8 cases were 2+, and 1 case was 4+. New or worsening tricuspid regurgitation developed in only 1 patient. The patient was found to have 2+ regurgitation before the procedure and 3+ regurgitation after TLE. This patient’s tricuspid regurgitation remained stable as shown on subsequent echocardiograms over a 1-year follow-up period.

**Major complication cases.** Case 1. A 36-year-old woman with history of nonischemic cardiomyopathy and a single-lead ICD presented with ICD lead fracture. The lead dwell time was 85 months. A locking device and laser sheath were used to free adhesions from the subclavian vein. When the lead was removed from the right ventricle, real-time TEE revealed a large pericardial effusion, and the blood pressure suddenly decreased. Although pericardiocentesis led to temporary hemodynamic improvement, a rapid sternotomy had to be performed to stabilize the patient. Direct inspection revealed a laceration on the free wall of the right ventricle, which was repaired surgically. A drain was placed and removed 2 days later with no pericardial effusion seen on repeat TTE. She received a single-chamber ICD via the right subclavian vein and was discharged several days later.

Case 2. A 34-year-old woman had a history of nonischemic cardiomyopathy status post dual-chamber ICD placement. The dwell time for each lead was 51 months. Her ejection fraction improved to the point where she was off medications directed at heart failure and elected to have her device removed. As the laser sheath was being advanced over the right ventricular lead, there was a sudden complete loss of blood pressure with the TEE revealing a large pericardial effusion (Figure 2). This was instantly recognized with TEE, and a median sternotomy was performed within 2 min of recognition. Direct inspection revealed a large amount of blood coming from the right atrium/SVC. A large laceration of the lateral wall of the right atrium/distal SVC junction was discovered. A bovine pericardial patch was sewn into place at the junction of the SVC and right atrium. She was discharged 6 days later.

Case 3. A 70-year-old man with nonischemic cardiomyopathy status post dual-chamber ICD placement referred for upgrade to a biventricular ICD. He had undergone successful extraction of a right ventricular ICD lead along with placement of new right ventricular ICD and coronary sinus pacing leads 42 days before presentation. Unfortunately, a device pocket infection developed, and he was referred for device extraction. At the time of extraction, the dwell time for each lead was 192 months for the atrial lead and 1.4 months for the ventricular lead.

**TABLE 3** Transesophageal Echocardiography Findings

<table>
<thead>
<tr>
<th>Intracardiac Masses, n</th>
<th>Baseline (n = 14)</th>
<th>New/Worsened (n = 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 cm</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>&gt;1 cm and &lt;2 cm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>&gt;2 cm</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Unsptified</td>
<td>8</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Pericardial Effusion, n</th>
<th>Baseline (n = 14)</th>
<th>New/Worsened (n = 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trace</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Small</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Moderate</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Large</td>
<td>1</td>
<td>3</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Tricuspid Regurgitation, n</th>
<th>Baseline (n = 25)</th>
<th>New/Worsened (n = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>2+</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>3+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4+</td>
<td>1</td>
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</tbody>
</table>

**FIGURE 2** New Pericardial Effusion

Intraprocedural TEE revealing new pericardial effusion and right ventricular inversion during attempted lead extraction. TEE enabled the rapid detection of a new, expanding pericardial effusion that resulted in sternotomy and direct cardiac access in <2 min. TEE = transesophageal echocardiography.
for the right ventricular and coronary sinus leads. The right atrial lead was easily pulled back from its right atrial connection with simple traction; however, it was not freed from the innominate vein. A mechanical sheath was used without success. The lead was then successfully grasped with a snare; however, it could not be freed. During this attempt, a precipitous drop in blood pressure developed with new, large pericardial effusion seen immediately on TEE. Sternotomy was rapidly performed, and a laceration in the right atrium was identified that was quickly closed. He remained hemodynamically stable throughout his hospital stay and was discharged 8 days later.

Case 4. A 48-year-old man with a history of D-transposition of the great arteries status post Mustard baffle procedure and dual-chamber pacemaker placement was referred for removal of fractured leads and placement of new leads into the right atrium and ventricle. Dwell time for his leads was 86 months. After entry into the pacemaker pocket, the ventricular lead was cut, and a locking device was secured to it. A laser sheath was advanced over the ventricular lead with gentle traction and laser delivery. The ventricular lead was freed of adhesions at the level of the subclavian vein. Unfortunately, the lead could not be removed as it was adhered to the ventricular free wall despite freeing the lead all the way to the ventricular insertion site. The laser sheath was removed, and attention was turned to removing the atrial lead. Using the laser sheath and locking stilet, the adhesions around the atrial lead were removed at the level of the subclavian vein, and the atrial lead was then removed with gentle traction. Manual pressure was held over the lead insertion site for 5 min. ICD leads were then successfully inserted in the right atrium and right ventricle without difficulty. The patient seemed to tolerate the procedure well and was extubated without difficulty. Several hours after the procedure, the patient had an episode of hematemesis. Complete blood count revealed a significant drop in hemoglobin from 13 to 10 g/dl the following morning. He then had 1 episode of hematochezia. He underwent upper endoscopy, which revealed a linear tear in distal esophagus with a visibly bleeding vessel. He underwent successful hemostatic clip placement with stabilization of hemoglobin and no further evidence of bleeding. He was discharged 2 days later.

DISCUSSION

Previous studies of TLE have reported a major complication risk as high as 4% with an overall mortality rate as high as 1.86% (1-4). In our study, in 4% of patients major complications developed in the form of laceration of the right atrium/SVC (n = 2), laceration of the right ventricle (n = 1), and upper GI bleeding (n = 1). Excluding the upper GI bleed, 3 patients had intracardiac structural damage caused by the extraction itself with immediate recognition of pericardial tamponade prompting rapid sternotomy.

In all 3 major complications caused by TLE itself, the time from recognition of tamponade to sternotomy was <5 min, and there were no in-hospital deaths. Although vascular laceration was initially suggested by an invasive arterial monitor, TEE allowed verification that a laceration had in fact occurred and prompt surgical planning to repair the laceration. Previous case reviews involving TLE and SVC lacerations have led to a consensus that more than a 5- to 10-min delay from injury to open access to the heart often resulted in death (7). Having direct access to TEE throughout the case could facilitate rapid decision making and help to minimize the time from recognition of major complications to opening the chest.

Without a control arm in this case review, we are unable to definitively state that continuous TEE reduced the time to sternotomy. One could theorize, however, that being able to immediately review real-time images could save seconds or even minutes compared with the process of setting up and obtaining TTE images, which represents 1 alternative to TEE. TTE may be inherently limited by poor acoustic windows and the need for direct access to the anterior chest for image acquisition. Finally, identification of the location of the laceration could affect the surgical approach, and this may be better facilitated by direct real-time visualization with TEE as opposed to TTE.

Another alternative to TEE for monitoring during TLE is intracardiac echocardiography (ICE). This technology has previously been shown to be both safe and feasible for TLE (11). Like TEE, ICE could allow for visualization of vegetations, tricuspid regurgitation, and rapid detection of pericardial effusions. One limitation of this tool is the need for manipulation of the ICE catheter by the proceduralist to obtain images. This is in contrast to TEE in which continuous images can be monitored and different views obtained by a different operator, allowing the proceduralist to focus on lead extraction. Thus far, there have been no comparisons of outcomes related to the use of TEE and ICE, and further studies are needed to compare these 2 options.

Continuous TEE may be useful in the evaluation of intracardiac masses and may assist in management
decisions related to them. Detection of lead-related vegetations by TEE affects the duration of antibiotic treatment as well as the approach to lead extraction because open surgical extraction should be considered for vegetations larger than 2 cm. Previous studies suggested that leads with intracardiac masses smaller than 1 cm in greatest diameter could be extracted safely (1). More recent small observational studies have suggested safe extraction of leads with masses larger than 1 cm (12). In our review, TLE was performed in 13 patients with intracardiac masses considered vegetations. With no interatrial communication seen on TEE, all 13 underwent TLE with no clinically obvious pulmonary embolisms. Additionally, our center opted to avoid TEE before the TLE procedure for infected leads so that the patient would be receiving anesthesia related to the TEE only once.

Another potential complication of TLE is tricuspid regurgitation. One study found a 9.1% incidence of traumatic tricuspid regurgitation with 1 major risk factor being the use of a laser (13). In our review, 1 patient (1%) experienced worsening tricuspid regurgitation (2+ to 3+), prompting close follow-up. Serial echocardiograms revealed stable regurgitation without compromised right ventricular function.

One final benefit of TEE is not in recognition of a problem but in ruling out complications in the setting of hypotension. Intraprocedural hypotension is not uncommon, and potential causes include the effects of anesthesia, increased vagal tone during lead manipulation, right ventricular inversion during extraction, and complications, as previously described (Figure 2). Major cardiovascular complications may be suggested by hemodynamic compromise or a change in cardiac contour on fluoroscopy. However, being able to immediately review TEE images would rapidly enable the team to differentiate the structural complication (laceration, cardiac rupture, pericardial tamponade, pleural effusion) from other potential causes of hypotension. This would likely limit the time to diagnosis and, possibly, overall procedural time if hypotension is occurring frequently and requiring such investigation.

In our review, intraprocedural hypotension developed in 8 patients. In 4 of these patients, no cardiac structural damage or pericardial effusion was identified, allowing for continuation of the procedure without unnecessary delays or premature termination.

TEE does not come without its own inherent risks. In our review, 1 patient (1%) had a complication attributed to TEE itself in the form of an upper GI bleed several hours after the procedure. He required urgent upper endoscopy with successful hemostatic clip placement of a lacerated vessel and remained stable afterward. Previous studies have reported a similar morbidity rate of 0.2% to 1.2% involving a GI bleed in intraoperative and nonoperative TEE (14,15). Major GI complications occur in as many as 1.2% of patients and may occur 24 h after the procedure (16). Such risks must be weighed against the potential benefit of TEE, and patients at higher risk of GI complications, such as those with esophageal varices, should not be considered for continuous TEE monitoring.

Another important consideration that needs to be made when deciding on continuous TEE monitoring is the cost. No previous studies have provided a cost analysis of TEE in TLE, and such analysis was not attempted in our study. Previous studies of TEE used during cardiac surgery have proved this strategy to be cost-effective through improved surgical outcomes and a reduction in the need for postoperative studies (17,18). We are unable to extrapolate these data to TLE given its obvious differences, and further studies are needed to evaluate whether TEE for TLE is cost-effective.

Our results are consistent with those of previous studies that examined the utility of TEE in patients primarily undergoing TLE (1,9). Our patient population comprised predominantly patients requiring laser lead removal, and a majority of the leads extracted were ICD leads. The rates of both procedural success and major complications were similar to those of previous investigations (1,2,6,19). Compared with the study reported by Regoli et al. (9), we were able to use TEE to detect right ventricular inversion as well as quickly rule out a pericardial effusion or other vascular laceration during periods of hypotension and thus avoid unnecessary surgical intervention as well. In our study, 7 patients (7%) immediately benefited from direct TEE monitoring. These included 3 cases of pericardial tamponade resulting in rapid surgical intervention and 4 cases of transient hypotension without TEE findings, allowing continuation of lead extraction. There were no in-hospital deaths in our study population. Therefore, we additionally propose that TEE can be used to differentiate hypotension due to vascular laceration from other transient causes of hypotension in real-time fashion to improve the safety of lead extraction.

**STUDY LIMITATIONS.** This was a retrospective, single-center, observational study. All patients undergoing TLE were monitored with TEE, and, thus, there was no control group with which to compare outcomes. Inclusion criteria were decided on by the
operators. This study examined in-hospital outcomes alone, with no post-hospital follow-up.

CONCLUSIONS

Continuous monitoring with TEE provides clinically useful information during TLE. Rapid identification and localization of cardiovascular defects on TEE can enable faster diagnosis and intervention. Additionally, it can help to avoid unnecessary surgical exploration and premature termination of cases in which hypotension is not accompanied by worrisome findings on TEE.

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REFERENCES


PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: The number of transvenous lead extractions is increasing, as is the number of operators and hospitals performing this procedure. Although this procedure is generally safe, a laceration of the SVC or one of the cardiac chambers represents a catastrophic outcome that requires rapid diagnosis to facilitate repair. TEE may be one tool that operators can use for rapid diagnosis of a vascular laceration.

TRANSITIONAL OUTLOOK: The role of imaging during transvenous lead extraction is becoming increasingly more important. Further work needs to be done to determine that TEE and other imaging modalities can improve patient outcomes.

KEY WORDS: implantable cardioverter-defibrillator, pacemaker, transesophageal echocardiography, transvenous lead extraction.