Differences in Complication Rates between Large Bore Needle and a Long Micropuncture Needle during Epicardial Access – Time to Change Clinical Practice?

Running title: Gunda et al.; Micro-puncture needle for Epicardial Access

Sampath Gunda, MD, MHA1*; Madhu Reddy, MD, FACC, FHRS1*; Jayasree Pillarisetti, MD1; Moustapha Atoui, MD, FACC1; Nitish Badhwar, MD, FACC, FHRS2; Vijay Swarup, MD, FACC, FHRS3; Luigi DiBiase, MD, PhD, FACC, FHRS4; Sanghamitra Mohanty, MD, FACC, FHRS5; Prashanth Mohanty, MBBS5; Hosakote Nagaraj, MD, FACC6; Christopher Ellis, MD, FACC, FHRS7; Abd Rasekh, MD, PhD, FACC, FHRS8; Jie Cheng, MD, PhD, FACC, FHRS9; Krzysztof Bartus, MD, PhD, FACC, FHRS10; Randall Lee, MD, FACC, FHRS2; Andrea Natale, MD, FACC, FHRS5; Dhanunjaya Lakkireddy, MD, FACC, FHRS1

1Mid-America Cardiology & University of Kansas Medical Center, Kansas City KS; 2University of California, San Francisco, CA; 3Arizona Heart Rhythm Center, Phoenix, AZ; 4Montefiore Medical Center, Bronx, NY; 5Texas Cardiac Arrhythmia Institute, St. David’s Medical Center, Austin, TX; 6Nebraska Heart Institute, Lincoln, NE; 7Vanderbilt University Medical Center, Nashville, TN; 8Texas Heart Institute at St. Luke’s Episcopal Hospital, Houston, TX; 9Texas Heart Institute, Houston, TX; 10Jagiellonian University, Krakow, Poland

*contributed equally

Correspondence:
Dhanunjaya (DJ) Lakkireddy, MD, FACC, FHRS
Professor of Medicine
Mid America Cardiology
University of Kansas Hospital
Kansas City, KS 66160
Tel: 913-588-9406 / 913-575-2157
Fax: 913-588-9770
E-mail: dlakkireddy@gmail.com

Abstract:

Background - A “dry” epicardial access (EA) is increasingly used for advanced cardiovascular procedures. Conventionally used large bore needles (Tuohy or Pajunk needle; LBN) have been associated with low but definite incidence of major complications with EA. Use of micropuncture needle (MPN) may decrease the risk of complications. We intended to compare the outcomes of LBN with MPN for EA.

Methods and Results - We report a multicenter observational study of consecutive patients who underwent EA for ventricular tachycardia (VT) ablation or lariat procedure using the LBN or MPN. Oral anticoagulation was stopped prior to the procedure. Baseline characteristics and procedure related complications were collected and compared. Of the 404 patients, LBN and MPN was used in 46% and 54% of patients respectively. There was no significant difference in the incidence of inadvertent puncture of myocardium between LBN and MPN needle (7.6% vs 6.8%, p=0.76). However, there was a significantly higher rate of large pericardial effusions with LBN compared to MPN (8.1% vs 0.9%; p<0.001). The incidence of pleural effusions were not significantly different between both (1.6% vs 2.3%, p=0.64). LBN group had an increase in “other complications” compared to MP (open heart surgery to repair cardiac laceration (6 vs 0), injury to liver (1 vs 0), coronaries (1 vs 0) and superior epigastric artery requiring surgical exploration (0 vs 1).

Conclusions - The use of MPN is associated with decreased incidence of major complications and the need for surgical repair and routine use should be considered for EA.

Key words: epicardial reentry, ventricular tachycardia, electrophysiology, pericardial effusion
Introduction

Percutaneous epicardial access (EA) has become an increasingly important step for mapping and ablating complex ventricular arrhythmias and also for the left atrial appendage (LAA) exclusion using an epicardial ligation system like the Lariat device (LARIAT) \(^1\). EA using the sub-xiphoid approach can be challenging and is associated with a low but definite incidence of major complications including pericardial effusion from right and left ventricular puncture resulting in tamponade, pleuro-pericardial fistula, coronary artery or vein laceration and visceral injury among others. The cumulative incidence of these complications has ranged from 6% to 25% in some case series \(^2\-^4\). Pericarditis seems to be most common complication occurring in the majority of the patients. The incidence of right ventricular myocardial puncture ranges from 4.5-17% using the sub-xiphoid approach \(^5\-^6\). Despite this higher incidence of myocardial puncture, the incidence of myocardial tear or pericardial effusion requiring open surgery is relatively low. This difference in the incidence of myocardial puncture and large pericardial effusion may be related to the "auto closure" of the myocardial puncture site. Conventionally used needles like the Tuohy and/or Pajunk needle are large bore (LB) needles and are 18G needles. It is possible that the relatively large tip of these LB needles have contributed, at least in part, to the many of the above complications \(^7\).

The thin bore (21G) micropuncture (MP) needle (Figure 1) is been increasingly used in cardiac interventions for routine vascular access to prevent major vascular complications. The smaller tip of the MP needle probably explains why damage to the vascular and surrounding structures could be relatively more forgiving. Observational studies suggest that MP needles may be better than LB needles in minimizing post-procedural vascular complications and randomized trials are underway \(^8\). However there are no data in the literature comparing the use of MP needle
vs LB needle for EA procedures.

We sought to compare the procedural complications during EA associated with use of MP needle versus LB needle. We hypothesize that use of MP needle will decrease the EA related complications compared to LB needle.

Methods and materials

We performed a multicenter observational study of all consecutive patients undergoing EA either for ablation of ventricular tachycardia (VT) or LAA exclusion using the LARIAT from January 2010 to June 2014, at the participating institutions. Study was approved by the institutional review board. Baseline demographics, laboratory parameters, procedural characteristics and complications were collected and analyzed.

Oral anticoagulation was stopped 5 days prior to the procedure. Patients undergoing Lariat procedure were bridged with low molecular weight heparin (LMWH) with the last dose held on the morning of the procedure. Pre-procedural cardiac imaging was mandated for all patients undergoing the Lariat procedure to assess the LAA anatomy but was used to evaluate the chest and cardiac anatomy.

Epicardial Access

EA was performed as per standard of practice as described previously by Sosa et al. A dry intrapericardial access was obtained through a sub-xiphoidal pericardial puncture (2 finger breadths below the tip of the xiphoid). (Figures 2 and 3) The needle was angled at 20–30 degrees advanced into the pericardial space while aiming toward the left mid-clavicle at the cardiac border under fluoroscopic guidance. The angle entry was adjusted according to whether an anterior or posterior approach is preferred. Puncturing the pericardial space was performed under negative pressure to confirm pericardial puncture from right ventricular puncture. An 18-gauge
epidural introducer needle (Tuohy or Pajunk needle) was used in the LB needle group, where as a 21G MP needle was used in the MP needle group. In MP needle group, when significant subcutaneous tissue was encountered which was making the needle bend, a short large bore needle was used to support the MP through the subcutaneous tissue (telescoping approach). Care was taken not to advance the 18G needle beyond the subcutaneous tissue. The entry of the needle into the pericardium was always done in the left lateral view.

Subsequently, contrast medium was injected to demonstrate the position of the needle tip, and a J-tipped, floppy guide wire of 0.018" and 60 cm in length was then introduced through the needle until its tip was free within the pericardial space. A 15cm long sheath was advanced into the pericardial space over the guide wire to enable aspiration of pericardial fluid and delivery of the ablation catheter to the epicardial surface of the atrium and ventricle.

A tactile sensation of puncture through the pericardium, generally sought with the LB needle, was not routinely perceptible with the MP needle. A 0.18 inch long wire was placed and exchanged to a larger sheath subsequently. Pericardial access was performed under transesophageal (TEE) guidance for patients undergoing LARIAT procedure or intracardiac echocardiography (ICE) to assess for ventricular puncture and pericardial effusion.

Procedural complications

Complications of the procedure were assessed and recorded in the registry prospectively.

Pericardial access related complications were divided as major and minor. Major complications included large pericardial effusions causing tamponade, drainage, blood transfusions, open heart surgery for the cardiac repair, abdominal exploration and repair. Minor complication include inadvertent puncturing of the RV myocardium.

Large pericardial effusion (with or without cardiac tamponade) was defined as
accumulation of more than 500ml of fluid in the pericardial space. Inadvertent myocardial puncture was defined as accidental penetration of myocardium with the EA needle leading to entry of needle into the ventricular chamber or myocardium (as identified by intracardiac contrast or myocardial staining respectively) with or without significant pericardial effusion, without need for open heart surgery and without the need for stopping the procedure. Pericardial drain was placed post-procedure for all patients and left in place 12-24 hours or until the pericardial effusion was less than 50ml over a period of 4 hours in all patients.

Statistical analysis

Continuous variables are expressed as mean ± SD. Categorical variables were presented as proportions. Categorical variables which are normally distributed were analyzed using Chi-square test and Fischer’s exact test whenever appropriate. Continuous variables which are normally distributed were analyzed using independent sample T-test and those non-normally distributed were analyzed using the Mann-Whitney U test. Logistic regression analysis was used to assess for the predictors of outcomes. All statistics were performed using IBM SPSS Statistics for Windows, Version 22.0. (Armonk, NY: IBM Corp). A p value of <0.05 was considered as statistically significant.

Results

A total of 404 (185 with LB and 219 with MP needle) consecutive patients underwent EA for VT ablation (N=91) and the lariat procedure (N=313) at participating institutions and were included in the current study. Of the 185 (45%) patients who had EA performed using a LB needle 54 (29%) patients had VT ablation and 131 (71%) patients had the lariat procedure. Of the 219 (55%) patients who had EA performed using a MP needle, 37 (17%) patients underwent VT ablation and 182 (83%) of patients underwent the lariat procedure. All patients who underwent
Lariat procedure had anterior EA and 60 (63%) patients undergoing VT ablation underwent posterior EA. Baseline characteristics are compared between the LB and MP needle groups in table 1. Both the groups were similar in the distribution of baseline characteristics and medication use.

The incidence of large pericardial effusions was significantly higher in LB needle when compared to MP needle group (15/8.1% vs 2/0.9%, \( p<0.001 \)). The trend was similar for both the types of procedures. The incidence of large pericardial effusions were higher with the use of LB needle vs MP needle in patients undergoing lariat procedure (8/6.1% vs 1/0.5%, \( p=0.005 \)) and in patients undergoing VT ablation (7/13% vs 1/2.7%, \( p=0.13 \)) (Table 2). The incidence of pleural effusions was not significantly different with the two needle groups (3/1.6% vs 5/2.3%, \( p=0.64 \) with LB vs MP needles respectively). Injury to liver (n=1) and left anterior descending coronary artery (n=1) occurred in patients in the LB needle group, whereas injury to the superior epigastric artery injury (n=1) occurred in the MP needle group (0 vs 1). Patient with liver injury underwent laparotomy to drain the sub-capsular hematoma. Patient with coronary artery injury underwent coronary angiogram followed by placement of covered stent. Patient with superior epigastric artery injury underwent drainage of rectus sheath hematoma with ligation of injured vessel (See data supplement for details). The incidence of pericardial and pleural effusion effusions were not significantly different in the anterior vs posterior EA.

Minor complications in the form of inadvertent RV myocardial entry was seen frequently with both LB and MP needles (14/7.6% vs 15/6.8%, \( p=0.76 \) respectively). Of the 14 patients who had inadvertent myocardial puncture in the LB needle group, 6 patients needed surgical repair. Of the 15 patients in the MP needle group, none required surgical repair.

On multivariate regression analysis after adjusting for other measured variable, use of
MP needle was associated with 91% decrease in development of large pericardial effusions (OR=0.09, CI: 0.011-0.729, p=0.02) (Table 3).

**Discussion**

Study Findings: In our large, multicenter study, we report that the use of MP needle for EA for interventional pericardial procedures is associated with a decreased risk of large pericardial effusions and subsequent need of surgical repair when compared to using conventional LB needle. Inadvertent myocardial injury is common with both needles, however the injury from the MP needle seems to be more forgiving. To the best of our knowledge, there have been no studies in the literature evaluating the safety and efficacy of MP needle when compared to the LB needle.

EA is being increasingly performed for interventional electrophysiology procedures. Conventionally, EA has been performed with Tuohy needle (Tuohy bevel, 18 gauge, 1.3 x 80 or 150 mm; Braun, Kronberg, Germany) designed to enter virtual spaces or with Pajunk needle (Pajunk Medical Systems, Norcross, GA) in patients undergoing VT ablation. The complications rate with EA has been one of the major limiting factors in performing these procedures. Sacher et al reported a complication rate of 9% in 156 patients undergoing EA with LB needle 5 and the RV puncture accounted for 5% of cases, whereas Della Bella et al reported a complication rate of 4.1% in 218 patients at 6 European centers over a period of 8 years 5,10.

Large pericardial effusion and consequent tamponade are the most feared complications and can be devastating if not emergently treated with frequent draining or with surgical repair 11. In a single center study by Tung et al, major complications were seen in 8.8% of the patients and epicardial bleeding from RV puncture seems to be the major complication 12. Inadvertent RV puncture ranged from 4.5-17% of the cases but majority of these cases had <80ml pericardial
bleeding without serious consequences. Pericardial effusions associated with the epicardial access and the ligation of the appendage using the Lariat causes intense inflammation leading to significant amounts of serosanguineous rather than hemorrhagic effusions. In such cases even if some small amount of blood would make the effusion appear bloody, making it very difficult to assess the actual amount of bleeding. We wanted to use a volume which was clinically more relevant. In contrary to previous studies where “pericardial bleeding” of >80ml was considered large/significant, we have considered >500ml of bloody effusion significant enough to either intervene or delay the drain removal and therefore considered them as “large pericardial effusions”.

Although we had few patients with smaller (<500ml) pericardial effusions, most of these effusions were not clinically significant and none of the patients needed transfusions or additional interventions. Unfortunately we did not consistently collect effusion data when the effusions were smaller or intermediate in all the participating centers.

Newer 21G MP needle is 7-15 cm in length developed by Cook® Medicals Bloomington, IN, used for placement of 0.014 and 0.018 inch diameter wire guides into the vascular systems used initially for the femoral arterial access during cardiac catheterization or during subclavian/axillary vein access during cardiac device placement to minimize the vascular complications and other related collateral damage. MP needle is much smaller at the tip with a smooth shaft to tip transition eliminating hang-ups during the access and is believed to be associated with less trauma during access. Ambrose et al compared the LB needle with MP needle in patients undergoing cardiac catheterization through femoral arterial access and reported a significantly higher vascular event rate using the LB when compared to a MP needle (15.5 versus 9.4%) \textsuperscript{13,14}. 

\begin{center}
DOI: 10.1161/CIRCEP.115.002921
\end{center}
A “dry” EA (as needed to VT ablation and Lariat procedures) is quite different and much more challenging when compared to EA for draining an existing large pericardial effusion. During an EA to drain a large pericardial effusion, the EA needle traverses the soft tissue beneath the sternum and enters the tough pericardium resulting in a sudden “give in” that is safely buffered by the pericardial fluid. However, during a “dry” EA, the safety buffer doesn’t exist and often times the needle inadvertently overshoots into the RV causing some trauma to the myocardium. Despite the complexity of EA and severity of the associated complications, there have not been significant strides in minimizing the complications of EA.

The resistance at the tip of the LB needle is significantly higher than a small bore MP needle while penetrating a tough pericardial tissue. This obviously requires a higher force to facilitate the entry of the needle across the pericardial tissue force required to enter a tough pericardium is much higher for a large bore (greater surface area) needle compared to a micro puncture (lesser surface area). This perhaps explains the reason why a MP needle can be advanced through the pericardium with less force and torque, in a more controlled fashion when compared to an LB needle. The shearing forces of a MP needle on the RV wall are probably lower than a LB needle. Even if there was an inadvertent entry of the RV wall by the MP needle the likelihood of “auto seal” is probably higher than that caused by a LB needle. This is supported by our study findings that despite having a similar incidence of inadvertent RV puncture, major complications were significantly lower when a MP needle was used for EA.

With the current increase in the number of procedures requiring EA, any improvement in the safety of the procedure, as demonstrated in our study by the use of MP needle with or without telescoping approach, would have a positive impact on the learning curve of newer operators. In large patients with significant abdominal soft tissue the outer shorter large bore needle provides
support and through this a long MP needle can be advanced safely without bending facilitating a safer pericardial access.

**Clinical Implications**

EA related complications while performing VT or lariat procedures can be devastating. Use of MP needle instead of conventional LB needle can decrease the incidence of peri-procedural large pericardial effusions and the requirement for surgical repair. Operators should probably consider using a MP needle for EA to improve the safety profile of the procedure routinely.

**Study Limitations**

Ours is an observational multicenter study with its inherent limitations. The use of the type of needles were operator dependent and not randomized. However, it is a fairly large, multicenter study with well-balanced groups. A randomized study comparing the two types of needles may not be really necessary to appreciate the value of a less traumatic MP needle.

**Conclusions**

In our multicenter, observational study, we found that for obtaining EA, the use of MP needle is associated with a significantly decreased risk of peri-procedural large pericardial effusions and subsequent surgical repair when compared to the conventional LB needle. MP needle should be routinely considered for EA access to minimize these major complications.

**Conflict of Interest Disclosures:** L. Di Biase serves as a consultant/advisory board member of Biosense Webster, St. Jude Medical, and Hansen. A. Natale reports honoraria from Biosense Webster and serving as consultant/advisory board member of Janssen, Boston Scientific, Medtronic, and St. Jude Medical. R. Lee is a consultant for SentreHEART Inc, with equity in the company. D. Lakkireddy has received unrestricted research grant from SentreHEART, Inc.;
References


**Table 1:** Comparison of baseline characteristics between use of Large bore (Pajunk/Tuohy needle) (LB needle) vs Micro-puncture needle (MP needle).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>LB Needle (N=185)</th>
<th>MP needle (N=219)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ±SD)</td>
<td>63 ±13</td>
<td>69 ±13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Males (%)</td>
<td>121 (65)</td>
<td>131 (60)</td>
<td>0.24</td>
</tr>
<tr>
<td>Body mass index (kg/m²) (mean ±SD)</td>
<td>30 ±7</td>
<td>30 ±7</td>
<td>0.44</td>
</tr>
<tr>
<td>Caucasians (%)</td>
<td>124 (94)</td>
<td>172 (98)</td>
<td>0.24</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>106 (57)</td>
<td>144 (66)</td>
<td>0.21</td>
</tr>
<tr>
<td>Diabetes Mellitus (%)</td>
<td>46 (25)</td>
<td>65 (30)</td>
<td>0.28</td>
</tr>
<tr>
<td>Strokes (%)</td>
<td>53 (40)</td>
<td>65 (62)</td>
<td>0.22</td>
</tr>
<tr>
<td>Chronic renal insufficiency (%)</td>
<td>27 (15)</td>
<td>34 (16)</td>
<td>0.79</td>
</tr>
<tr>
<td>Ejection fraction (%) (mean ±SD)</td>
<td>49 ±13</td>
<td>52 ±11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CHADS2 score (median ±SD)</td>
<td>2 ±1.3</td>
<td>3 ±1.3</td>
<td>0.05</td>
</tr>
<tr>
<td>CHADS2VASc score (median ±SD)</td>
<td>3 ±1.6</td>
<td>3 ±1.68</td>
<td>0.12</td>
</tr>
<tr>
<td>HASBLED score (median ±SD)</td>
<td>3 ±0.9</td>
<td>3 ±1.19</td>
<td>0.97</td>
</tr>
<tr>
<td>Aspirin use (%)</td>
<td>77 (75)</td>
<td>89 (64)</td>
<td>0.06</td>
</tr>
</tbody>
</table>
**Table 2**: Comparison of complications associated with use of LBN vs MPN.

<table>
<thead>
<tr>
<th>Complications</th>
<th>LB Needle (N=185)</th>
<th>MP needle (N=219)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MAJOR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large pericardial effusion</td>
<td>15 (8.1)</td>
<td>2 (0.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>- requiring drainage</td>
<td>-</td>
<td>9 (4.5)</td>
<td>-0.01</td>
</tr>
<tr>
<td>- open heart surgery and repair of the ventricle or coronary</td>
<td>-</td>
<td>6 (3.2)</td>
<td>-0.007</td>
</tr>
<tr>
<td>Other major complications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Liver hematoma and surgical drainage</td>
<td>-1 (0.6)</td>
<td>-0</td>
<td></td>
</tr>
<tr>
<td>- Injury to coronaries</td>
<td>-1 (0.6)</td>
<td>-0</td>
<td></td>
</tr>
<tr>
<td>- Superior epigastric artery puncture</td>
<td>0</td>
<td>-1 (0.5)</td>
<td></td>
</tr>
<tr>
<td><strong>MINOR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadvertent right ventricular entry with no significant pericardial effusion</td>
<td>14 (7.6)</td>
<td>15 (6.8)</td>
<td>0.769</td>
</tr>
</tbody>
</table>
Table 3: Predictors of development of large pericardial effusion

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio</th>
<th>Confidence Interval</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of MP needle</td>
<td>0.09</td>
<td>0.011-0.729</td>
<td>0.02</td>
</tr>
<tr>
<td>Age</td>
<td>1.014</td>
<td>0.940-1.093</td>
<td>0.71</td>
</tr>
<tr>
<td>BMI</td>
<td>1.024</td>
<td>0.937-1.119</td>
<td>0.60</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>2.572</td>
<td>0.514-12.86</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Figure Legends:

**Figure 1:** The largebore (LB) Pajunk needle (18 Fr) and a long micropuncture (MP) needle (21 Fr). The lower most picture shows the long MP needle is introduced through the large short needle in a telescoping approach.

**Figure 2:** EA using a LB pajunk needle. A – marking the general approach to the pericardial access aiming towards the left shoulder; B – entry of the LB Pajunk needle below the Xiphoid process; C – Entry of the LB Pajunk needle into the pericardial space with staining of the pericardial tissue; D – Staining of the pericardial tissue in the AP view; E – Wiring of the pericardial space with a 0.032 wire.

**Figure 3:** shows the pericardial access using a long micropuncture needle. Panel A to C show the different stages of the EA with wiring in the left lateral view. Panel D to F show the same in the AP view.
Largebore Pajunk Needle

Micropuncture Needle

Micropuncture Needle with telescoping approach
Differences in Complication Rates between Large Bore Needle and a Long Micropuncture Needle during Epicardial Access - Time to Change Clinical Practice?
Sampath Gunda, Madhu Reddy, Jayasree Pillarisetti, Moustapha Atoui, Nitish Badhwar, Vijay Swarup, Luigi Di Biase, Sanghamitra Mohanty, Prashanth Mohanty, Hosakote Nagaraj, Christopher Ellis, Abdi Rasekh, Jie Cheng, Krzysztof Bartus, Randall Lee, Andrea Natale and Dhanunjaya Lakkireddy

_Circ Arrhythm Electrophysiol._ published online June 15, 2015;
_Circulation: Arrhythmia and Electrophysiology_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2015 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-3149. Online ISSN: 1941-3084

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circep.ahajournals.org/content/early/2015/06/15/CIRCEP.115.002921

Data Supplement (unedited) at:
http://circep.ahajournals.org/content/suppl/2015/06/15/CIRCEP.115.002921.DC1

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Circulation: Arrhythmia and Electrophysiology* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Circulation: Arrhythmia and Electrophysiology* is online at:
http://circep.ahajournals.org/subscriptions/
Supplemental Material

Management of complications: Liver injury, Left anterior descending coronary artery and superior epigastric artery:

One patient developed “liver injury” with the use of LB needle. After successful ventricular tachycardia ablation, patient became hemodynamically unstable with no evidence of pericardial bleeding. Emergent CT scan revealed a moderate to large sub-capsular hepatic hematoma. After initial stabilization and blood transfusion, patient underwent midline laparotomy with drainage of the blood, placement of laparotomy pads followed by manual compression which contained the bleeding. Then peri-hepatic packing was placed with close monitoring post operatively. The packing was removed after 24 hrs and the patient did well over the next few days without any other complications.

One patient had distal left anterior descending coronary artery puncture with the use of LB needle during EA for ventricular tachycardia ablation. Following EA, this patient had new ST elevations in the lateral precordial leads followed by persistent bloody pericardial effusions that did not stop even after reversing the anticoagulation. Given the high clinical suspicion for coronary injury, patient underwent coronary angiography which revealed the perforation of LAD between mid- distal portion and successfully stented (covered stent) without further complications.

Patient with superior epigastric artery injury had persistent leak from the epicardial access site post procedurally. Ultrasound examination of the abdomen revealed a rectus sheath hematoma of 4X4 cm in size. Patient was hemodynamically stable. However given persistent bleeding and significant pain, exploration of the rectus sheath was performed with evacuation of the hematoma followed by ligation of injured artery. Patient was monitored closely over a period of 24 to 48 hours without further complications.