Multimodal imaging employed during extraction of pacing or defibrillator leads from perfusion-fixed human hearts

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Introduction

Lead extractions are relatively low risk, but the complications of superior vena cava (SVC) tear and cardiac avulsion have a high mortality.[1] Clinical factors such as lead dwell time, patient age, presence of implantable cardioverter-defibrillator (ICD) SVC coils, and number of indwelling leads are parameters that predict risks and procedural complexities. However, there is considerable patient-to-patient variation. It is not unusual for the patient to be a "black box" of unknown challenges for the extractor. Recently, there has been a considerable amount of energy invested into employing advanced imaging that can improve lead extractions. Current literature has reported added benefits of using computed tomography (CT) and ultrasound.[2–4] In some cases CT can inform the extractor of vascular patency, lead binding sites, and perforations.[5] Similarly, ultrasound can further detail the vascular binding sites[2,5] that can result in serious complications during extractions. We also believe that CT and ultrasound imaging define individual patient challenges, such as lead–tissue attachments and cardiac perforations.

In this report, we demonstrate CT and intracardiac echocardiography (ICE) images that provide the extractor with critical insights relative to lead–tissue interfaces. We also employ videoscopes to highlight the correlations between direct visualization and CT or ICE in human hearts, supporting the beneficial role of advanced imaging in lead extractions. By studying these images in this unique setup, the common tools used can enhance understanding and inform clinical decisions and techniques.

KEY TEACHING POINTS

- A cardiac computed tomography (CT) scan prior to a lead extraction procedure can aid in preprocedural planning and define case challenges.
- The use of intracardiac echocardiography (ICE) imaging can further define those challenges intraprocedurally.
- Comparing CT and ICE images to direct endoscopic visualizations allows for better understanding of clinical imaging.

Case report

This study was approved by the research committee of LifeSource (Minneapolis, MN), a regional organ and tissue procurement organization. Human hearts with previously implanted leads were donated and preserved in our Visible Heart Laboratories (University of Minnesota). Heart 0172 was from an 89-year-old woman (54 kg, 1.57 m) who had dual-chamber Medtronic 5076 pacing leads (active fix, 6F, Minneapolis, MN). Heart 0034 was from a 67-year-old man (73 kg, 1.85 m) with a history of cardiomyopathy. A Sprint Fidelis 6.6F right ventricular (RV) lead had been implanted with an active fix pacing lead (Medtronic) in the right atrium (RA). The cause of death in both cases was deemed as *natural*.

Before each study, hearts were scanned with a Siemens CT scanner (Munich, Germany). Next, they were

KEYWORDS Complications; Human hearts; Imaging; Lead extraction; Ultrasound
(Heart Rhythm Case Reports 2020;6:918–921)

Funding: This study was supported by Medtronic (research contract), and the Institute for Engineering in Medicine, University of Minnesota. Sponsors had no involvement in study design, data collection/analysis/interpretation, report writing, or decision to submit for publication. Disclosures: Dr Iaizzo has a research contract with Medtronic; Dr Eggen is employed by Medtronic; and Dr Vatterott is a consultant with Medtronic, Boston Scientific, Philips, Cook Medical, and Inspire. M. Holm has no conflicts to disclose. **Address reprint requests and correspondence:** Dr Paul A. Iaizzo, University of Minnesota, 420 Delaware St SE, B195 Mayo, Minneapolis, MN 55455. E-mail address: iaizz001@umn.edu.

https://doi.org/10.1016/j.hrcr.2020.08.025

cannulated and perfused with a clear buffer that flowed through the heart chambers with a pulsatile pump. Leads were then extracted with mechanical or laser sheaths. We collected intraprocedural multimodal visualizations with ICE (Boston Scientific, Marlborough, MA), fluoroscopy (Ziehm Imaging, Nuremberg, Germany), and videoscopes (Olympus, Tokyo, Japan). These unique images were used by the extractor to better understand the relationship between direct visualization and obtained clinical imaging. With the help of advanced imaging in the clinic, patient challenges can be identified before extraction procedures are performed.

Discussion

The lead extraction procedures performed in these perfusion-fixed human hearts can be viewed in the Online Video. For Heart 0172, the CT images showed that the RV lead had multiple attachments to the tricuspid valve. The lead was severely adhered to the septal leaflet. Of interest, a nearly identical image was obtained using ICE (Figure 1), which delineated lead involvement within the tricuspid apparatus. This finding was verified with direct visualization.

Footage of the RV lead passing through the septal leaflet of the tricuspid valve before its successful extraction can be seen in Figure 1A; the white probe in the valve annulus is the ICE probe. On the corresponding ICE image (Figure 1C), one can observe the lead surrounded by the septal leaflet. Figure 1D displays a 2-dimensional view of the CT scan that highlights the lead body intertwined in the valvular anatomy. Similarities between the CT, ICE, and videoscopic images accentuate the relationship between clinical images and what is actually happening inside the patient.

The right-left twisting action of the TightRail sheath (Philips, Eindhoven, Netherlands) was used to free the implanted lead from the scar in the SVC. The small incorporated blade can be seen protruding 0.5 mm from the sheath in the Online Video. Both the TightRail and GlideLight Laser Sheaths (Philips) were used to remove the lead from the tricuspid valve. When tension was applied to the lead, the tension was transferred from lead to leaflet. Visualization of the approaching laser demonstrates how a tricuspid valve may be significantly damaged during the extraction process, depending on the degree of lead–tissue interaction. Knowledge of this interaction allows the procedural physician to potentially alter the technique to protect the tricuspid valve apparatus during the lead extraction.

In the case of Heart 0034, ICE imaging helped to identify significant lead–tissue attachment at the SVC-RA junction, matching the feedback from CT analysis. The Sprint Fidelis ICD lead (red arrows) can be seen deeply engaged in the tissue relative to the pacing lead (green arrows) in both ICE and videoscopic images (Figure 2).

Figure 2A displays the ICE probe next to the leads at the SVC-RA junction. In the ICE image (Figure 2C), the ICD lead was encapsulated in the tissue and therefore appeared as integrated in the vessel wall (red arrow). The pacing lead was positioned more toward the center of the lumen (green arrow). By studying these correlated images, we hope future extractors can translate the knowledge from this unique study to the clinic by using appropriate imaging to help identify case challenges early on, such as during case planning. This strategy gives extractors time to adjust how they approach cases, including adding or changing tools or modifying resources available. This will, we hope, lead to more successful and safer lead extractions.

Limitations

A limitation of this study is that these human hearts were perfusion fixed, making it easier to compare static CT and ICE images. Nevertheless, gated CT imaging can correlate with ICE.[5] Though other ultrasound imaging modalities such as transesophageal echocardiography or phased-array ICE were not used in this study, these are currently employed to facilitate lead extractions[2] and should produce similar results. Another limitation of this setup is the use of the ICE probe without a steerable sheath. Advancing the ICE probe could result in vascular complications in some cases. Risk is minimized in patients by placing the ICE catheter within a steerable sheath.

Vascular space was not an issue in either of the specimens studied here, though sometimes SVC occlusion means ICE cannot be used. Further, artifacts and reverberations can contaminate image interpretation. Using the steerable sheath with the ICE probe to view the leads from multiple angles decreases the chance of an incorrect image interpretation.

Clinically, the cost of including imaging in an extraction is important. Ongoing clinical trials assessing new CT and ICE technologies are attempting to determine if case challenges can be identified in the planning stages. This would define required resources (ie, on-call cardiovascular surgery team) and, it is hoped, reduce procedural costs.

Conclusions

We presented correlations between CT, ICE, and direct visualization within perfusion-fixed human specimens, highlighting how imaging can define potential patient-specific challenges. Often, a CT scan prior to lead extraction can both define patient challenges and assist with procedural planning. ICE can further define those challenges and guide decision-making. The educational footage provided here emphasizes how imaging sheds light on the “black box” of challenges presented with each extraction patient.

We hope this article encourages the use of additive clinical imaging modalities during lead extractions and also advances lead extraction imaging in the research setting. With growing interest in lead extraction imaging, the development of future innovations such as CT

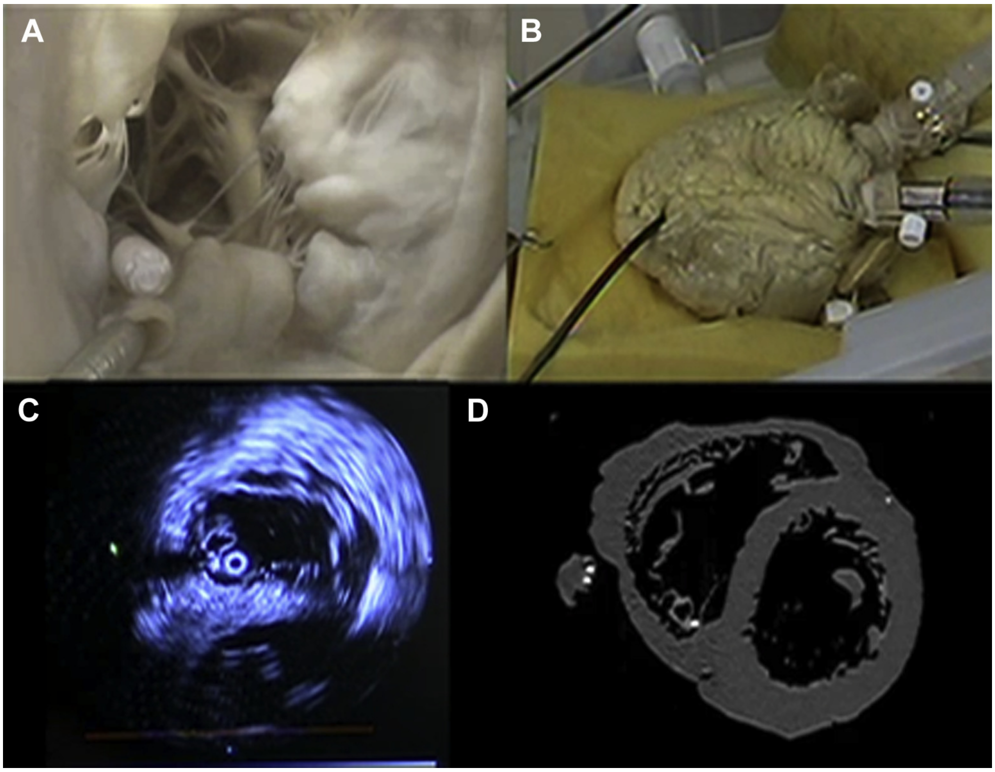

Figure 1 Similarities of computed tomography (CT) imaging and intracardiac echocardiography (ICE) imaging in Heart 0172. **A:** Cannulated, fixed human heart. **B:** Right ventricular lead passing through the septal leaflet of the tricuspid valve, before successful extraction. The probe with the white tip near the valve annulus is the ICE catheter. In the corresponding ICE image (**C**), the septal leaflet can be seen. **D:** Slice of the CT scan that highlights the bright lead body intertwined within the valve leaflet.

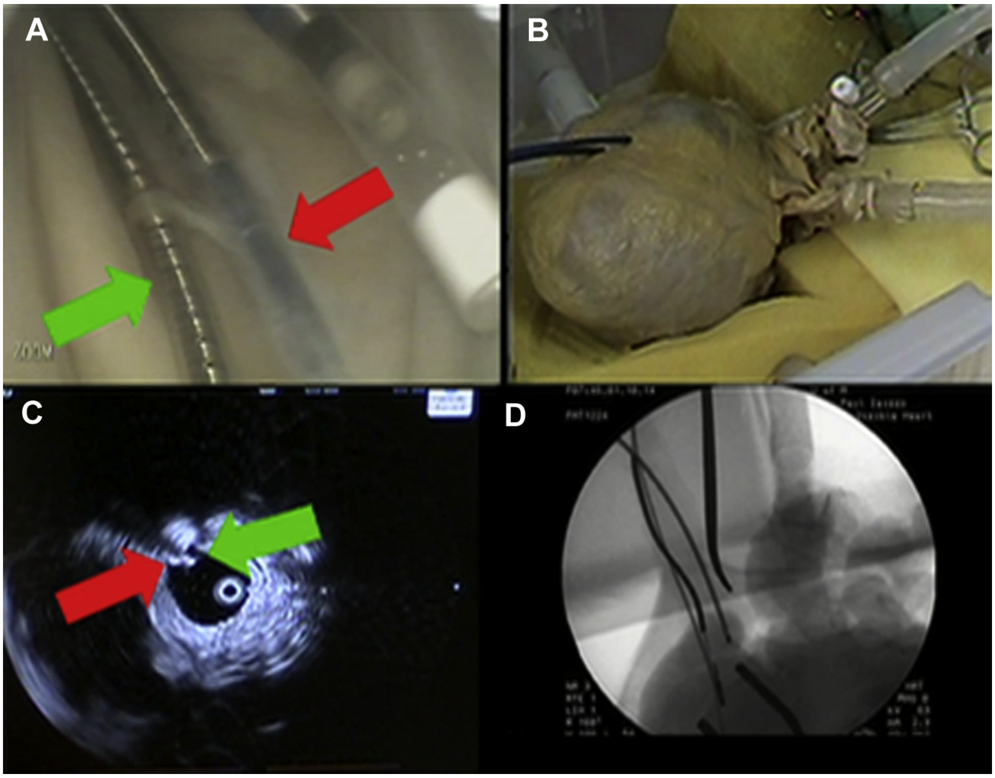

Figure 2 Multimodal imaging of Heart 0034 including **A:** videoscopic, **B:** overhead, **C:** intracardiac echocardiography (ICE), and **D:** fluoroscopic. This heart elicited high degrees of lead–tissue adherence around the superior vena cava–right atrium junction, as observed in the ICE imaging (**C**). This image shows an encapsulated lead (*red arrow*) behind the other lead (*green arrow*) within the vessel lumen.

algorithms and improved ultrasound techniques will be expedited, benefiting all patients.

Acknowledgements

We acknowledge Boston Scientific for use of ultrasound system.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2020.08.025.

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