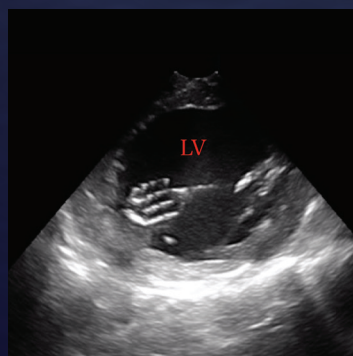
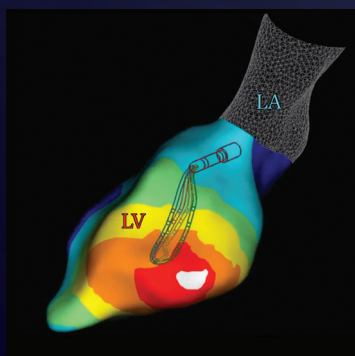
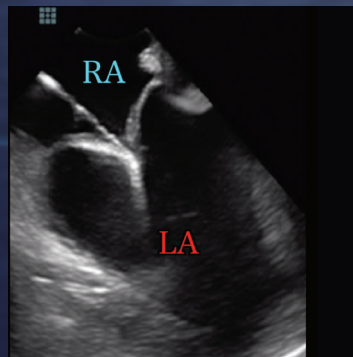
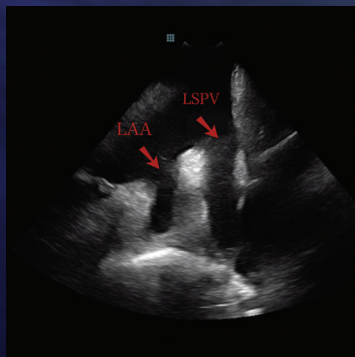
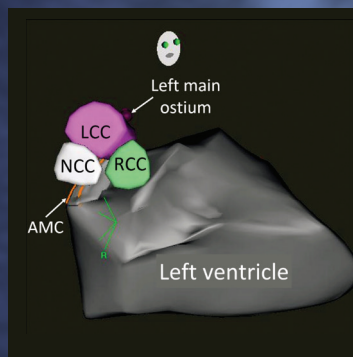
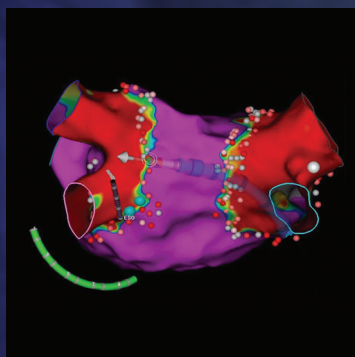


FLUOROSCOPY REDUCTION TECHNIQUES

for Catheter Ablation
of Cardiac Arrhythmias

Includes
Digital Edition
with Videos



Editors:

MANSOUR RAZMINIA

PAUL C. ZEI

Forewords by:

AMIN AL-AHMAD

WILLIAM G. STEVENSON

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Editors:

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Preface

Dear Readers,

We are excited and delighted to present to you what we hope is a comprehensive, state-of-the-art, yet practical overview of the rationale, methodology, and **“hands-on” tips and tricks for reduction or elimination of fluoroscopy during mapping and catheter ablation of cardiac arrhythmias**. We intend this text to address the entire spectrum of commonly (and less commonly) performed procedures. We envision a hands-on guide that will assist the electrophysiologist and their team in the electrophysiology laboratory to safely and effectively work toward significant reduction in fluoroscopy utilization.

At the time of this writing, it is quite clear to most every electrophysiologist that **reducing radiation exposure to the patient, physician, and EP lab staff is a critical goal for multiple reasons**. If we consider the “As Low as Reasonably Achievable (ALARA)” tenet for radiation exposure and risk, **the ultimate goal should be the complete elimination of fluoroscopy exposure**, and hence associated risk. Indeed, even very low exposure is still too much exposure if the alternative is zero radiation exposure, so long this alternative remains safe and can allow the electrophysiologist to achieve successful outcomes no worse than otherwise. One of the many pleasant surprises to which most every author in this text and we can attest is an observation that **procedural safety has likely improved significantly after adoption of these techniques**. It turns out that having a more realistic, real-time visualization of catheter vs. tissue relationships improves the operator’s understanding of catheter location and hence lowers risks of perforation or other traumatic complications. These observations are beginning to be borne out in the ever-growing literature evaluating fluoroscopy-free or minimal fluoroscopy catheter ablation.

There is an inherent challenge to writing a text on this subject at this time in our field. It is fair to say that there has yet to be widespread adoption of the techniques outlined in this text. Moreover, the technological tools available to assist all of us in this process continue to evolve, improve, and mature. As a result, providing the most up-to-date advances, data, and recommendations is critical to ensuring the reader has a useful reference that can be utilized for quite some time. We believe the combination of a host of expert and experienced authors and a **rich library of videos** accompanying this text serves that goal.

There are a few bookkeeping points we would like to make. The first is terminology. Nearly every author in this text has fully adopted a completely fluoroscopy-free approach to their procedures. Keep in mind that at the time of this writing, this approach is an off-label use of most of the tools and technologies described in our text. However, as our authors have relayed over and over again throughout our text, both the available published data and their vast personal experiences have demonstrated safety and efficacy of this approach. Second, a completely non-fluoroscopic procedure is an easily defined entity, as zero radiation is zero radiation. But, how do we define *reduced* fluoroscopy? Reduced in relation to what standard? Numerous references report “typical” fluoroscopy utilization during common ablation procedures, so is an EP physician’s average fluoroscopy use below those reported numbers considered reduced? Or should the standard be something else? We argue that in the context of our text, fluoroscopy reduction should be seen as a notable reduction in fluoroscopy reliance in the reader’s personal usage in most cases. **Fluoroscopy should be viewed as generally unnecessary, or at best a modality needed in a very narrow range of situations**. There will always be challenging cases where fluoroscopy may have a role, but an overall significant reduction should be at least the initial goal.

As you read through each chapter, you will notice several things. First, there is clearly diversity in some details on how to perform aspects of each particular procedure. That is inherent to our field in general, and there is by no means a need to alter one’s entire workflow to accommodate fluoroscopy reduction or elimination. On the other hand, there are several important common themes you will notice. The importance of both ICE and EA mapping goes without saying. **Core**

competencies that should absolutely be mastered in a fluoroscopy-free approach include ultrasound-based vascular access (Chapter 5), ICE-guided transseptal puncture (Chapter 6), familiarity (if not expertise) in ICE manipulation and views (Chapter 2), and a thorough understanding of the underlying principles, capabilities, and limitation of mapping systems. In the latter regard, your local clinical specialist for your mapping system can prove to be an invaluable resource.

Speaking of mapping systems, we want to also emphasize some additional important points. One critical theme in this text is that we charged the authors, when possible, to provide information that is agnostic to the specific mapping system or ICE system. You will see that each author clearly has more experience with one system or another, and so the expertise they convey will be focused on that system. **However, we have ensured that the general principles discussed are applicable across platforms, and if indeed there are features or limitations specific to one system or another, those are addressed appropriately.**

We would also like to point out some interesting observations that we have made during our journey through this process. As implied earlier, we have all noticed anecdotally, now more and more corroborated by published data, that **a fluoroscopy-free approach appears to be associated with improved safety, i.e., fewer complications.** We postulate several factors. Vascular access guided by ultrasound allows direct visualization of the vascular structures and their relationships. This is a vast improvement to either an approach based on physical landmarks or fluoroscopy, as neither of these traditional approaches can visualize these relationships. Second, **some of the simplest and most straightforward ablation procedures we perform have potentially been significantly improved.** When ICE is utilized during typical CTI ablation, for instance, commonly as an adjunct to PVI when clinically indicated, we have acquired a significantly improved understanding of the local anatomy, as structures that cannot be otherwise easily visualized are seen on ICE, including prominent Eustachian ridges, CS ostia, trabeculations, and so on. Indeed, on many occasions, it is specifically these anatomic variants that have hindered successful ablation, and visualization has helped to identify the issue at hand. This principle also applies to many, if not most of the other commonly performed ablation procedures. Moreover, aside from whether or not one utilizes contact force sensors during catheter ablation, **the ability to see in real-time catheter vs. myocardial relationships is vastly improved over fluoroscopic imaging.** This very likely improves both safety and efficacy.

At the time of this publication, we realize that areas of need for further fluoroscopic reduction include primarily epicardial access-based procedures and device implantation. As of this writing, there are operators out there working towards these goals, and we expect new chapters to be added on these and other topics in future editions of this text.

Some final words of advice. The fluoroscopy reduction journey, of course, involves a learning curve. We suggest breaking down each procedure into individual sub-steps and working on fluoroscopy reduction for each step. For instance, for PVI, start with adaptation of ultrasound-guided vascular access, then once mastered, perhaps work on catheter placement, then move on to left atrial mapping and ablation, including esophageal monitoring, and finally work on transseptal puncture. During this process, please feel free to reach out to any of the authors in this text. One of the wonderful aspects of our field is that it is populated with generous and humble individuals, and we are all explicitly available if you would like to contact us with further questions or if you would even like to visit our EP labs to observe procedures. In fact, several of us have been hosting visitors for quite some time already.

Again, thank you for your interest in this topic, and we wish you all the success in achieving your goals.

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How to Perform Radiofrequency Ablation of Atrial Fibrillation Using No Fluoroscopy

Robin Singh, MD; Paul C. Zei, MD, PhD

Background

Radiofrequency (RF) catheter ablation for atrial fibrillation (AF) has evolved significantly since the first description of targeting focal pulmonary vein (PV) triggers by Haïssaguerre and colleagues.¹ The field has witnessed an evolution and refinement of various RF techniques, including abandonment of a segmental, ostial approach² in favor of antral circumferential lesion sets,³ in large part to minimize the risk of PV stenosis. Point-by-point contiguous lesions have given way to continuous “drag” lesion sets, resulting in shorter procedural times and increased durability of PV isolation (PVI).⁴ A growing number of operators are adopting a short-duration, high-power (up to 50 W) RF ablation approach,⁵ given dramatically shorter reported procedural times, and a theoretical benefit of creating effective lesions primarily through resistive heating, while minimizing conductive heating that may increase the risks of thermal injury to extra-cardiac structures. Lesion durability has also likely improved due to numerous technological innovations, including irrigated tip ablation catheters with contact force sensing, steerable sheaths, as well as real-time measures of ablation energy delivery.^{6,7}

While PVI remains integral for both paroxysmal and persistent AF patients, the utility of additional ablation remains unclear given the results of STAR AF II⁸ and other studies.⁹ As a result, there remains considerable

heterogeneity in approaches to persistent AF. The current approach of the authors is to target organized atrial arrhythmias following PVI with focal or linear ablation, but if AF persists, to perform external cardioversion with subsequent attempts to induce non-PV triggers with programmed atrial stimulation and/or administration of chronotropic agents such as IV isoproterenol. A voltage map in sinus rhythm may help localize abnormal, potentially proarrhythmic substrate that may be targeted for ablation (**Figure 13.1**). Posterior wall isolation¹⁰ may be pursued in select patients presenting for repeat procedures, while targeting complex, fractionated electrograms (CFAE)¹¹ or mapping rotors,¹² and other additional ablation targets remains relatively controversial (e.g., Topera, Abbott, Abbott Park, IL).¹³ Various complex mapping catheters, enabling the rapid acquisition of a large number of data points during electroanatomic mapping (EAM), have facilitated techniques for rapid and precise mapping of potential ablation targets and validating clinical end points (e.g., PentaRay, Biosense Webster, Irvine, CA; Rhythmia, Boston Scientific, Charlestown, MA; Advisor HD Grid Mapping Catheter, SE, Abbott). While discussing the merits of the aforementioned approaches is beyond the scope of this chapter, we aim to provide insights into the fundamental approaches to low/zero fluoroscopy mapping and ablation, which can be adapted to future techniques, with current zero-fluoroscopy techniques utilizing primarily EAM and intracardiac echocardiography (ICE).

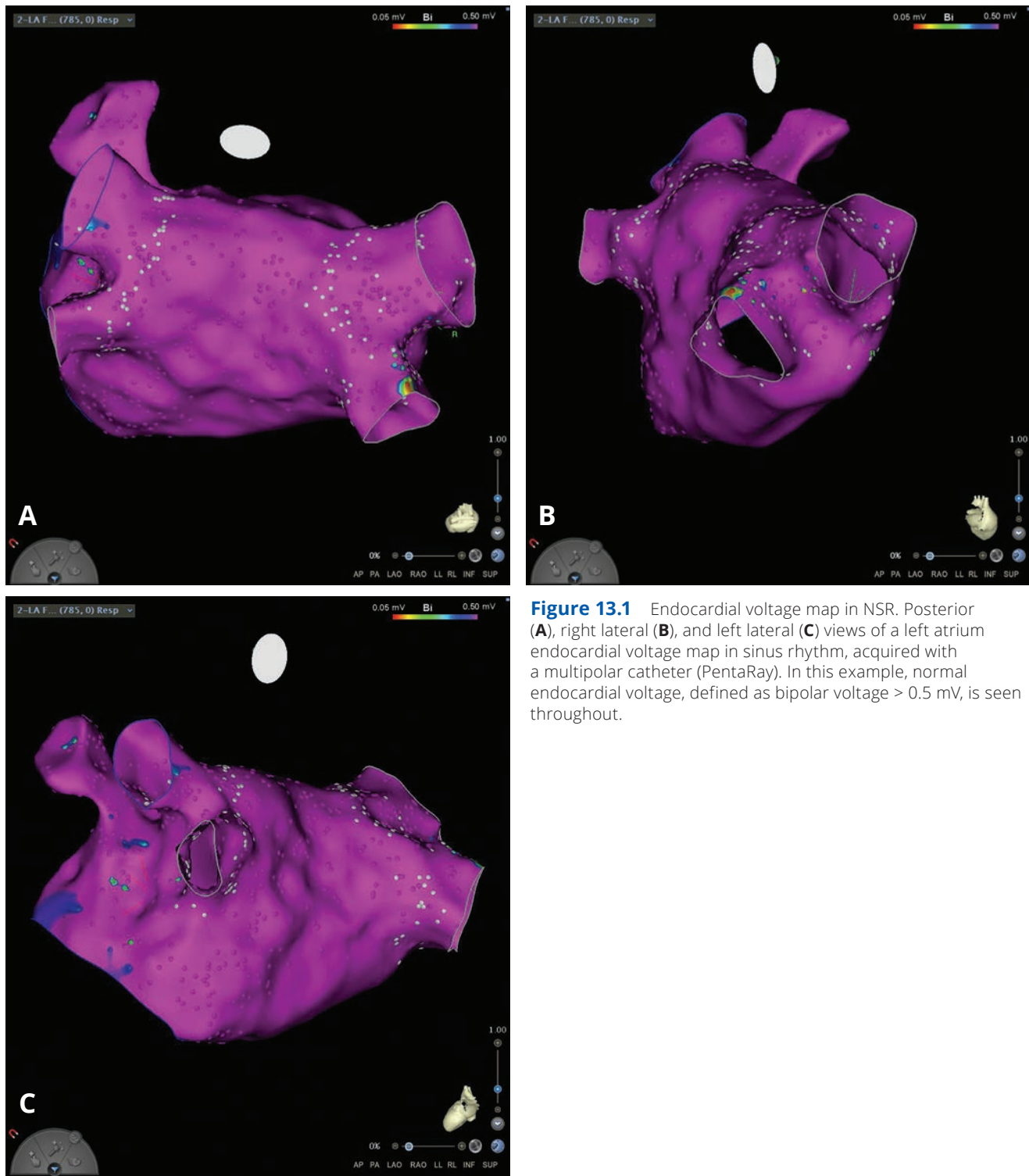


Figure 13.1 Endocardial voltage map in NSR. Posterior (A), right lateral (B), and left lateral (C) views of a left atrium endocardial voltage map in sinus rhythm, acquired with a multipolar catheter (PentaRay). In this example, normal endocardial voltage, defined as bipolar voltage > 0.5 mV, is seen throughout.

Procedure

Access and Catheter Placement

The absence of an intracardiac thrombus is typically confirmed with a preoperative TEE, although there is increasing utilization of ICE to interrogate the left atrial appendage (LAA) intraprocedurally.¹⁴ Following

induction of general anesthesia, bilateral femoral venous access is obtained utilizing a vascular ultrasound probe (Chapter 5), with placement of access sheaths for advancement of catheters. These include a multielectrode mapping catheter (e.g., PentaRay or Lasso, Biosense Webster; Advisor HD Grid Mapping Catheter, SE,

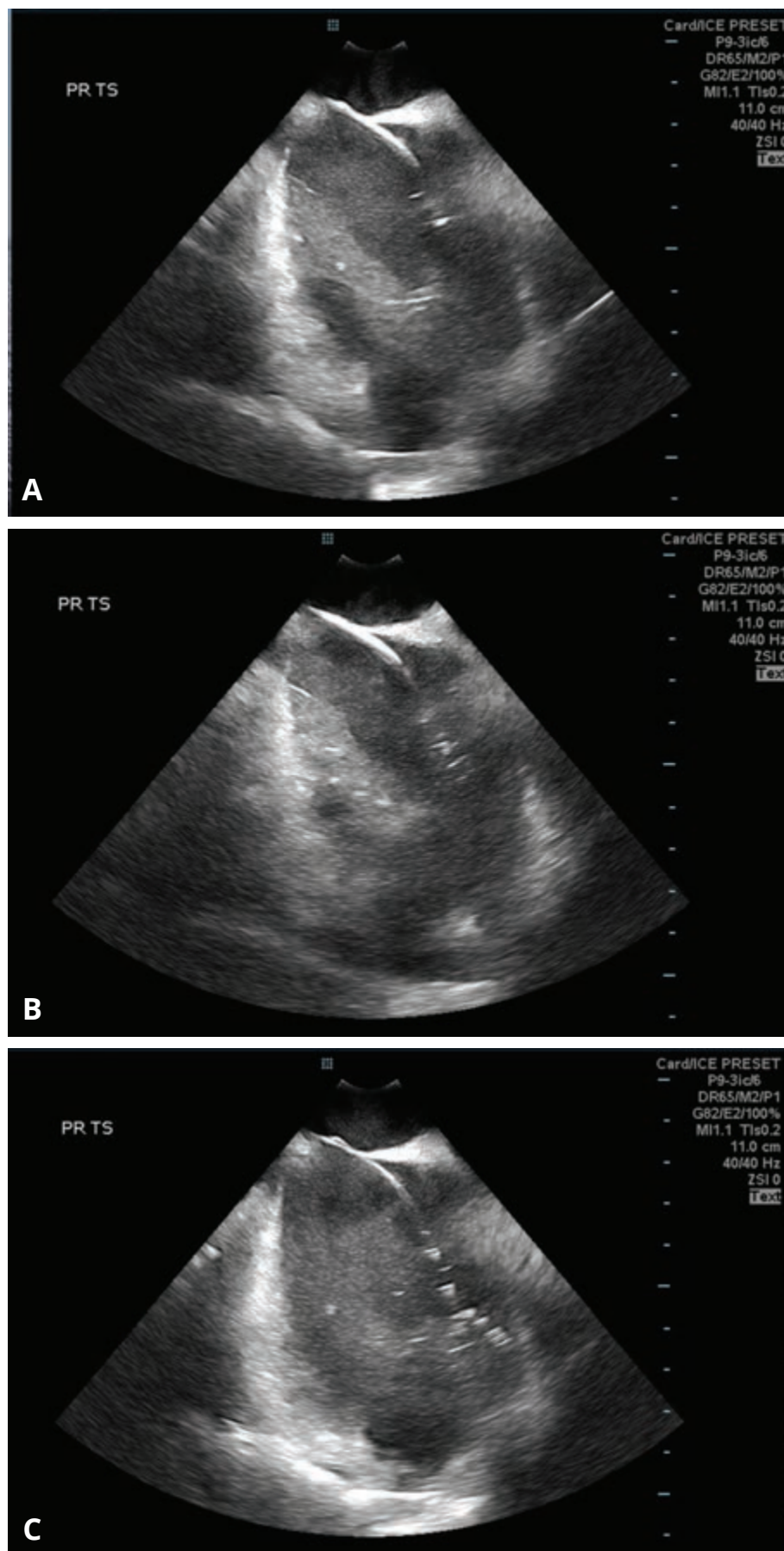


Figure 13.2 Visualization of catheters on ICE (long transseptal sheath). In this image, the ICE probe is directed towards the left atrium, toward the left superior pulmonary vein and posterior wall. A PentaRay mapping catheter is directed towards the left superior pulmonary vein (LSPV), with progressive still images of the advancement of the transseptal sheaths (A-C). Please see [Video 13.1](#) for additional images.



Figure 13.3 Visualization of the esophageal probe location on CARTO. A PA view of a left atrial endocardial map, with visualization of a quadripolar (Josephson, Abbott) mapping catheter attached to the esophageal temperature probe within the esophageal lumen. Note that the quad catheter is typically attached at a fixed offset from the tip of the temperature probe to prevent the possibility of RF/heat transfer to the quad electrodes (see text). In this example, the esophageal temperature probe (and esophagus) are located adjacent to the right inferior pulmonary vein.

Ablation

The ablation and high-density mapping catheters are advanced via the steerable and fixed curve long sheaths, respectively, to the LA via ICE (**Figure 13.4**). A dense (typically >2000 points) EAM is created of the LA,

identifying all the PVs, the LAA, and the mitral valve (MV) annulus. RF energy is then delivered to create a continuous WACA lesion set around each pair of ipsilateral PVs. Specific catheter movements may be accomplished through direct catheter steering mechanisms or with augmentation with the long steerable sheath. Most sheaths currently are not directly visualized in the mapping system; thus, catheter curve, direction, and extension within the LA must be visualized through ICE. Utilizing a sheath that can be visualized within the mapping system (Vizigo, Biosense Webster) can facilitate this process (**Figure 13.5**). As mentioned, the authors typically utilize a hybrid drag approach with continuous RF delivery, maintaining the catheter at each ablation location for a prescribed time based on a combination of variables including power, anatomic location, catheter stability, impedance decrease, and electrogram amplitude diminishment.

At the time of this writing, the evolution of several novel RF delivery strategies is ongoing, with the potential for these various techniques to be incorporated into standard AF RF ablation in the future. Real-time measures of RF energy delivery that may predict lesion formation include ablation index (AI), which incorporates contact force, power, and time of RF,⁶ force-time integral (FTI), which simply integrates contact force over time,⁷ may have benefit. Delivery of short duration (4–5 seconds), high power (50W) lesions in order to shorten lesion formation time and minimize lesion depth is also gaining acceptance.⁵ Automated algorithms to mark RF ablation sites have also been developed.¹⁶ It is quite likely that such approaches can be easily incorporated into a reduced/zero fluoroscopy workflow.

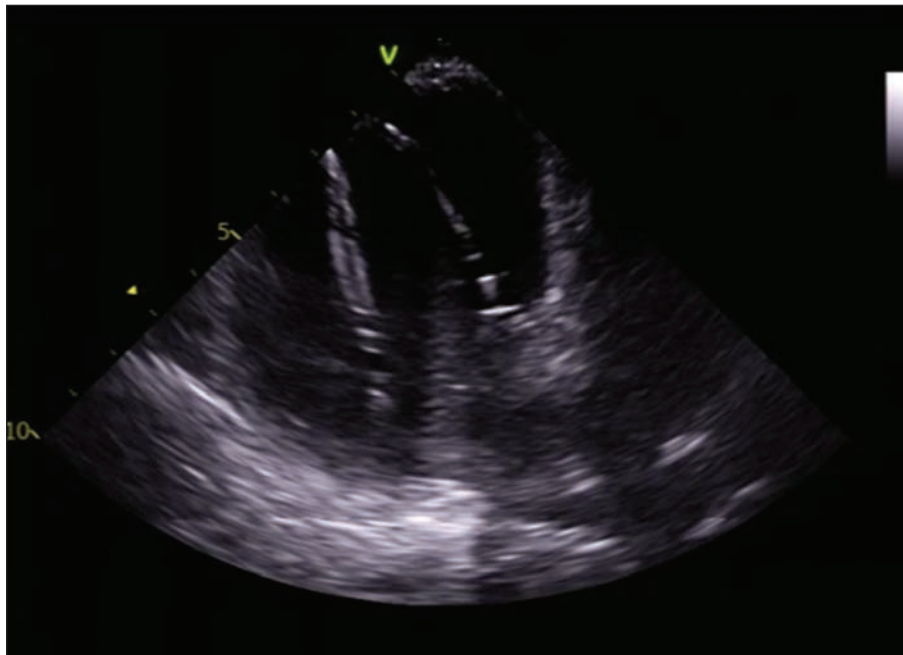


Figure 13.4 ICE visualization of PentaRay and SmartTouch introduced in LA. An ICE image of the left atrium demonstrates both a PentaRay and ablation catheter in the left atrium, directed towards the LSPV and posterior wall, respectively. Please see **Video 13.2** for additional information.

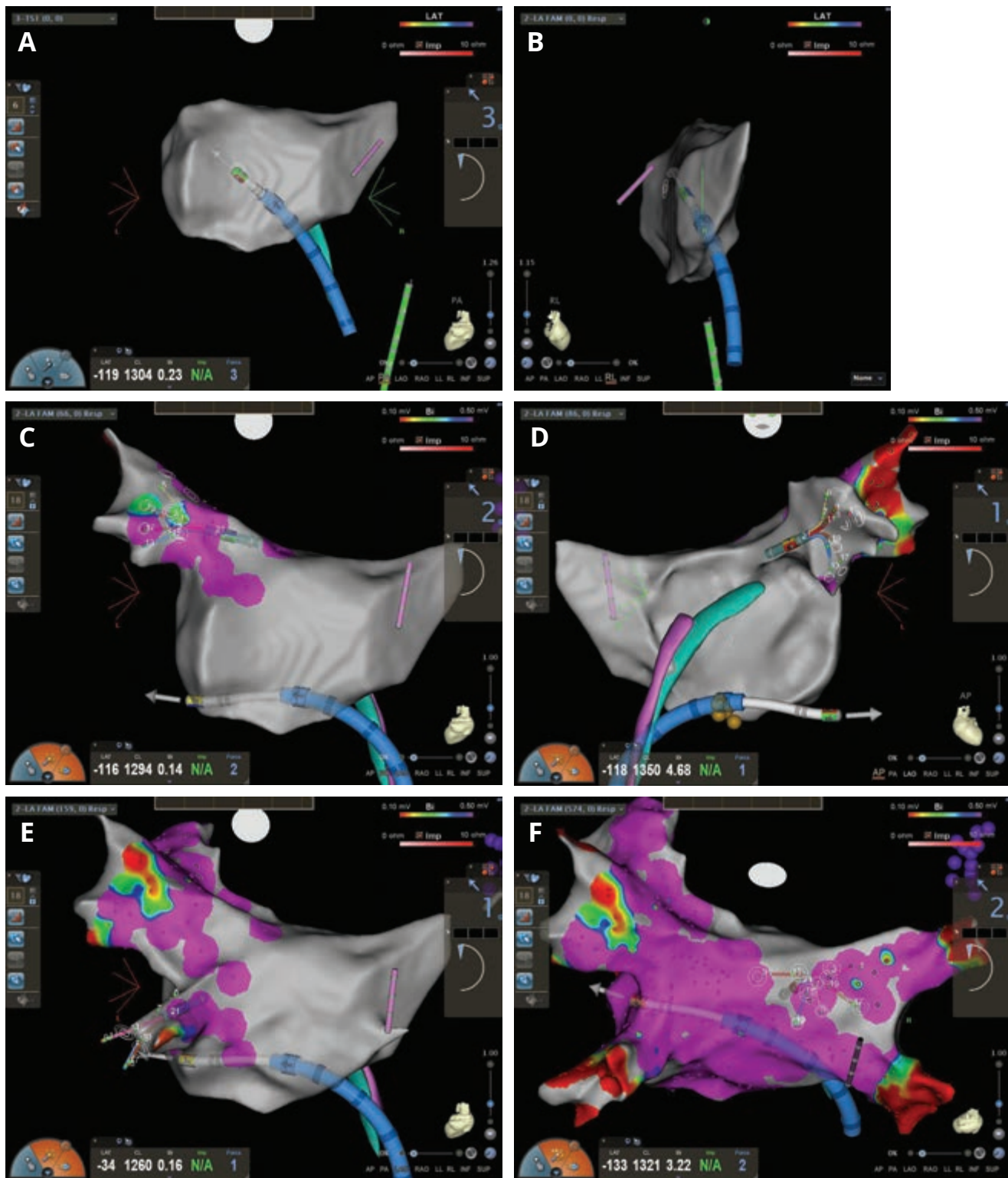


Figure 13.5 Steerable sheath (Vizigo) visualization on CARTO. Still images of endocardial mapping with a multipolar (PentaRay) catheter, with the ablation catheter visualized within the left atrium, passed through a steerable sheath visualized on the mapping system. This allows reliable manipulation of the steerable sheath (and ablation catheter) primarily via the mapping system. Note that Figures 13.5A–F show progressive mapping creation of an endocardial left atrial map using a multipolar mapping catheter (PentaRay) and ablation catheter (Smartouch STSF), with assistance of a steerable sheath (Vizigo) that can be visualized on the mapping system.

How to Perform Papillary Muscle Premature Ventricular Complex Ablation Using No Fluoroscopy

Oliver D'Silva, MD; Hany Demo, MD;
Theodore Wang, MD; Mansour Razminia, MD

Introduction

Ablation of ventricular ectopy originating from the left ventricular papillary muscles poses unique challenges. The complex 3-dimensional (3D) structure of the papillary muscles is often difficult to appreciate using fluoroscopy and a 3D mapping system alone. Furthermore, maintaining catheter stability while mapping and ablating on these mobile structures is another challenge. A non-fluoroscopic approach that involves a high reliance on intracardiac echocardiography (ICE) may actually enhance procedural success, as it allows for a better understanding of the papillary muscle anatomy and for monitoring catheter stability during mapping and ablation.

Procedure

Choice of Access to the Left Ventricle

Ablation of ventricular arrhythmias involving the papillary muscles may be performed via a transeptal or retrograde aortic approach. The retrograde approach may be preferred for the posteromedial papillary muscle (PMPM) and the medial aspect of the anterolateral papillary muscle (ALPM). Transeptal access may be more suitable to address arrhythmias arising from the lateral aspect of the ALPM.¹ When an aortic valve prosthesis or significant atheromatous peripheral vascular or aortic disease is present, a transeptal approach is preferred.

Vascular Access and Creation of Right Atrial Geometry

Percutaneous femoral vascular access is obtained by the modified Seldinger technique guided by vascular ultrasound. If a retrograde approach is planned, an 8-Fr sheath (Input PS, Medtronic, Minneapolis, MN) is placed in the right femoral artery. If a transeptal approach is planned, one 8-Fr sheath is placed in the right femoral vein. In both instances, one 7-Fr sheath (Input PS, Medtronic) is placed in the right femoral vein; one 10-Fr long sheath (Super Arrow-Flex introducer, Teleflex, Morrisville, NC) and another 6-Fr sheath (Input PS, Medtronic) are placed in the left femoral vein. A 9-Fr ICE catheter (ViewFlex, Abbott, Abbott Park, IL) is inserted through the 10-Fr long sheath in the left femoral vein and advanced to the inferior vena cava (IVC) while maintaining an echo free-space at the tip of the transducer as previously described. The ICE catheter is then advanced to the right atrium (RA). An anterior curve is applied to the ICE catheter, and it is then maneuvered across the tricuspid valve into the right ventricle (RV) to evaluate for any baseline pericardial effusion. Baseline images are stored.

A 3D mapping system is essential to the non-fluoroscopic approach; the choice of mapping system is dependent on operator and system availability. In our center, a 6-Fr decapolar catheter (Inquiry, Ten Ten Diagnostic Catheter, Abbott) is inserted into the right femoral vein and advanced to the IVC under the guidance

of the electroanatomic mapping (EAM) system (EnSite Velocity, Abbott). Geometry of the IVC is collected as the decapolar catheter is advanced to the IVC. The appearance of electrograms on the distal bipoles of the decapolar catheter indicates when the catheter tip has reached the border of the inferior RA and IVC, as described in Chapter 14. The decapolar catheter is then advanced into the RA and into the SVC. The RA–SVC junction is marked by a loss of electrogram signals on the proximal poles of the decapolar catheter as the catheter enters the SVC. Geometry of the SVC is collected on the EAM system. The decapolar catheter is then withdrawn into the RA. Under ICE and EAM guidance, the decapolar catheter is placed inside the coronary sinus (CS) to serve as a reference for the EAM system.

Transseptal Access to the Left Ventricle

A weight-based heparin bolus is administered prior to the transseptal puncture. The activated clotting time (ACT) is monitored throughout the procedure, and intravenous heparin boluses are administered to target an ACT of 300 to 350 seconds.

From the home view on ICE, clockwise rotation is added to visualize the interatrial septum and the left atrium (LA). Then, a posterior tilt is added, and minimal counterclockwise rotation is applied to visualize the SVC. Next, through the 8-Fr sheath, a 180-cm, 0.032-inch J-wire (fixed-core J-tip guidewire, Medtronic) is advanced inside the SVC under direct visualization of the ICE. The 8-Fr sheath is withdrawn from the body and exchanged for a transseptal sheath-dilator assembly (SL-0, Abbott), which is advanced over the wire into the SVC. The wire is then withdrawn from the body. The RF Transseptal Needle (NRG RF Transseptal Needle, Baylis Medical, Montreal, Canada) is placed in the sheath-dilator assembly. The sheath-dilator assembly is withdrawn minimally to expose the blunt tip of the RF Transseptal Needle. The transseptal assembly is withdrawn into the RA, while tracked on the EAM system and on ICE, until tenting of the interatrial septum is seen on ICE. In contrast to RF ablation of atrial fibrillation, which requires left

pulmonary veins visualization on ICE while performing transseptal puncture, a relatively anterior and inferior transseptal puncture is preferred for ablation of ventricular tachycardia. This can be achieved by visualizing the transseptal needle tip on the mid to inferior part of the septum after the ICE catheter is rotated slightly counterclockwise relative to the location of the 2 left-sided pulmonary veins. Hemodynamic pressure monitoring is used to confirm entry into the LA along with direct ICE visualization.

If a standard transseptal needle, rather than an RF Transseptal Needle, is used, the operator will rely solely on ICE to track the sheath-dilator assembly position, without exposing the needle tip, as it is withdrawn from the superior vena cava (SVC) down to the interatrial septum.

Under ICE guidance, a steerable duodecapolar catheter with 2-2-2 spacing (Livewire, Abbott) or an Advisor HD Grid Mapping Catheter, SE (Abbott) may be inserted through the SL-0 transseptal sheath into the LA and then across the mitral valve into the left ventricle (LV) (**Figure 18.1**).

Retrograde Access to the Left Ventricle

A weight-based heparin bolus is administered prior to entering the LV. The ACT is monitored throughout the procedure, and intravenous heparin boluses are administered to target an ACT of 300 to 350 seconds.

A steerable duodecapolar catheter with 2-2-2 spacing (Livewire, Abbott) is inserted through the right femoral arterial sheath. The duodecapolar catheter is advanced retrogradely into the aorta and geometry is continuously collected on EAM. As the catheter approaches the aortic arch, a curve is applied. The desired distal U-curve is confirmed by noting the reversal of the sequence of distal to proximal electrode numbers on EAM. This U-curve is maintained during the advancement of the duodecapolar catheter toward the aortic cusps to avoid dissection of the coronary arteries (**Figure 18.2**). ICE may be used to visualize the duodecapolar catheter as it is prolapsed across the aortic valve. From the home view on ICE, minimal counterclockwise rotation is applied to visualize the long axes of the aortic valve, aorta, and LVOT (**Figure 18.3**).

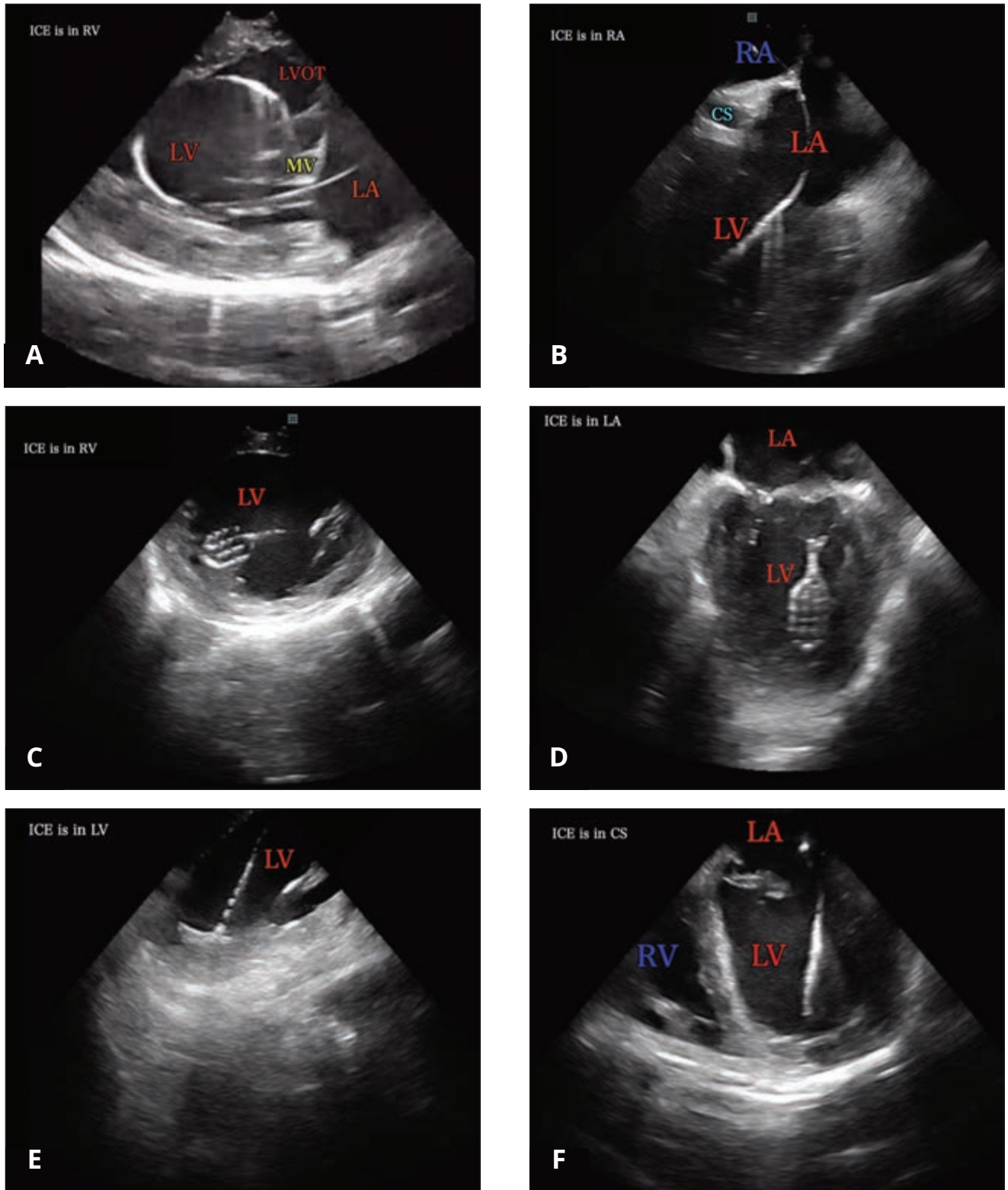


Figure 18.1 **A:** ICE catheter is placed in the RV and showing a steerable duodecapolar mapping catheter with 2-2-2 spacing passing through the SL-0 transseptal sheath and across the mitral valve into the LV. **B:** ICE catheter is placed in the RA and showing the Advisor HD Grid Mapping Catheter, SE, passing through the SL-0 transseptal sheath and across the mitral valve into the LV. **C:** ICE catheter is placed in the RV and showing the Advisor HD Grid Mapping Catheter, SE in the LV via transseptal approach. **D:** ICE catheter is placed in the LA and showing the Advisor HD Grid Mapping Catheter, SE across the mitral valve into the LV. **E:** ICE catheter is placed in the LV and showing the Advisor HD Grid Mapping Catheter, SE in the LV via transseptal approach. **F:** ICE catheter is placed in the coronary sinus and showing the Advisor HD Grid Mapping Catheter, SE across the mitral valve into the LV. ICE: intracardiac echo, RA: right atrium, RV: right ventricle, LA: left atrium, LV: left ventricle, CS: coronary sinus.