Catheter ablation is the mainstay of treatment in the management of cardiac arrhythmias. The number of catheter ablation procedures performed worldwide in the past 25 years has significantly increased and is expected to increase further. Cardiac ablation requires catheters to be advanced and manipulated within cardiovascular structures. This manipulation has traditionally been performed under fluoroscopic guidance. The advent of 3D electro-anatomic mapping systems (EAM) and intracardiac echocardiography (ICE) has reduced reliance on fluoroscopy. However, fluoroscopy remains an integral part of ablation procedures in the hands of most operators.

Rationale for Eliminating Fluoroscopy When Possible

The optimal goal for fluoroscopic exposure is known by the acronym ALARA (as low as reasonably achievable). Ionizing radiation can result in two types of tissue injury: stochastic (carcinogenic and genetic effects); and deterministic (also called tissue reactions).

The most commonly used model for stochastic effects is the ‘linear non-threshold’ model, i.e. any small amount of radiation involves an increase in cancer risk with no threshold, and the probability increases linearly with increasing radiation dose.¹ For deterministic effects (such as skin injuries or cataracts), there is a minimum threshold of dose for the effect to happen and severity increases with rising dose. The threshold for skin injuries is considered to be 2–3 Gy, but for radiation-induced opacities in the eye lens, the International Commission on Radiological Protection (ICRP) has proposed 500 mGy as the threshold.¹ The ICRP gives a dose threshold of 500 mGy for non-cancer effects of ionizing radiation to the heart.¹

Patients can receive a large dose of radiation during complex catheter ablations for AF or ventricular tachycardia (VT). Most experienced cardiac electrophysiologists have an exposure per annum of around 5 mSv with a typical cumulative lifetime attributable risk in the order of magnitude of one cancer (fatal and non-fatal) per 100 exposed subjects.²

Multiple studies have confirmed the increased risks of orthopedic problems associated with the use of lead aprons. The WIN for Safety group’s survey showed that 19.5% of interventional cardiologists had orthopedic problems.³ Ross et al.⁴ surveyed three physician groups to study; they compared the effects of standing for long periods while wearing lead aprons (cardiologists) with lengthy standing at an operating table without weights (orthopedic surgeons) and standing for short periods while examining patients (rheumatologists). They found the cardiologists wearing lead aprons had a significantly higher incidence of skeletal complaints and missed more days from work because of back pain than individuals in the control groups.

Fluoroless AF Ablation Technique

The advent of 3D mapping and intracardiac echocardiography (ICE) has provided unique opportunities for significant reduction in and potential elimination of fluoroscopy during most ablation procedures. AF ablation is the most commonly performed complex ablation procedure and is traditionally associated with a long duration of fluoroscopy.

The authors have adopted a zero-fluoroscopy approach for the majority of AF ablation procedures. SG has personally performed ~200 AF ablation procedures using zero fluoroscopy. The physician and other staff do not wear lead aprons to eliminate orthopedic risks and the...
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X-ray system is paused for the whole procedure (eliminating radiation-related risks to patients and personnel). AF ablations are performed with 3D mapping using the CARTO 3™ system ( Biosense Webster). Access to right and, rarely, left femoral veins is obtained under handheld ultrasound guidance and four sheaths are placed.

A CARTOSOUND® ICE catheter (Biosense Webster) is advanced from the right femoral vein to the right atrium (RA). This is performed using live image obtained from the ICE catheter. We ensure that there is always echo-free space at the tip of transducer to avoid inadvertent venous perforation by the catheter.

ICE images are obtained from the RA using various deflections of the catheter. The location of the coronary sinus (CS), cavo-tricuspid isthmus, superior vena cava (SVC), interatrial septum (IAS), left atrial appendage and pulmonary veins are drawn in 3D using CARTOSOUND (Biosense Webster). The desirable puncture site on the atrial septum is specifically tagged on this map. The esophagus is visualized using ICE and marked on the CARTOSOUND module. A 10-pole temperature-sensing probe is placed in the esophagus and the position of the probe is confirmed using ICE.

Next, a bidirectional, THERMOCOOL™ SmartTouch catheter (Biosense Webster) is advanced to the RA via a steerable sheath, and a limited fast anatomic map (FAM) of the CS, SVC and interatrial septum is obtained using the sound images as a guide. The contact force-sensing technology provides an additional layer of safety for catheter movements without fluoroscopy. A decapolar CS catheter is now placed. Any decapolar catheter can be visualized on the 3D mapping system after creation of the FAM map by the ablation catheter and is quite easily positioned in CS. Heparin is administered to achieve an activated clotting time (ACT) of >350 seconds.

A long wire is placed in the SVC from the right femoral vein and the position of the wire in the SVC is confirmed on ICE. An SL-0 sheath and dilator complex are advanced over the wire and is seen in the SVC. The wire is removed, and sheath is flushed. A 71-cm Agilis NxT™ (St Jude Medical) needle is connected to the mapping system via a Duomode™ Cable (Baylis Medical) and advanced via the SL-0 sheath. When the needle tip exits the SL-0 sheath, the tip can be visualized in the SVC as an electrode on 3D mapping system. The needle, dilator and sheath complex are pulled down from the SVC and the needle is directed towards the previously tagged optimal puncture location on the IAS. The position of the needle on the desired site on the IAS is confirmed on ICE and radiofrequency (RF) energy is delivered to cross the IAS. The use of a RF-activated needle allows for transseptal puncture without significant manual pressure and decreases the risk of inadvertent LA perforation from the needle and the sheath ‘jumping’ across the septum. The needle is removed while the tip of the dilator is remains in place across the septum.

A ProTrack™ 260 cm wire (Baylis Medical) is placed in the left atrium (LA) via the SL-0 sheath. This wire has an atraumatic pigtail loop at the tip, which can be easily visualized in the LA using ICE. The SL-0 sheath and dilator are advanced into the LA over this wire. After the septum is dilated by a to-and-fro movement of the sheath between the RA and the LA, the sheath is pulled back into the RA while the wire is maintained in the LA. The ablation catheter is used to access the LA using the same transeptal puncture by using a buddy technique using the existing wire. The Agilis sheath is advanced in the LA over the ablation catheter. The ablation catheter is now stabilized and the SL-0 sheath is re-advanced into the LA over the ProTrack wire. After the SL-0 sheath position has been confirmed in the LA, the wire and dilator are removed and replaced with a multipolar mapping catheter.

A previously obtained 3D CT or MRI rendering of the LA and pulmonary veins is merged with the CARTOSOUND map of the LA, and a FAM of the LA is created using the multipolar catheter.

A complete bi-antral pulmonary vein isolation is then completed in standard fashion, while the catheters are visualized on the 3D mapping system. The use of contact force sensing eliminates the need to use fluoroscopy to assess catheter to tissue contact. Additional FAM data are collected as needed to refine views of the anatomic structures. Additional linear and focal ablation can also be performed using the same map without any need for fluoroscopy. At the end of the procedure, ICE imaging is performed to confirm a lack of pericardial effusion and the catheters are removed from the body.

A similar approach can be taken for other left atrial arrhythmias including atrial flutters and left-sided accessory pathways. Right atrial arrhythmias (such as typical flutter, atrioventricular nodal reentry tachycardia, atrioventricular re-entry tachycardias and atrial tachycardias) are routinely mapped without fluoroscopy. The operator uses the ablation catheter to create a FAM map of the RA then place other catheters, such as the high right atrial catheter, CS catheter and right ventricle (RV) catheter as they can be visualized on CARTO after a FAM has been created. Impedance-based mapping systems such as EnSite™ have the advantage of not needing a sensor-based catheter to visualize the diagnostic catheters; this allows the operator to make a definite diagnosis before deciding which ablation catheter to use.

Ablation of VT and premature ventricular contractions can also be easily performed using a fluororeless approach. We routinely use Cartosound to map the anatomy of the LV and RV before placing other catheters in the body. Transseptal access is performed in the same way as described for AF ablation. Retrograde access is facilitated by visualizing the wire in the descending aorta and using a longer sheath (~40 cm) to navigate the tortuosity of femoral and iliac arteries.

Procedure Time
We do not see any significant increase in procedure time for right-sided ablations or retrograde VT ablations. The time to transseptal access is increased by approximately 5 minutes for zero fluoroscopy procedures compared to when fluoroscopy is used.

Complications
There has been no difference in complication rate between procedures performed with or without fluoroscopy. It is important that patients remain in same position for the duration of procedure to maintain accuracy of the EAM-generated map; longer procedures usually require use of general anesthesia to eliminate the risk of patient movement.
Learning the Technique
Zero fluoroscopy ablation has a steep learning curve for most operators. Most physicians who are comfortable using EAM and use fluoroscopy only for initial catheter placement or trans-septal puncture can expect to feel confident using the zero-fluoroscopy approach after about 10–15 AF ablations. Operators may choose to wear lead aprons for their initial cases to gain confidence with their technique. Physicians who continue to place significant reliance on fluoroscopy for ablation will benefit from starting with using fluoroscopy for initial catheter placement and trans-septal puncture then performing left atrial mapping and ablation with minimal or no fluoroscopy. These operators may require 25–50 cases to feel confident about performing zero fluoroscopy ablation.

Remaining Need for Fluoroscopy
In rare circumstances (<5 % cases), brief use of fluoroscopy is necessary to facilitate some components of the procedure. Most commonly encountered scenarios include:

- A thick IAS can rarely require the use of extra force to get the sheath across the IAS, and fluoroscopic visualization can facilitate this process.
- We still use fluoroscopy for right atrial catheter placement and trans-septal puncture in patients with recently implanted (within the past 6 months) cardiovascular devices to prevent lead dislodgement.

Under these circumstances, a lead apron is worn for the necessary amount of time, then removed as soon as fluoroscopy is no longer necessary.

Limitations and Tips for Troubleshooting
Zero-fluoroscopy approach has minor limitations related to the need for ICE for trans-septal and left ventricular procedures, operator learning curve and the necessity to obtain pre-procedural imaging in the initial phases of the learning curve. In our experience, the use of ICE has not changed significantly after the adoption of zero-fluoroscopy technique. The pre-procedural CT/MRI also becomes optional for most operators after approximately 50 cases.

The sheaths can not be visualized on mapping system and sheath orientation has to be predicted based on catheter tip movement on operating the steerable mechanism or by visualizing the sheath catheter assembly on the ICE. The approximate position of the sheath can be assessed by slowly advancing the sheath over the ablation catheter and when proximal electrodes turn “black” the sheath has covered those electrodes.

Future Directions
The number of cardiac ablation procedures is projected to grow worldwide due to increased safety and access to technology. Improvements in 3D mapping technology will allow operators to perform a greater number of ablations without fluoroscopy. The long guiding sheaths with embedded electrodes near the distal end are in development. This will allow visualization of the distal portion of sheaths on 3D mapping system, increasing safety and efficiency of fluoroless procedures. The authors are hopeful that, in the near future, fluoroscopy will become an adjunct (if not extinct) rather than a necessary tool for cardiac ablation.

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