BRIEF REPORT

Reduction and elimination of operator exposure to radiation during endocardial ventricular arrhythmia ablation procedures over time

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Introduction

Radiation exposure is an occupational hazard in cardiac electrophysiology. Although electrophysiologists wear radioprotective garments for protection from radiation, there are still risks associated with exposure to radiation. Moreover, long-term use of heavy protective vests and skirts can contribute to orthopedic injuries.[1] Historically, fluoroscopic utilization was quite substantial and was essential to guide safe and effective procedures.[2] Over the years, advancements in technology, nonfluoroscopic imaging methods, via electroanatomic mapping systems and intracardiac echocardiography (ICE), have provided electrophysiologists with the technology for performing catheter ablations with minimal to no ionizing radiation for treatment of most arrhythmias.

In contrast to ablation of atrial fibrillation and supraventricular tachycardia, the use of techniques to minimize or eliminate fluoroscopy exposure for catheter ablation of ventricular arrhythmias (VAs) has not been well described. However, many of the same techniques involved in low- or zero-fluoroscopy strategies can also be used for ablation of ventricular tachycardia (VT) and premature ventricular contractions (PVCs).

We sought to assess operator exposure to radiation during ablation of VT or PVCs over an extended period at our institution that included incorporation of zero-fluoroscopy ablation techniques.

Materials and Methods

Study cohort and fluoroscopy data collection

We performed a retrospective study on VA (i.e., VT and PVC) ablation procedures at Brigham and Women's Hospital between January 2009 and November 2022. All subjects provided written consent for inclusion in observational research studies at the time of their procedure as part of an Institutional Review Board–approved protocol. Data were extracted from a database including all patients undergoing VA ablation maintained during the study period. All procedural data were automatically abstracted directly from fluoroscopy equipment and a recording system (GE Healthcare, Chicago, IL) and entered into a database used for the creation of a procedural report. Acute complications that occurred at the time of the procedure were also included in this database and included in the procedural report. Major complications include vascular access site injuries, major bleeding recognized at the time of the procedure, cardiac arrest, coronary artery injury, pericardial effusion, cardiac implantable electronic device lead dislodgement, unexpected conduction system injury, and thromboembolism including stroke and myocardial infarction. Patients who underwent epicardial, needle, and alcohol ablation were excluded due to the nature of these procedures requiring fluoroscopy and cine angiography. We also evaluated procedures with no fluoroscopy utilization and compared the clinical and procedural characteristics with contemporaneous and similar procedures using at least 1 second of fluoroscopy.

Statistical analysis

Continuous variables are summarized as mean ± SD and categorical variables as absolute frequency and percentage. For univariate analysis, an independent *t* test was used for continuous variables and a chi-square or Fisher exact test for categorical variables. All tests were 2-sided, and a *P* value of <.05 was considered statistically significant. Data were analyzed using IBM SPSS version 27.0 (IBM, Armonk, NY).

Results

Clinical characteristics of the study cohort

A total of 2297 VA ablations were performed in our electrophysiology laboratories during the study period. Among

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KEY FINDINGS

- Fluoroscopy times used during ablation of endocardial ventricular arrhythmias have diminished steadily over time.
- The use of zero-fluoroscopy techniques has increased over the past 5 years and over 40% of endocardial ventricular tachycardia ablations are completed without any radiation exposure to the patient or operator.
- There are no observable differences in intraprocedural complication rates related to the use of zero-fluoroscopy techniques.

2297 total VA ablations, detailed fluoroscopy data were available on 2266 (98.7%) procedures. Of those, 1311 (57.8%) had endocardial VT ablation, 838 (37%) had PVC ablation, and the remaining 117 (5.2%) had epicardial, needle, or alcohol ablation.

Radiation exposure and zero-fluoroscopy procedures in VT and PVC ablation cases

There was an overall reduction in the average fluoroscopy time (excluding the zero-fluoroscopy case) with an average fluoroscopy time of 9.22 minutes in 2022, compared with 34.9 minutes in 2009.

Since 2017, completely fluoroscopy-free VA ablation numbers increased (Figure 1) from 1% in 2017 to 42.3% in 2022 ($P < .001$). The mean fluoroscopy duration and the mean fluoroscopy dose decreased dramatically over time, and this reduction remained statistically significant despite analyzing only procedures that utilized any amount of fluoroscopy (Figure 2). For VT ablation, mean fluoroscopy dose per ablation was 836.6 mGy in 2009 as compared with 41.4 mGy in 2022, and for PVC ablation, mean fluoroscopy dose per ablation was 562.8 mGy in 2009 as compared with 44.4 mGy in 2022.

Procedural safety associated with fluoroscopy use in VT and PVC ablations

Intraprocedural complication rates were similar among the groups, and there was no statistically significant difference observed. The overall intraprocedural complication rate was 0.9% (n = 19 of 2149) in procedures with fluoroscopic utilization and 0.9% (n = 1 of 117) in procedures with zero fluoroscopy (P = .664). The one major complication observed during a zero-fluoroscopy PVC ablation in 2022 was cardiac perforation. The 19 major complications in the fluoroscopy use group observed over the study period included cardiac perforation (n = 9), cardiac arrest with post-shock electroanatomical dissociation (n = 1), coronary artery injury (n = 1), thromboembolism (n = 3), and vascular site injury (n = 5) There were no reported incidences of pacing or defibrillator lead dislodgement observed in either group during the study period.

Discussion

Study results

Our study demonstrates a steady reduction of radiation exposure for all ablation procedures over time. In addition, ablation procedures that do not require fluoroscopy have become more

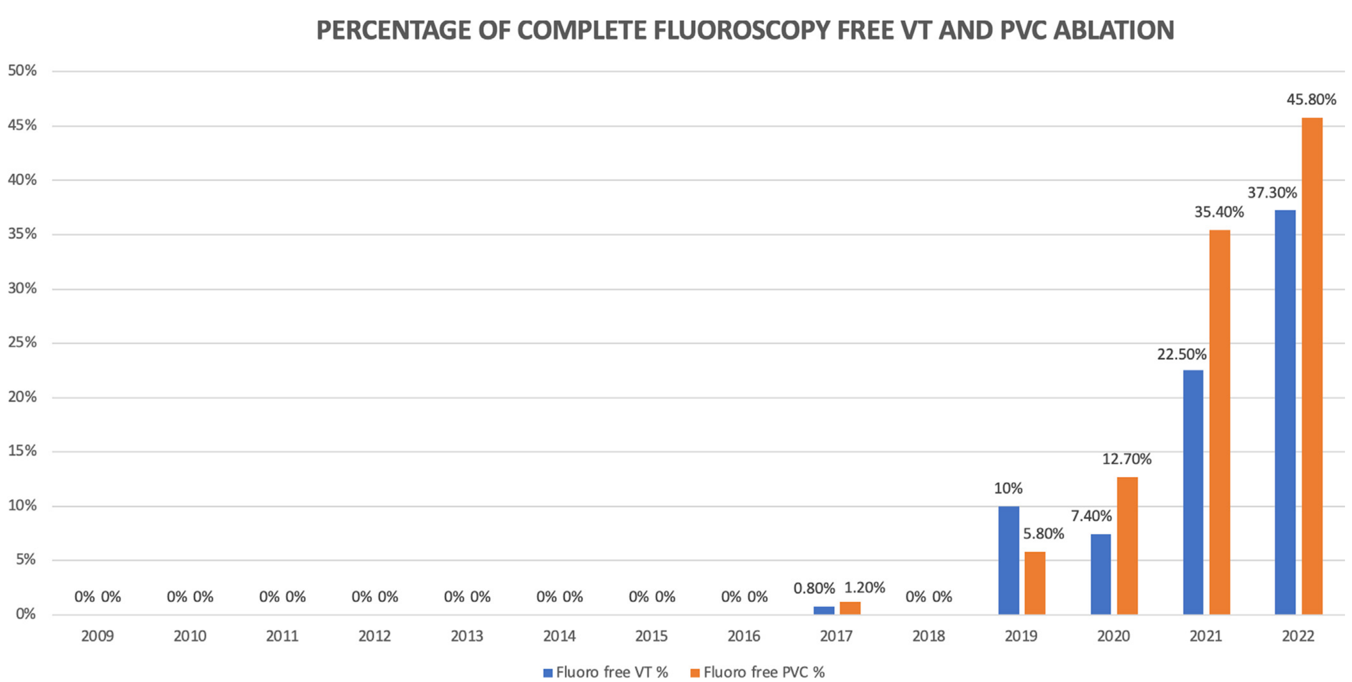

Figure 1 Percentage of ventricular arrhythmia ablations performed without any fluoroscopic utilization over time. PVC = premature ventricular contraction; VT = ventricular tachycardia.

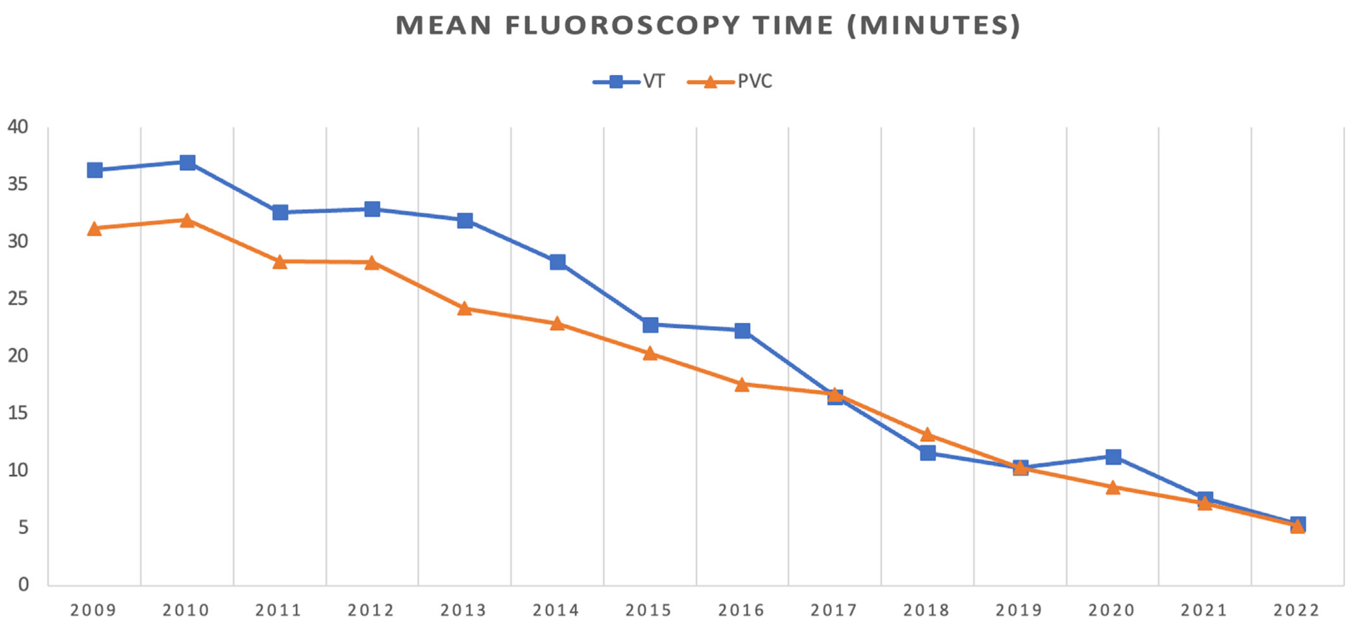

Figure 2 Trend of mean fluoroscopy time during ventricular ablation performed between 2009 and 2022 (time is shown by minutes). PVC = premature ventricular contraction; VT = ventricular tachycardia.

common. Moreover, reduction in fluoroscopic utilization was not associated with increased periprocedural complication. We are not showing complications rates per year.

Radiation exposure and its long-term risks are underappreciated by physicians. The National Council for Radiation Protection and International Commission on Radiological Protection recommend limiting the annual effective dose to optimize occupational exposure.[3] Via stochastic and deterministic effects on operators, exposure to ionizing radiation can cause cataracts and cancer,[4,5] and in one study, the risk of radiation induced cancer after catheter ablation was 0.07% to 0.1% per 60 minutes of fluoroscopy.[1] Although the overall utilization of fluoroscopy is not as high as in other electrophysiology procedures such as device implantation, ablation procedures for VA are often more complex, and procedure durations can be much longer. Prolonged and long-term use of heavy protective vests and skirts poses risk of occupational hazard, back pain, and orthopedic issues.[6]

Prior investigations into occupational exposure of radiation for electrophysiologists

To evaluate occupational and patient radiation risk in the electrophysiology laboratory, Wunderle and colleagues[7] analyzed radiation dosimetry recorded by their electrophysiology physicians and laboratory personnel and found a nearly 70% decrease in the average occupational radiation doses between 2010 and 2017. The findings of this study are consistent with our results reflecting a strong trend in reduced fluoroscopy exposure in our laboratories.

Apart from occupational hazard posed to the operator, there is also a concern regarding ionizing radiation on the fetus during pregnancy. Due to this, among other potential concerns, interventional cardiovascular disciplines including electrophysiology may attract fewer female physicians to pursue careers,[8] with multiple reviews and reports aiming to address this issue.[9–11] Prior studies have reported that fetal radiation exposure <50 mGy was generally considered negligible with no adverse effects on the pregnancy or the fetus.[12] Our study demonstrates very low levels of radiation use during a complex VT ablation at 44.4 mGy in 2022, well within safe exposure rates to pregnant operators using protective shielding when using fluoroscopy. Of course, radiation exposure is not a concern for operators choosing to use zero fluoroscopy for ablation of VAs.

Safety of zero-fluoroscopy ablations

Advancement in technology over the years including improvement in 3-dimensional (3D) electroanatomic mapping, the ability to create more precise high-density maps, improvement of ICE imaging, and ICE integration in the 3D mapping system enabled providers to perform safe VA ablations with minimal or zero fluoroscopic utilization.

To be able to perform safe and successful VA ablation without relying on fluoroscopic imaging, one should be very familiar with how to utilize several available and routinely used technologies and tools. Preprocedural imaging such as contrast-enhanced computed tomography (scan and magnetic resonance imaging scans can help procedural planning and can be integrated to mapping systems for additional guidance during the procedure (Figure 3). With advancements in mapping technology, current mapping systems can create a reliable and detailed 33 map of cardiac chambers and associated structures, with the ability to project catheter movement and location in relation to these cardiac structures reliably and real time. Integration of ICE to delineate detailed anatomy including device leads (if applicable), ventricles, and associated structures such as the moderator band, papillary muscles,

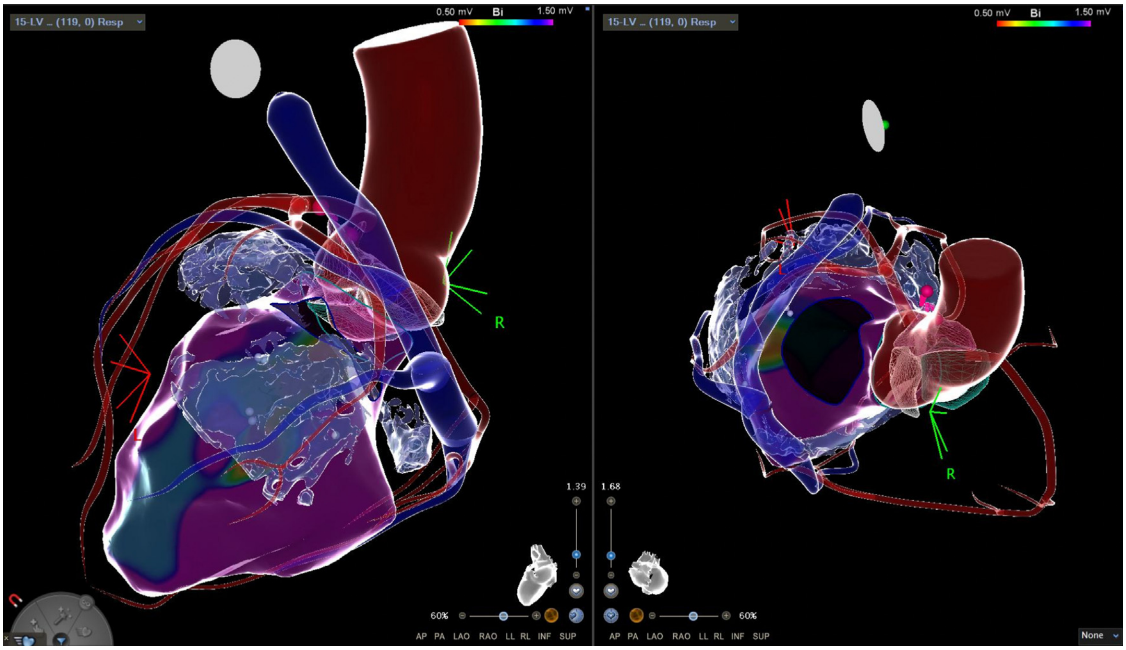

Figure 3 Contrast-enhanced cardiac computed tomography (CT) scan merged with electroanatomic map and soundmap. Note scar delineation (blue), coronary arteries (red), and veins (blue) from contrast-enhanced cardiac CT scan, and aortic cusps delineation by soundmap is merged with aortic root from the CT scan.

outflow tract structures including the aortic and pulmonary valve cusps, and even coronary arteries is possible (Figure 4). With some mapping systems, structures imaged on ICE can be contoured and then projected onto the 3D electroanatomic map, resulting in the potential for increased fidelity of real-time catheter-tissue visualization and spatial localization. This 3D anatomical map provides more detailed and true real-time guidance, as opposed to 2D fluoroscopic imaging. Utilizing ICE during catheter manipulation in the cardiac chamber and observing lesion formation during ablation gives direct and real-time monitoring and enables operators to identify complications early. At our center, all VA ablations are performed with ICE and 3D mapping.

Patient selection

Patient selection at our center is mainly dependent on the operator with some purposely practicing a zero-fluoroscopy approach and others practicing a low-fluoroscopy approach. Zero-fluoroscopy operators proceed with no fluoroscopic utilization regardless of the approach to access the left ventricle (transseptal or retrograde approach), or whether the patient has a cardiac implantable electronic device. With current advancements in 3D mapping and ICE integration, it is feasible to perform safe procedures utilizing 3D mapping systems to depict the lead location along with direct visualization under ICE. Exceptions are patients who may require cryoablation, coronary angiogram, alcohol ablation, and epicardial ablation in which all operators utilize fluoroscopy during these cases. While all the operators performing VA ablation in the present study use ICE and 3D mapping, operators who would not normally use these tools will incur additional costs for the procedure when using these zero- and reduced-fluoroscopy techniques.

Study limitations

We used a procedural database with a limited number of specific variables collected related only to the procedure. The database did not include clinical characteristics of patients, long-term follow-up, or whether a patient had an implanted device. In addition, the database did not record complications that might be recognized until after the completion of the procedure. For example, a late presentation of a retroperitoneal bleed or a late thromboembolic event. This limits our ability to analyze possible correlations with certain patient level variables (for example, the presence of a transvenous pacing lead) and fluoroscopy exposure required at the time of the procedure. Nonetheless, we believe that our limited analysis remains valuable as the trend in reduced radiation exposure and rising use of zero-fluoroscopy procedures is of interest to cardiac electrophysiologists interested in using these techniques.

This study describes a single-center experience at a center with a relatively high volume of cases performed by experienced operators. Our zero-fluoroscopy approach relies heavily on ICE and 3D mapping integration, which may not be available on all mapping systems. Therefore, our results describing a zero-fluoroscopy approach may not be generalizable to operators who use different mapping systems or who have limited experience using ICE. Last, given that this was a large cohort retrospective analysis aimed to study periprocedural intervention and safety, a long-term outcome is not reported. It is possible that minimal or zero-fluoroscopy approaches lead to worse longer-term outcomes with a higher VA recurrence rate. However, the operators involved in this study maintain identical acute procedural endpoints including lack of inducibility of targeted VA; thus, longer-term success rates would not be expected to be different.

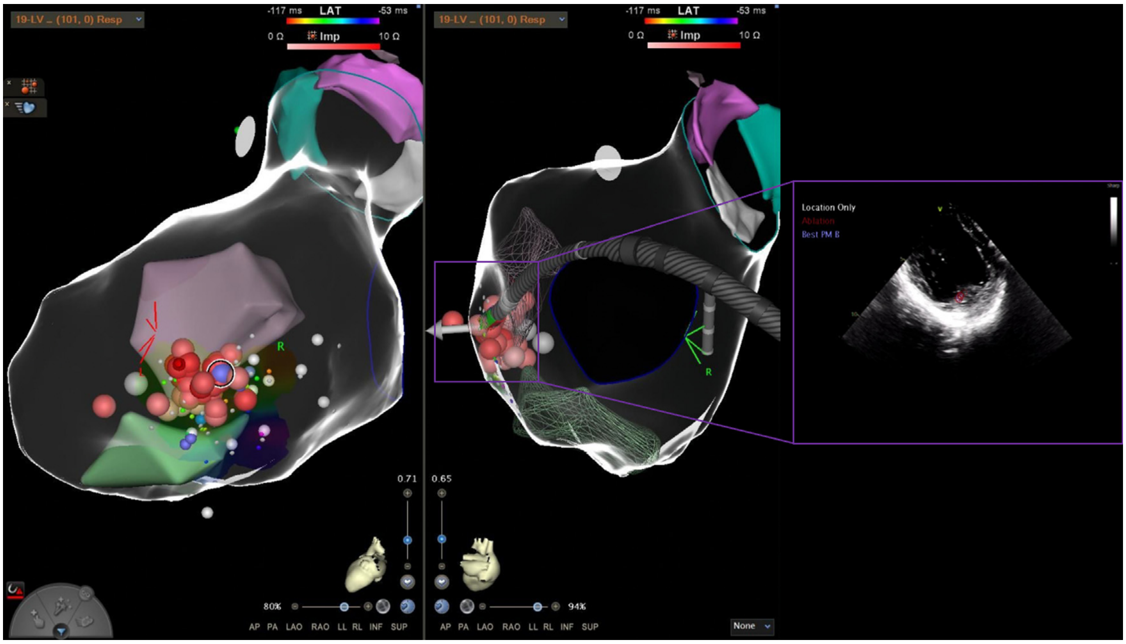

Figure 4 Example of intracardiac ultrasound integrated to mapping system. Note delineation of aortic valve cusps, left ventricle, and anterior/posterior papillary muscle by soundmap. In the blow-out image, the anterolateral papillary muscle and ablation lesions are shown on intracardiac echocardiography.

Conclusion

In this study, we demonstrate a dramatic reduction in fluoroscopy used during VA ablation over time. This reduction in radiation exposure poses less risk not only for operators and electrophysiology lab personnel, but also for our patients. Moreover, our study shows the feasibility of zero-fluoroscopy VA ablation without compromising safety. It is important to highlight that developing skills and familiarity with ICE and 3D mapping is crucial to perform safe and successful VA ablation without fluoroscopic reliance.

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Authorship: All authors attest they meet the current ICMJE criteria for authorship.

Patient Consent: All subjects provided written consent for inclusion in observational research studies.

Ethics Statement: This study was approved by the institutional review board at Brigham and Women's Hospital. This study was conducted according to the Helsinki Declaration guidelines on human research.

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