

# Nonfluoroscopic and Radiation-Limited Ablation of Ventricular Arrhythmias in Children and Young Adults: A Case Series

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**Abstract** The purpose of this study was to report the feasibility and procedural technique of minimal or no fluoroscopy in the ablation of ventricular arrhythmias in the pediatric population. A retrospective review was performed of all patients <21 years old who underwent ablation of ventricular arrhythmias using three-dimensional (3D) mapping with no or minimal fluoroscopy at a single institution. Five patients underwent electrophysiology studies for ventricular tachycardia or frequent premature ventricular complexes. Three patients had right-sided arrhythmias, and two patients had left-sided arrhythmias. Electro-anatomic mapping with the 3D EnSite NavX system and radiofrequency ablation was used in all patients. No fluoroscopy was used in the patients with right-sided arrhythmias. The two patients with left-sided arrhythmias had 1.0 and 1.9 min of fluoroscopy, respectively. The mean procedure time was 168 min (range 95 to 270). There has been no recurrence at mean follow-up of >1 year. Three-dimensional mapping systems have allowed pediatric electrophysiologic procedures to be performed with minimal to no fluoroscopy in patients with challenging arrhythmias, including ventricular arrhythmias. The decrease in radiation exposure decreases the risk of long-term adverse sequelae resulting from radiation exposure, which is especially important in children.

**Keywords** Pediatric · Ventricular tachycardia · Nonfluoroscopic · 3D mapping · Catheter ablation

## Introduction

The practice of interventional electrophysiology has conventionally used fluoroscopy for catheter guidance, placing both patient and catheterization laboratory team at risk of radiation exposure. Recent studies have shown that children are potentially at greater risk of radiation-induced injuries, and their longer life-span results in increased risk for late development of neoplasms [6, 7, 11]. Fortunately, the advent of three-dimensional (3D) mapping has advanced to the point of allowing a significant decrease in the use of fluoroscopy [5, 6], even allowing fluoroscopy-free ablation of more complex arrhythmias, such as atrial fibrillation [4]. This article describes the procedural technique for radiation-free electrophysiologic procedures and is the first description of 3D mapping and ablation of ventricular arrhythmias with minimal or no fluoroscopy, a more challenging arrhythmia substrate.

## Methods

This retrospective review evaluated all patients <21 years of age who underwent ablation of ventricular tachycardia (VT) using 3D mapping with no or minimal fluoroscopy at a single institution. Patient demographic, procedural data, and follow-up status was collected. The EnSite NavX system (St. Jude, Minneapolis, MN) was used for 3D mapping, and the EP-Medsystem Workmate (St. Jude) was used for pacing and recording. No additional imaging

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modalities (i.e., magnetic resonance imaging [MRI] or intracardiac echocardiogram [ICE]) were used.

### Procedural Technique

Patients were prepped and draped in a standard fashion with 12-lead electrocardiogram patches and 3D NavX patches attached in the standard positions. All but one patient was placed under general anesthesia. After femoral venous access was obtained, a steerable 6F octapolar catheter (Bard, Murray Hill, NJ) was advanced from the level of the femoral veins to the heart while being monitored on 3D NavX. This allows for readjustment of the catheter if it prolapses or deviates into venous side branches while being advanced into the heart. Once intracardiac electrograms were noted (indicating the inferior vena cava [IVC]–right atrium junction), an anatomic reference was made on 3D NavX. The catheter was then advanced through the right atrium where the SVC was marked at the point of loss of intracardiac signals. Using “virtual” right and left anterior oblique projections, right atrial geometry was obtained by making broad catheter sweeps in the right atrium (setting a faster “EnSite responsiveness” confers a more natural movement to the catheter). In the three patients with right-ventricular arrhythmias, and the one patient with left-ventricular outflow tract (LVOT) arrhythmia, the octapolar catheter was advanced into the right ventricle and right-ventricular (RV) outflow tract (RVOT), thus allowing ventricular geometry to be obtained. The steerable octapolar catheter was then placed in the coronary sinus. Using the premade geometry, a combined 6F His/RVA octapolar catheter [8] (Bard) was placed past through the tricuspid valve to the RV apex, and a 5F high right atrial catheter (St. Jude) was advanced into the right atrial appendage. A baseline electrophysiology study was performed. In all cases, a long steerable sheath (81 cm; Bard Channel Sheath) was used to assist with catheter manipulation and stability. To place the long sheath without radiation, a 150-cm J-wire was placed into the IVC through a 7.5F short sheath. The 7.5F short sheath was then exchanged over the wire for a long Channel Steerable Sheath (Bard). Once the distal sheath was within the IVC, the dilator and wire were removed. A 7F ablation catheter (Bard Stinger C Curve, 5-mm tip) was then advanced through the sheath while monitoring with 3D NavX. Once the catheter tip was within the blood pool (out of the sheath) the catheter could be visualized with 3D NavX allowing advancement using 3D virtual monitoring. To determine the proximity of the sheath to the catheter tip, the catheter was slowly withdrawn into the sheath until the signals on the proximal bipole were disrupted (as seen by alteration in the ablation catheter shape on the 3D NavX). In the patient with a left posterior fascicular VT, the Bard

Stinger C Curve and Channel Steerable Sheath was advanced through a patent foramen ovale (PFO). The patient with the LVOT VT was extensively mapped in the RVOT before mapping the left ventricle using a retrograde aortic approach (without a steerable sheath).

Electro-anatomic mapping was performed to determine the earliest site of ventricular activation during the ectopic beats and for Purkinje potentials in the patient with the left posterior fascicular LV tachycardia (as previously described) [8]. Pace-mapping was used to confirm appropriate location in all cases. The LVOT tachycardia underwent an aortic root injection and a selective left coronary injection to evaluate coronary location compared with ablation catheter tip (which accounted for fluoroscopy use). Ablation sites were marked using 3D NavX, and additional insurance application(s) were placed at and around the successful site. The end points of a successful case included a lack of spontaneous or inducible ectopic beats or VT.

### Results

Demographic data are listed in Table 1. Five patients underwent electrophysiologic study for VT or frequent premature ventricular contractions (PVCs). Three patients had a diagnosis of frequent right-sided PVCs with a dilated left ventricle as well as evidence of decreased or low normal function. One of these patients also had an unknown etiology of syncope. The fourth patient presented with left posterior fascicular, VT which recurred on anti-arrhythmic medications. The final patient had VT and a dilated left ventricle with approximately 80% of all beats being ventricular in origin.

No fluoroscopy was used in the patients with right-sided arrhythmias. The patient with the left posterior fascicular VT received 1 min of fluoroscopy during the procedure to confirm femoral venous access during sheath placement and to correlate the site of successful ablation to a fluoroscopic image. The patient with the LVOT VT had the focus mapped in close proximity to the base of the left coronary cusp and therefore received 1.9 min of fluoroscopy for an aortic root and a selective left coronary artery injection to evaluate coronary artery location compared with the ablation catheter.

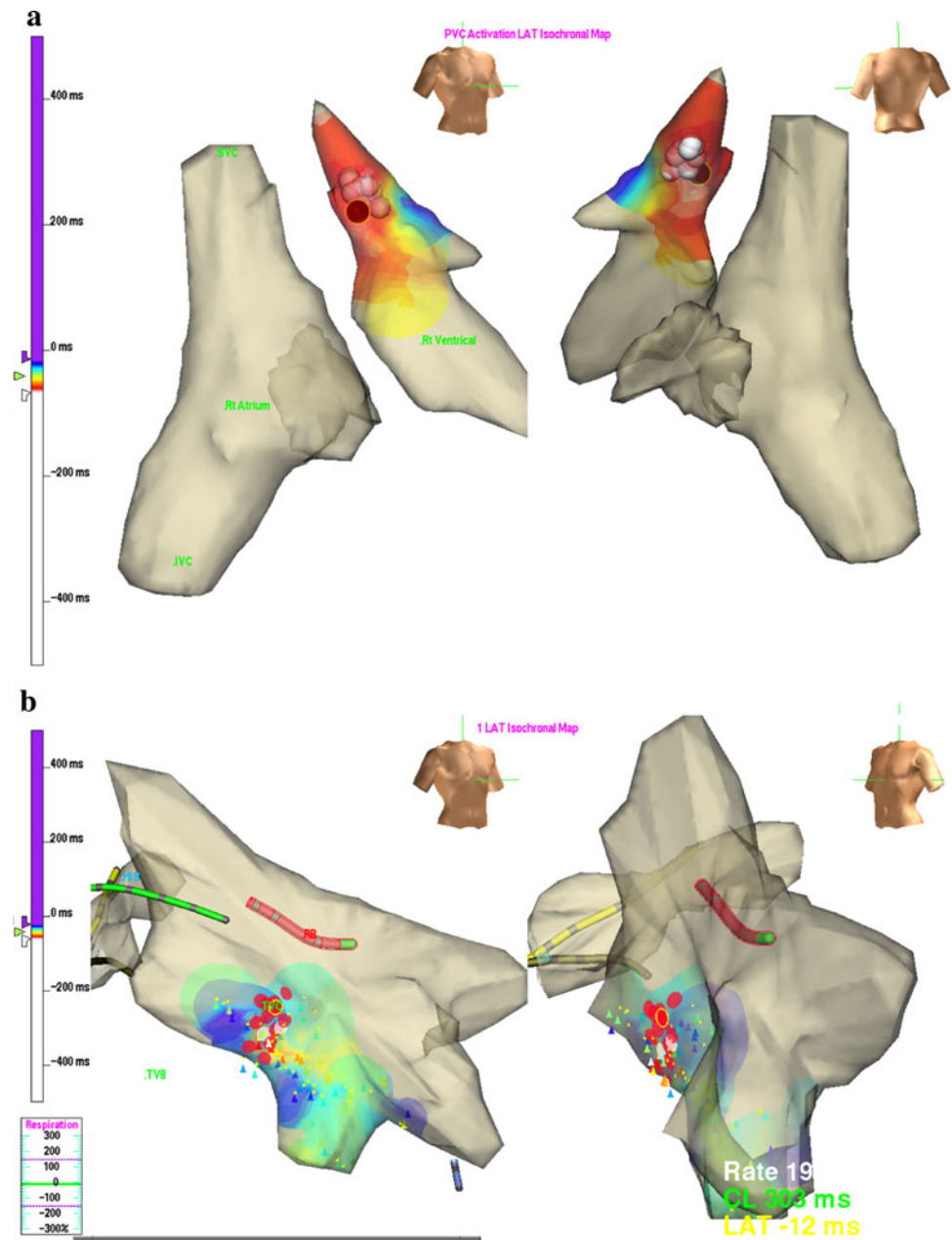
The site of successful termination of the arrhythmia included approximately 9 o'clock on the ventricular side of the tricuspid valve, two RVOT tachycardias (one on the lateral infundibulum of the RVOT and the other on the posterior RVOT), the mid left-ventricular septum (left posterior fascicular VT), and, finally, in close proximity to the left coronary cusp (Fig. 1). Radiofrequency energy was used in all cases. One patient developed a right bundle branch block during the procedure, which resolved in the

**Table 1** Patient demographics and electrophysiology data

Patient no.	Age (years)	Weight (kg)	Height (cm)	Sex	Arrhythmia substrate location	Procedure time (min)	Fluoroscopy time (min)	No. of lesions
1	10	73.2	161	F	Posterior RVOT	95	0	12
2	11	35.9	149	M	Mid-posterior LV septum (LPF VT)	249	1	14
3	15	61.8	181	M	9 to 10 o'clock on vent side of tricuspid valve	106	0	4
4	20	61.8	178	M	Lateral infundibulum of RVOT	121	0	6
5	20	90	193	M	Close proximity to left coronary cusp	270	1 min 56 s	15
Average	15.2	64.5	172			168	35 s	10.2

LPF left posterior fascicular

**Fig. 1** Examples of the 3D geometry and electro-anatomic mapping in a right-sided and a left-sided arrhythmia. **a** Right anterior lateral and posterior-anterior view of the 3D electrical anatomic map of the RVOT patient no. 1. The right atrial and RVOT geometry is shown. An electrical anatomic map showed the earliest activation (white surface) to be in the posterior outflow tract. The white spheres represent the ablation sites. **b** Right anterior lateral and left anterior oblique view of the 3D electrical anatomic map of the left posterior fascicular tachycardia in patient no. 4. The circular white and red marks represent the ablation lesions



recovery period; there were no other complications. At the conclusion of all procedures there were no premature ventricular beats or runs of VT on and off an isoproterenol infusion in all patients. The mean procedure time was 168 min (range: 95 min to 270). No complications occurred, and there has been no recurrence at an average follow-up of >1 year.

## Discussion

This case series demonstrates the procedure and feasibility of a nonfluoroscopic approach using a 3D navigation system for ablation of ventricular arrhythmias in pediatric patients. No additional imaging modalities (MRI or ICE) were used. Given the variety of cases in this series, including both left- and right-ventricular arrhythmias, this technique can be justified as an approach for many ventricular arrhythmias.

Decreasing radiation in pediatric patients has the potential to decrease the impact in long-term adverse sequelae in patients undergoing cardiac catheterization as well as those performing the procedures. The concept of ALARA (i.e., as low as reasonably achievable), supported by the American College of Cardiology and NASPE, is further reinforced by recent studies suggesting that children are potentially at greater risk of radiation-induced injuries, and their longer life-span puts them at greater risk of developing neoplasms [6, 7, 11]. These concerns, in part, have prompted the FDA to announce the *Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging* [3], which requires guidelines for device manufacturers and healthcare providers to mitigate radiation exposure for fluoroscopic procedures. Yet even though procedures with minimal radiation have been described in patients with Wolff-Parkinson-White syndrome before 2002 [2], the practice of radiation-free treatment is still relatively uncommon. This is highlighted by data being gathered from a multi-institutional study evaluating catheter ablation of VT in pediatric patients. In patients who did not undergo 3D mapping ( $n = 95$ ), the average fluoroscopic time was dramatically greater at 32.2 min (unpublished data, 6/2010).

We have described a nonfluoroscopic technique as well the basic demographics of patients who underwent minimal or radiation-free procedures for ventricular arrhythmias, a procedure that has not been previously described. The techniques discussed previously can essentially eliminate the use of radiation in these more complex procedures. Nevertheless, we have seen particular challenges to radiation-free catheterizations. The transition from fluoroscopy to nonfluoroscopic requires a learning curve, a fact mentioned in previous studies [10]. Second, small amounts of

radiation may be required for safety concerns, such as confirmation of appropriate venous and arterial access (as seen with our left-sided VT patient) or evaluation of coronary arteries or other anatomic substrate that are more effectively evaluated by fluoroscopy (as seen in our patient with LV outflow arrhythmia).

Some institutions have demonstrated the use of intracardiac or transesophageal echocardiography [1, 4, 5, 9] for use in transeptal puncture. However, we continue to believe that the small amount of radiation required for a transeptal procedure does not warrant the increased procedural cost, complexity, safety concerns, and additional venous access, which may be required for an echocardiogram-guided approach. Although we currently do not perform nonfluoroscopic transeptal procedures, this may be feasible because 3D-mapping systems incorporate transeptal needles and sheaths that can be “imaged” for transeptal access.

Finally, we have found that there may be alterations to the geography obtained by the 3D NavX system with changes to the impedance between the catheters and the chest patches (such as holding respirations, inserting a wire to the left atrium, and movement or dislodgement of a patch). Therefore, we occasionally obtained a brief fluoroscopic image to confirm catheter location compared with the generated geography.

## Conclusion

Three-dimensional mapping systems have allowed pediatric electrophysiologic procedures to be performed with minimal to no fluoroscopy in patients having more challenging arrhythmias, including ventricular arrhythmias. The decrease in radiation exposure decreases the risk of long-term adverse sequelae resulting from radiation exposure, especially the cumulative effect experienced by children.

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