Nonfluoroscopic catheter ablation of supraventricular tachycardias during pregnancy using simplified electroanatomic marker annotation

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Introduction

Hemodynamic, autonomic, and hormonal changes during pregnancy may predispose women to the occurrence of new-onset and recurrent arrhythmias.[1–3] Supraventricular tachycardias (SVTs) are predominant in this specific cohort.[4] Their occurrence during pregnancy may be associated with an increased risk of maternal mortality and may influence the outcome of pregnancy.[1,5] Pregnant patients with symptomatic arrhythmias might be managed medically, however, the potential adverse effects of antiarrhythmic medications remain substantial.[5] According to current guidelines, catheter ablation may be considered and performed at an experienced center without fluoroscopic guidance to avoid potentially harmful radiation exposure.[4] Nevertheless, access to catheter ablation in pregnant patients is somewhat limited because of the potential risks of the invasive procedure and possible radiation exposure.[6] We present 4 cases of pregnant patients who underwent successful catheter ablation of cardiac arrhythmias without X-ray exposure using simplified 3-dimensional electroanatomic marker annotation.

KEY TEACHING POINTS

- Nonfluoroscopic catheter ablation is safe and effective during pregnancy. The use of electroanatomic mapping systems may eliminate the need for fluoroscopy, minimizing radiation exposure and ensuring safety for both the mother and fetus.
- Simplified electroanatomic marker annotation may reduce procedure time and risks associated with prolonged interventions.
- In all patients in the study, the remaining period of pregnancy was uneventful and all mothers delivered healthy babies. Most patients had no recurrences of arrhythmia during long-term follow-up.

Case reports

Our patient population included 4 pregnant women who underwent electrophysiological studies and catheter ablations at St. Joseph's Heart Rhythm Center in Rzeszów, Poland between August 2017 and January 2020 due to symptomatic cardiac arrhythmias. The mean ± SD age of the patients was 27.0 ± 3.9 years (range, 23–32 years). Mean ± SD gestational age at the time of the ablation procedure was 24.5 ± 8.9 weeks (range, 13.0–34.0 weeks). All patients were in their first pregnancy at the time of the procedure and all had experienced palpitations since childhood. However, during pregnancy, the symptoms became more frequent and intensified. Moreover, patient 2 experienced a single syncope episode during pregnancy. Three patients had symptomatic tachyarrhythmias documented on 12-lead electrocardiograms and 2 of them had evidence of preexcitation on 12-lead electrocardiograms. Three patients were not treated medically and 1 patient was treated with oral metoprolol 25 mg once daily before being admitted to the hospital. All patients had structurally normal hearts. Detailed patients characteristics are presented in Table 1.

Catheter ablation was recommended after a multidisciplinary consultation with an electrophysiologist and obstetrician due to the potential risk to the fetuses and mothers. Using ultrasound-guided right femoral vein access,[7] a 10-pole diagnostic catheter (Hagmed, Rawa Mazowiecka, Poland) was introduced in the coronary sinus (CS) for SVT induction and atrial stimulation protocols. Next, an ablation catheter

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Table 1 Patients characteristics

Characteristic	Patient 1	Patient 2	Patient 3	Patient 4
Patient				
Age (y)	28	32	25	23
Weight (kg)	73	64	65	55
Height (cm)	169	164	160	164
Arrhythmia characteristic	AVNRT	WPW syndrome	WPW syndrome	AVNRT
Preoperative medication	None	None	None	Metoprolol 25 mg
Parity	First pregnancy	First pregnancy	First pregnancy	First pregnancy
Gestational week at procedure	34	23	28	13
Time of delivery (wk of pregnancy)	38	37	38	38
Follow-up period (y)	7	7	4	4
Recurrence of arrhythmia	None	None	1 y after procedure	None

AVNRT = atrioventricular nodal reentrant tachycardia; WPW = Wolff-Parkinson-White.

(Navistar; Biosense Webster, Diamond Bar, CA) was placed in the His bundle region and the right ventricle. The CARTO electroanatomic mapping system (Biosense Webster) was used for no fluoroscopy. A simplified electroanatomic marker annotation was implemented in all cases to shorten the procedure time and thus prevent potential maternal and fetal complications (Figures 1–4). A brief fast anatomic mapping geometry was also performed in patients 2, 3, and 4. The mean ± SD number of acquired mapping points was 7.0 ± 2.5 and the mean ± SD time required to map the first point was 27.5 ± 13.1 minutes. The mean ± SD mapping time was 12.5 ± 6.0 minutes. The mean ± SD radiofrequency (RF) ablation time was 251 ± 170 seconds. In the case of patient 1 and patient 4, a single RF application or a series of RF applications led to atrioventricular nodal reentrant tachycardia noninducibility. In patient 2, initial electrophysiological study revealed accessory pathway (AP) with an effective refractory period of 310 milliseconds. RF delivery led to transient loss of preexcitation, with its early recurrence after termination of applications. Thus, the long stabilization sheath was carefully advanced and, with its support, RF energy was

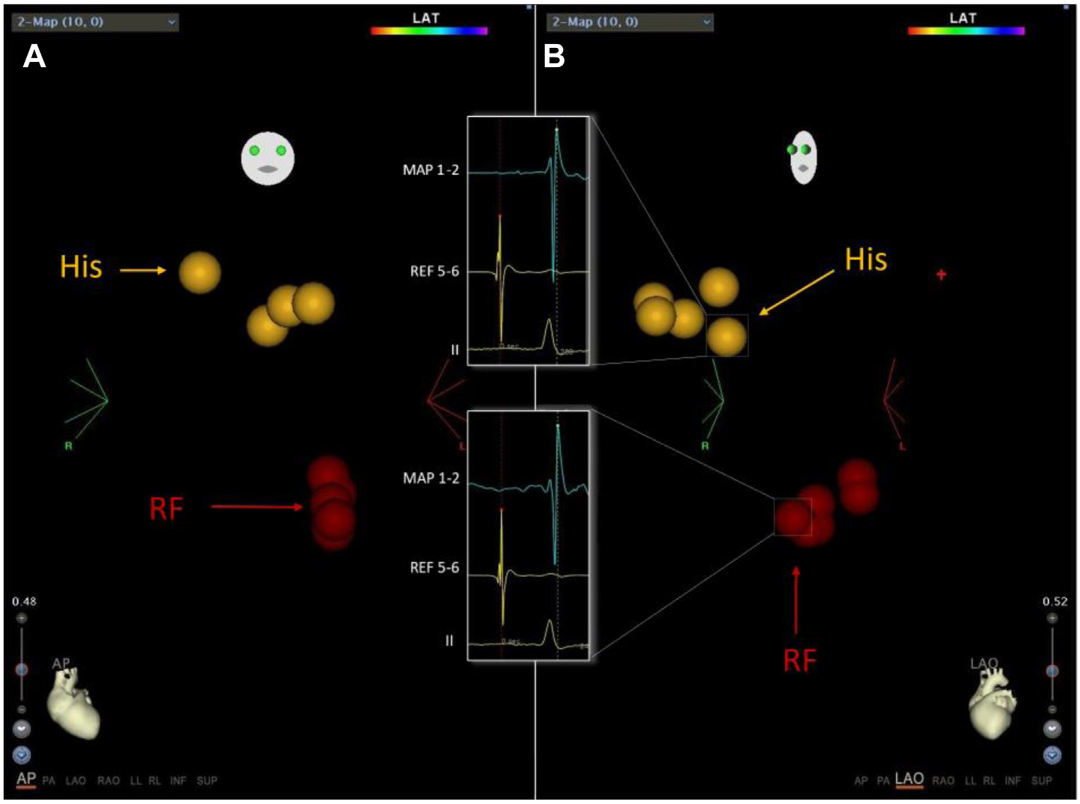

Figure 1 **A:** Electroanatomic mapping showing His bundle tags and radiofrequency application points in the anterior-posterior projection. **B:** Electroanatomic mapping showing radiofrequency application points in left anterior oblique (LAO) projection, with intracardiac electrograms panels recorded during the procedure. Potentials of His bundle and the slow pathway potentials are depicted.

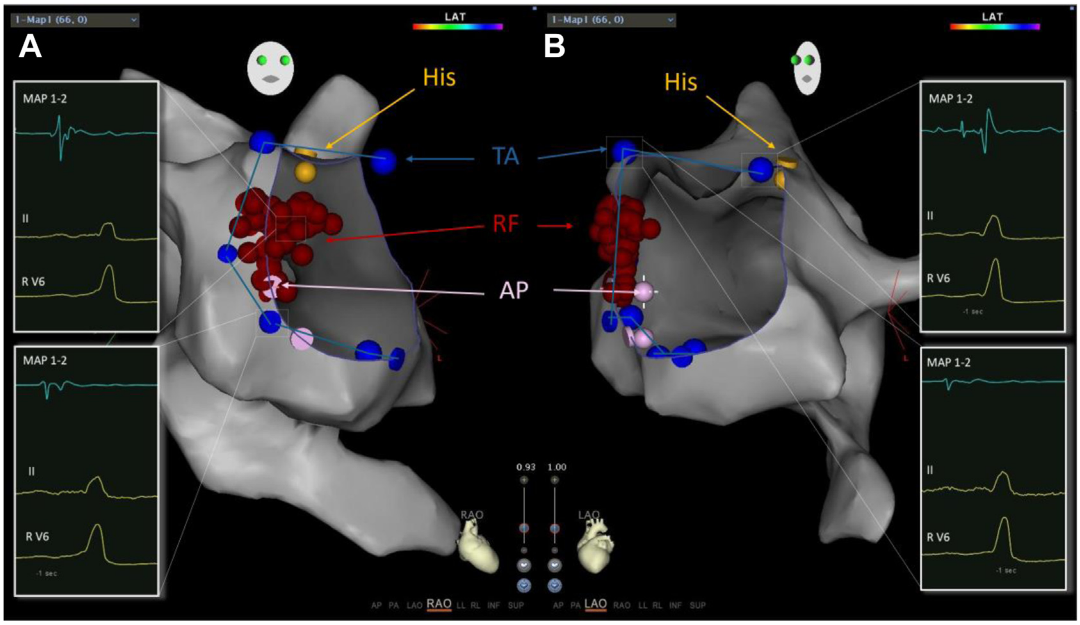

Figure 2 **A:** Electroanatomic mapping showing radiofrequency (RF) application points in right anterior oblique (RAO) projection, with intracardiac electrograms panels recorded during the procedure. The *upper panel* shows the antegrade right-sided accessory pathway (AP) potential before radiofrequency energy delivery and the *lower panel* shows the retrograde pathway potential located along the tricuspid annulus. **B:** Electroanatomic mapping showing radiofrequency application points in left anterior oblique (LAO) projection, with intracardiac electrograms panels recorded during the procedure. The upper panel shows the His bundle potential and the lower panel shows the intracardiac electrogram from the high right atrium. TA = tricuspid annulus.

delivered at the site of the AP location and successfully abolished the AP. In patient 3, an atrioventricular fusion was identified in the proximal CS and the effective refractory period was determined to be <290 milliseconds. Ablation was attempted in this area. However, only transient loss of preexcitation during applications was observed. Therefore, using a right femoral arterial and retroaortic approach, the ablation catheter was advanced to

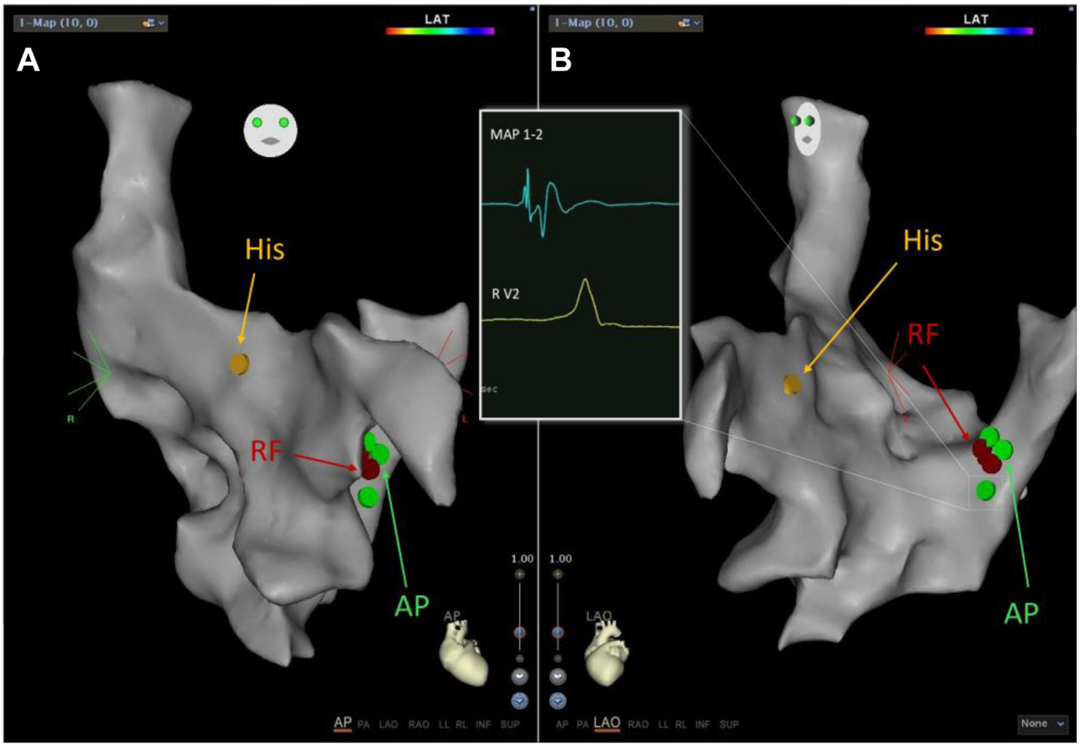

Figure 3 **A:** Electroanatomic mapping showing radiofrequency (RF) application points in the anterior-posterior projection. **B:** Electroanatomic mapping showing RF application points in left anterior oblique (LAO) projection, with intracardiac electrograms panels recorded during the procedure. The *panel* shows accessory pathway (AP) potential before radiofrequency energy delivery.

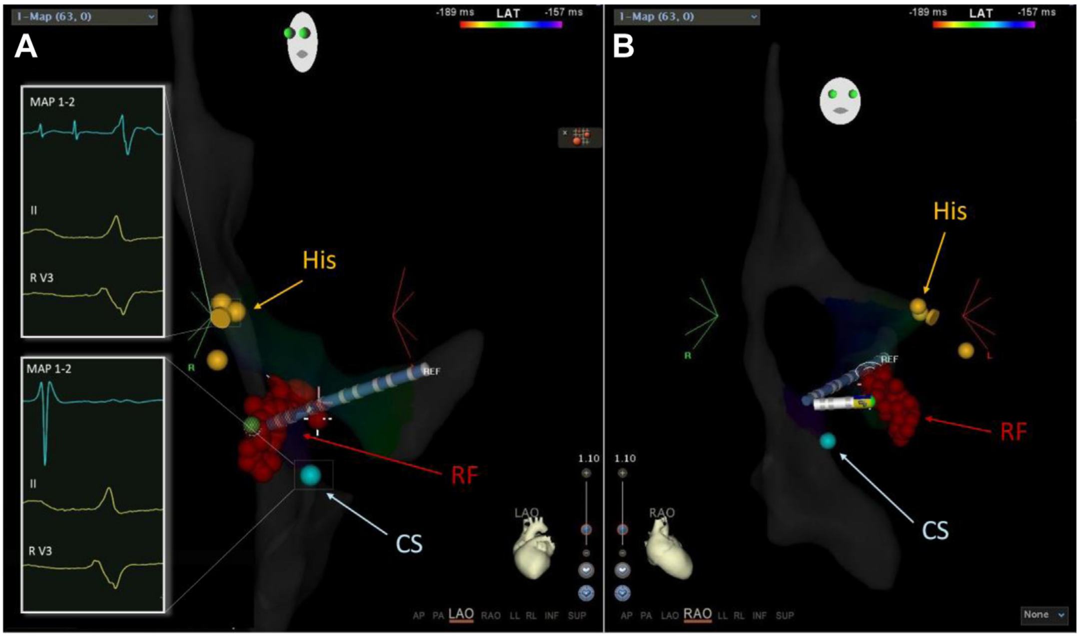

Figure 4 **A:** Electroanatomic mapping shows radiofrequency (RF) application points in the left anterior oblique (LAO) projection, with intracardiac electrograms panels recorded during the procedure. **B:** Electroanatomic mapping shows coronary sinus (CS) ostium, His bundle ad RF tags in right anterior oblique (RAO) projection.

the mitral annulus. Next, based on a previously obtained electroanatomic map of the right atrium and CS ostium, a single RF application was delivered at the opposite site to the annotated CS sites, resulting in successful elimination of the AP.

Because data regarding midazolam use in pregnancy are conflicting, with some literature reports describing its teratogenic effect,[8] all procedures were performed using local anesthesia without sedation. In 2 patients, 3000 units of unfractionated heparin were administered. In patient 3, left-sided ablation was performed, which required administration of heparin. In patient 2, in whom a long sheath was used, heparin was administered to empirically reduce the risk of thrombosis. However, it is important to highlight that there is currently no consensus regarding anticoagulant administration during right atrial procedures.[9] In patient 1, two boluses of intravenous salbutamol (0.25 mg) were used for baseline arrhythmia induction and to confirm the noninducibility of the atrioventricular nodal reentrant tachycardia after ablation.[10]

The mean ± SD procedure time was 71.3 ± 14.4 minutes. No complications occurred. Detailed procedure characteristics are presented in Table 2.

The patients had no evidence of arrhythmia at the time of discharge from the hospital and all of them delivered a healthy child—three patients at 38 weeks of pregnancy and 1 patient at 37 weeks of pregnancy (Table 1). Mean ± SD follow-up time was 5.5 ± 1.7 years. During the follow-up period, 3 patients showed no evidence of the arrhythmia recurrence. However, 1 year after the procedure, patient 3, with Wolff-Parkinson-White syndrome, was admitted to the hospital with a recurrence of the same symptoms, without apparent delta wave in the electrocardiogram, and was scheduled for repeat electrophysiological study. During the right ventricle stimulation protocol, retrograde conduction through the AP was revealed at a similar site as previously ablated. There was no evidence of preexcitation during stimulation and no antegrade conduction through AP was found. Stimulation protocols repeatedly induced atrioventricular reentrant tachycardia with cycle length of 447 milliseconds. The ablation electrode was placed in the proximal CS, and RF energy (25 W, 83 seconds total RF time) successfully eliminated the AP. The patient had no evidence of arrhythmia at the time of discharge from the hospital. During the 4-year follow-up period, no arrhythmic symptoms reoccurred.

None of the children developed any arrhythmias during follow-up.

Discussion

The exact mechanisms of arrhythmia development during pregnancy remain unknown. However, hemodynamic,

Table 2 Procedures characteristics

Procedure	Case 1	Case 2	Case 3	Case 4
Procedure time (min)	60	90	75	60
No. of mapping points	10	8	5	5
Time required to map the first point (min)	44	32	17	17
Total mapping time (min)	4	18	14	14
Radiofrequency time (s)	107	456	121	310
Total no. of radiofrequency applications	1	9	4	10
Power (W)	27	34	34	21
Maximal temperature (°C)	42	38	38	42

hormonal, and autonomic changes that occur during pregnancy have been identified as risk factors for cardiac arrhythmias.[2,3,5,11] Increased heart rate, plasma catecholamine concentrations, raised cardiac output, and increased sympathetic activity at rest have been reported to contribute to proarrhythmia.[5] Furthermore, certain electrocardiographic changes have been observed in pregnancy, such as prolonged maximum P-wave duration and shortened PR interval, which may make pregnant women more susceptible to arrhythmias.[5,12,13] Risk factors predisposing to arrhythmia in pregnant women are older age and congenital heart disease.[4] Moreover, arrhythmia risk peaks in the third trimester.[2]

Most arrhythmias are benign.[1,5,14] However, pathologic supraventricular and ventricular rhythm disturbances are also increasing in prevalence, and an increasing trend in maternal mortality related to cardiac arrhythmias has been reported in the United States.[1,5] Atrial fibrillation and other SVTs are the most frequently reported arrhythmias in pregnancy.[4] Other tachyarrhythmias, such as ventricular tachycardia or premature ventricular contractions, are rare during pregnancy but may also occur.[5] It is therefore important to develop appropriate therapeutic strategies that allow for the effective treatment of arrhythmias, while limiting the risk of maternal and fetal complications.

Fetal adverse outcomes, including intrauterine growth retardation, preterm birth, and congenital heart disease, have been reported in pregnant women with arrhythmias, and management is dependent on the specific arrhythmia diagnosed.

Treatment of arrhythmias in pregnant women poses a therapeutic challenge due to potential adverse effects on the fetus.[15,16] Pregnant patients with symptomatic arrhythmias might be managed medically, however, the potential adverse effects of antiarrhythmic medications remain high, and failure to control the arrhythmia may occur.[5,16,17] According to the European Society of Cardiology Clinical Practice Guidelines, the acute management strategies for SVT include vagal maneuver, electrical cardioversion, β-blockers, and verapamil.[4] Propafenone, β-blockers, procainamide, and verapamil are reserved for long-term management.[4] The recommendation of catheter ablation for the management of SVT is IIA; the level of evidence is C according to the European Society of Cardiology and Heart Rhythm Society guidelines.[4,18] It is recommended to postpone ablation to the second trimester and the procedure should be performed at an experienced center.[4] Furthermore, catheter ablation is recommended for recurrent drug-refractory atrioventricular nodal reentrant tachycardia, atrioventricular reentrant tachycardia, focal atrial tachycardias, cavotricuspid isthmus–dependent atrial flutter, and certain benign right-sided ventricular tachycardias.[4] The European Society of Cardiology and Heart Rhythm Society guidelines also include the recommendation of catheter ablation in symptomatic women with recurrent SVT before they become pregnant.[18,19] Moreover, catheter ablation with electroanatomic mapping systems in experienced centers in drug-refractory and poorly tolerated ventricular tachycardias may be considered.[4]

The main challenge in performing catheter ablation during pregnancy is to limit radiation dose and avoid its teratogenic adverse effects.[14,16,20] Other studies have found that most fetal adverse effects occur at fetal doses of ionizing radiation >200 mGy, but exposure of <50 mGy is not associated with increased risk of fetal malformation.[5,21,22] Damilakis and colleagues[23] reported that abdominal shielding of the mother limits fetal radiation exposure to theoretically <1 mGy.[23] Protecting the mother and fetus from radiation is crucial to avoid malformation and abnormal organogenesis. In recent years, many attempts have been made to achieve radiation-free imaging[16,20,24–27] and these advances allow performance of catheter ablation effectively and safely for mother and fetus.[28,29]

To avoid fluoroscopy exposure, we used the CARTO electroanatomic mapping system. The 3-dimensional navigation system allows navigation of catheters without the need for fluoroscopy and ionizing radiation. The elimination of fluoroscopy allows for the removal of possible teratogenic effects of radiation and makes the procedure safe for fetal development.[16]

However, in addition to zero-fluoroscopic catheter ablations, cases of minimal fluoroscopic catheter ablations during pregnancy have also been reported.[27,30] Greyling and colleagues[30] summarized published reports on catheter ablation of cardiac arrhythmias during pregnancy in the last decade. Of the 27 presented studies, 7 were performed using minimal fluoroscopy.[30] In addition, You and colleagues[27] compared minimal fluoroscopic and purely zero-fluoroscopic catheter ablation in gestational supraventricular arrhythmias. Sixteen cases describing catheter ablations with zero-fluoroscopy were compared with 24 cases using minimal fluoroscopy. More zero-fluoroscopy procedures were performed at a young gestational age, whereas minimal fluoroscopy procedures were mainly performed in the third trimester. Nevertheless, these findings demonstrate equal efficacy rates of successful ablation in both groups and add consideration to the role of zero-fluoroscopy in cardiac arrhythmia management during pregnancy. Other authors have mentioned the limitations of a zero-fluoroscopy approach in the case of patients with arrhythmias arising from the aortic cusps and with epicardial arrhythmias.[31]

Moreover, we used simplified electroanatomic marker annotation to shorten the procedure time and thus prevent potential maternal and fetal complications. The mean ± SD number of mapping points was 7.0 ± 2.5 and the mean ± SD mapping time was 12.5 ± 6.0 minutes. The simplified mapping method has also been reported by other authors.[32–34] However, our case series is the first to describe such a short mapping time associated with an effective therapeutic effect in pregnant women. Altogether, our findings provide evidence for effectiveness of nonfluoroscopic catheter ablation using simplified marker annotation.

Apart from the simplified 3-dimensional electroanatomic marker annotation described, there are other techniques that may be used for ablation in pregnant women. Intracardiac echocardiography provides real-time imaging, allowing precise catheter positioning and assessment of cardiac anatomic structures.[35] One novel algorithm, CartoSound, uses data obtained during intracardiac echocardiography imaging to automatically reconstruct the 3-dimensional anatomy of the left atrium without use of fluoroscopy.[36] However, the insertion of an additional intracardiac echocardiography catheter requires additional venous access and may increase procedural time. Another important technique is full fast anatomic mapping shell creation using multipolar mapping catheters. This method can offer more precise visualization of the heart chambers. However, given the rather moderate complexity of arrhythmogenic substrates in our patients, the clinical benefit of creating a full fast anatomic mapping shell would be limited. Instead, a targeted, simplified mapping strategy allowed for successful ablation, while minimizing procedural time and complexity. It should be acknowledged that multipolar mapping catheters are not equipped with contact force detectors and very detailed mapping can generate some small risk of mechanical perforation.[37,38] In addition, catheter exchange can be associated with some risk of thromboembolic events.[39] Of note, the use of multipolar mapping catheters is contraindicated in the presence of artificial cardiac valves.[40]

Limitations

This was a small case series mainly limited by sample size and the results should be validated in an independent larger cohort.

Conclusion

Our case series suggested that nonfluoroscopic catheter ablation using simplified marker annotation can be a safe and effective therapeutic option during pregnancy. Proper validation of the presented approach is warranted.

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