Nonsustained premature atrial contraction ablation guided by single-beat mapping using charge density mapping

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Introduction

Conventional mapping techniques require a sustained atrial arrhythmia to effectively perform activation mapping. Occasionally, atrial tachycardia (AT) episodes may be nonsustained, limiting the ability to perform activation mapping and subsequent ablation.[1] In some patients, these nonsustained episodes may be symptomatic, negatively impact quality of life, and be refractory to medical therapy.[2] Furthermore, these patients may not be offered ablation, since these brief episodes may be considered unmappable. We present a novel case describing the use of a noncontact charge density mapping system to effectively map and ablate a nonsustained AT in a highly symptomatic patient.

KEY TEACHING POINTS

- Unipolar charge density mapping system is effective in mapping of single premature atrial contractions and brief runs of atrial tachycardia that cannot be mapped reliably with conventional mapping catheters.
- Sequential point-by-point mapping approaches are inefficient and inaccurate; a panoramic, single-beat electroanatomical mapping may potentially help to regionalize the area of interest.
- This technology may also prove useful in the identification and mapping of non–pulmonary vein trigger(s) in patients with persistent atrial fibrillation.

Case report

A 59-year-old woman with hypertension, symptomatic persistent atrial fibrillation (AF) refractory to antiarrhythmic drug therapy, and supraventricular tachycardia underwent pulmonary vein isolation (PVI) and slow pathway modification for atrioventricular nodal reentrant tachycardia. After PVI, there was a brief AT that was earliest on the distal coronary sinus (CS) catheter. The mapping catheter was positioned over the adjacent endocardial area below the left inferior pulmonary vein; however, it could not be mapped, despite isoproterenol infusion, as it was no longer inducible. An implantable loop recorder was inserted at the end of the procedure, and she was continued on flecainide. Immediately after the procedure, she endorsed frequent, yet brief lifestyle-limiting palpitations observed on implantable loop recorder (ILR). There were no triggers or alleviating factors. The ILR interrogation showed an arrhythmia burden of 0.4% for AT/AF owing to nonsustained AT, with rates ranging from 115 to 170 beats/min, lasting on average for 5–10 seconds.

Symptoms persisted and intensified over the next 3 months despite flecainide. Therefore, she was referred for a repeat comprehensive electrophysiology study and ablation for definitive treatment of AT. Owing to the brief episodes and prior failure to map the AT during previous procedure with conventional mapping catheters, the AcQMap system (Acutus Medical, Carlsbad, CA) was used. The procedure was conducted under general anesthesia. At baseline, over a brief waiting period there were occasional premature atrial

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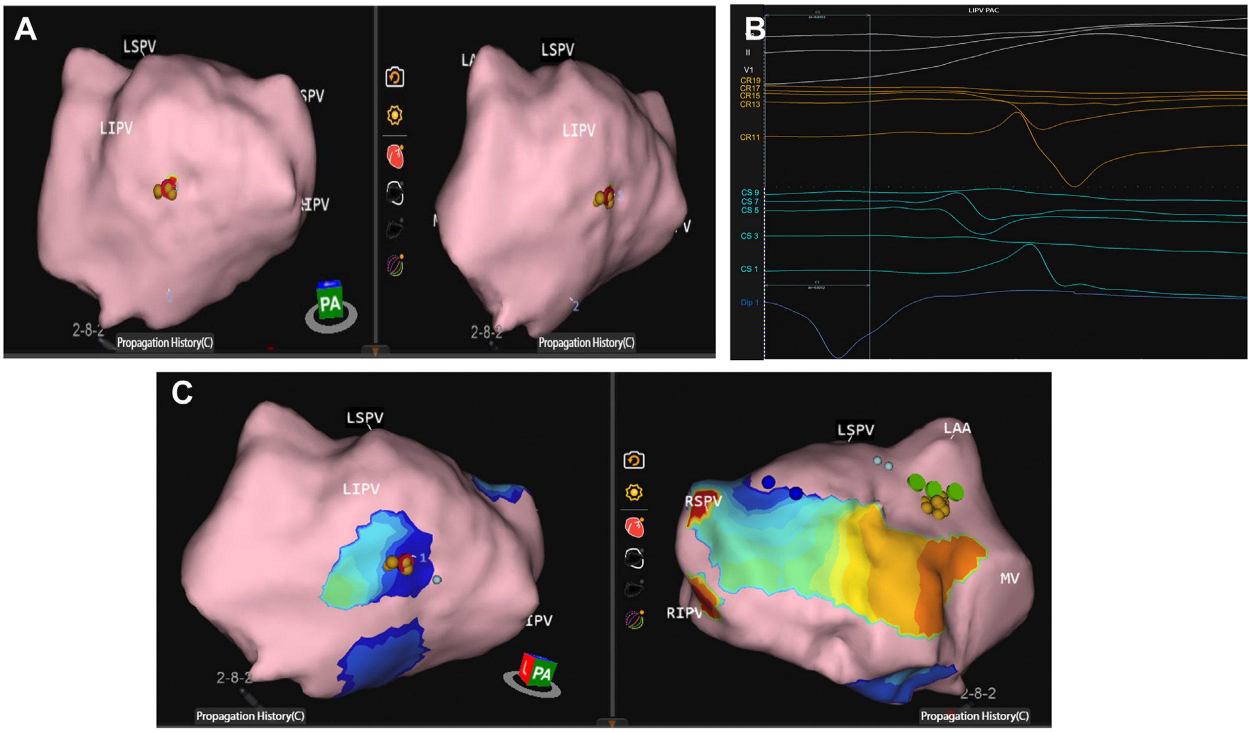

Figure 1 **A:** Premature atrial contraction (PAC) location: posterior base of the left inferior pulmonary vein (LIPV; *red disc*). Dipole 1 at the earliest source of charge (ie, origin of PAC). Gold dots indicate where ablation occurred. **B:** Dipole 1 (blue) signal at origin of the LIPV PAC map ~ 25 ms pre–P wave. CR unipolar signals in orange; CS unipolar signals in light blue; body surface leads II, V_1, and V_6 in white. **C:** Map visualization of the activation at the location of abrupt change in dipole activation around LIPV from -QS to R wave on the unipolar leads. Gold dots indicate where ablation occurred. LAA = left atrial appendage; LSPV = left superior pulmonary vein; RIPV = right inferior pulmonary vein; RSPV = right superior pulmonary vein; MV = mitral valve; PA = posterior anterior.

contractions (PAC) earliest on distal CS; therefore, heparin was initiated and trans-septal puncture was performed under intracardiac ultrasound and fluoroscopic guidance. The noncontact ultrasound and charge density catheter was advanced into the left atrium via a steerable sheath to create an electroanatomic map of the left atrium and perform activation mapping of PAC and nonsustained AT. Of note, all pulmonary veins were confirmed to have entrance and exit block. The AT cycle length was 350–500 ms that was <10 seconds in duration and infrequent. Activation mapping of the AT was repeated multiple times with the location mapped using a single p wave during the brief run to the posterior base of the left inferior pulmonary vein (LIPV) (Figure 1A–1C). Ablation at the LIPV AT site incited a brief tachycardia at a cycle length of 290–300 ms that then terminated. During the waiting period, rare PACs were observed. The PAC was mapped 3 separate times, localizing to the anterior aspect of the left atrial appendage, characterized by unipolar QS morphology and approximately -25 ms pre–p wave that was subsequently ablated (Figure 2A and 2B, Figure 3A–3F). After a 30-minute waiting period and 20-minute challenge with isoproterenol (20 mcg/min), there was no spontaneous or inducible AT.

At 3-month follow-up, she reported no palpitations and significantly improved quality of life, with ILR interrogation demonstrating a 0% AT/AF burden.

Discussion

This case provides the first report of using a unipolar charge density mapping system to effectively single-beat map and subsequently perform ablation of single PACs and brief runs of AT that cannot be mapped reliably with conventional mapping catheters.

Improvements in the field of electrophysiology have been biased toward increasing the quantity and quality of bipolar points collected while the core tenets remain fundamentally dependent upon a premise that each sequentially collected beat originates from a reproducible source, and conduction vectors remain constant across the substrate.[3] Although high-definition mapping has increased efficiency of point collection, mapping still requires contact. Brief episodes of tachycardia may fail to map accurately, as the location may be missed. Furthermore, pace-match mapping often proves difficult owing to masking of P waves within the T waves or inability to accurately discern changes in P-wave morphology in differing locations owing to subtle changes. A panoramic, single-beat electroanatomical mapping may potentially overcome these limitations.

The AcQMap Mapping System (Acutus Medical, Carlsbad, CA) uses a unique mapping catheter (AcQMap) that employs 48 M-band ultrasound transducers to sample the endocardial surface at 115,000 points per minute and measures cardiac potentials with 48 noncontact electrodes.

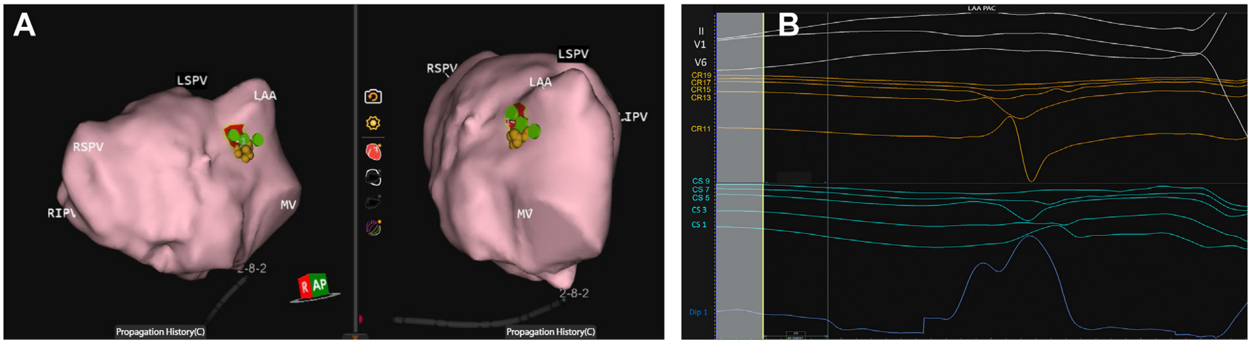

Figure 2 **A:** Premature atrial contraction (PAC) location: anterior aspect of left atrial appendage (LAA; *green discs*). Tachycardia mapped to the location of the LAA PAC. Dipole 1 at the earliest source of charge on LAA PAC map. Gold dots indicate where ablation occurred. **B:** Dipole 1 signal at origin of charge activation on the LAA PAC map ∼25 ms pre–P wave. CR unipolar signals in orange; CS unipolar signals in light blue; body surface leads II, V_1, V_6 in white. LSPV = left superior pulmonary vein; RIPV = right inferior pulmonary vein; RSPV = right superior pulmonary vein; MV = mitral valve; R.PA = right posterior anterior.

The final reconstructed anatomy, rapidly created within 1.5–3 minutes by ultrasound, provides the precise spatial relationship of the electrodes within the chamber. This is an essential requirement for the inverse solution (Poisson's equations) to accurately derive the location and magnitude of dipolar charge sources on the endocardial surface.[4] Once deployed, and even prior to completion of anatomy creation, the system can record detected rhythms for accurate localization of spontaneous triggering events within the occupied chamber.

A recent publication by Gagyi and colleagues[5] described the utility of the AcQMap system for the treatment of brief symptomatic runs of AT defined by the authors as "previously unmappable" with standard sequential mapping techniques. In 20 patients undergoing an ablation for brief AT, 15 were identified to have focal AT and acute success was achieved in 19 of 20 (95%) of patients (ablation was not attempted in the remaining patient owing to proximity to the atrioventricular node). Data were not provided with regard to duration of AT. Indeed, during the index PVI procedure for the current patient, a short burst of AT could not be readily mapped with earliest activation from the distal CS. The subsequent procedure using the noncontact charge density mapping system likely identified the same nonsustained AT on the endocardial surface inferior to the LIPV. Although ablation may not typically be offered for infrequent AT, our patient was highly symptomatic despite medical therapy. Conventional mapping systems with high-definition catheters are capable of simultaneous multipoint assessment; still, some of the arrhythmias may be rare, which would require the mapping catheter to be parked at the correct location. This case illustrates the successful use of noncontact charge density mapping to effectively

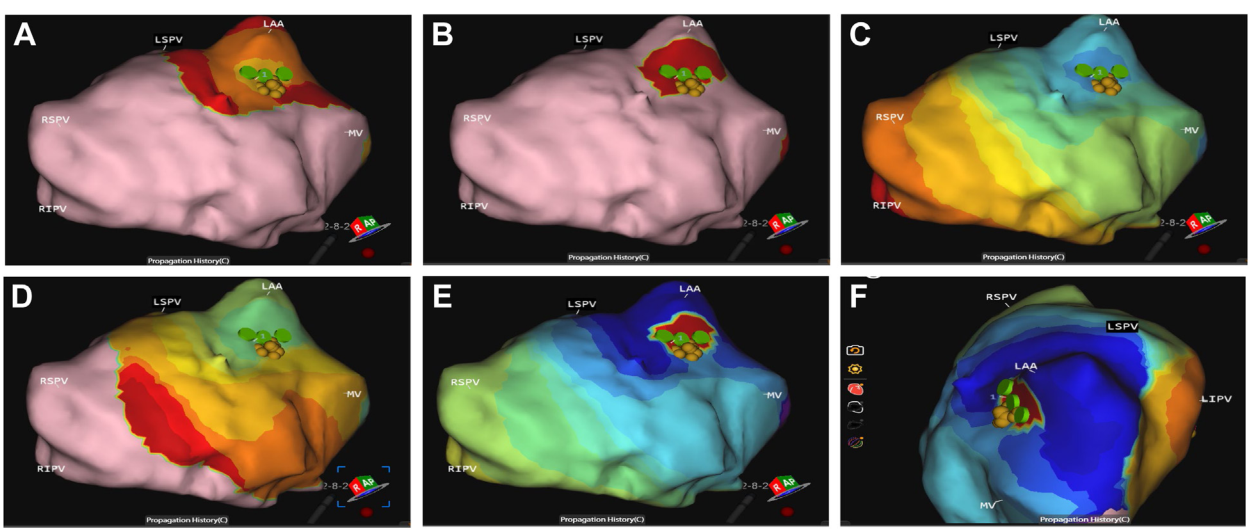

Figure 3 **A–F:** Series of images visualizing the focal activation of our tachycardia source via single-position mapping. Origin at the anterior aspect of left atrial appendage (LAA), same area of interest localized while mapping premature atrial contractions (PACs). Secondary firing at source of PAC within the single P-wave morphology used to map. LSPV = left superior pulmonary vein; RIPV = right inferior pulmonary vein; RSPV = right superior pulmonary vein; MV = mitral valve; R.PA = right posterior anterior.

map the entire left atrium using only a single beat and provide an option for patients who may have previously not been offered ablation or used for repeat ablation. For this to be considered routine use, further studies will be needed on the use of single-beat mapping at multiple centers to confirm feasibility and reproducibility.

Conclusion

This report describes a strategy that led to successful identification and subsequent ablation of a brief AT and single PAC using single-beat mapping with the AcQMap system in a patient that was previously unmappable by conventional contact mapping strategies.

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