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CASE REPORT
Electrophysiology

Single accessory pathway with multiple insertions? First-in-human 3D visualization using dipole charge density mapping: a case report

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Background Accessory pathways (APs) with multiple atrial insertions are often unrecognized and associated with initial catheter ablation (CA) failure. Recently, a novel dipole charge density mapping (DCDM) system was developed that allows mapping of complex arrhythmias based on a single beat. We aim to present the first-in-human report of 3D visualization of a single AP with two atrial insertion sites using high-resolution DCDM.

Case summary A 43-year-old man with recurrent symptomatic atrioventricular re-entrant tachycardia and previously failed CA attempts underwent repeated CA using DCDM. Dipole charge density mapping identified two quasi-simultaneous early atrial activation sites at the left lateral and left anterolateral atrial aspects of the mitral annulus, suggesting the presence of a single AP with dual atrial insertion sites. Successful radiofrequency CA was performed at the mid-body of the AP.

Discussion The true prevalence of APs with multiple atrial insertion sites may be higher than currently reported. This is the first-in-human report of 3D visualization of a single AP with two atrial insertion sites using high-resolution DCDM. Dipole charge density mapping allows the accurate localization of APs with multiple insertion sites based on a single beat.

Keywords DCDM • AP with multiple insertion sites • Single-beat mapping • Non-contact mapping • Case report

ESC curriculum 5.1 Palpitations • 5.5 Supraventricular tachycardia • 7.4 Percutaneous cardiovascular post-procedure

Learning points

- Accessory pathways with multiple atrial insertion sites are rare, frequently unrecognized, and associated with initial catheter ablation failure.
- The dipole charge density mapping mapping system is a non-contact high-resolution charge density-based mapping technology that allows visualization of global atrial activation combining highly accurate ultrasound-based 3D endocardial anatomy reconstruction with high-resolution propagation maps of electrical activation.
- Dipole charge density mapping allows the accurate localization of accessory pathways with multiple atrial insertion sites based on a single beat.

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Introduction

Atrioventricular re-entrant tachycardia (AVRT) is a common finding in the electrophysiology (EP) laboratory.[1] Although it is well established that some patients may have multiple accessory pathways (APs), there are a few recent reports suggesting the presence of single APs with multiple insertions.[2–6] Recently, a novel dipole charge density mapping (DCDM) system was developed for catheter ablation (CA) of complex arrhythmias. Due to its high spatial and temporal resolution, DCDM allows visualization of propagation wavefronts in small fields.[7–9] Using this novel global chamber mapping system, we aim to demonstrate the 3D visualization of a single AP with multiple insertions.

Summary figure

Time	Event
JUN 2021	First CA attempt • Acute success. Early recurrence.
JAN 2022	Second CA attempt • Failure to achieve non-inducibility.
NOV 2022	CA using DCDM: • Single-position, single-beat DCDM identify AP with two atrial insertion sites. • Successful CA using DCDM.
FEB 2023	3-month check-up • No preexcitation. No arrhythmia recurrence. Improved quality of life.

Case report

A 43-year-old male with recurrent symptomatic AVRT and previously failed attempts of CA underwent repeated CA using DCDM.

The patient was referred to our department for an EP study with recurrent symptomatic narrow QRS complex tachycardia (*Figure 1A*). His resting ECG showed ventricular pre-excitation (*Figure 1B*). During the CA procedure orthodromic AVRT using a left-anterolateral AP developed with catheter manipulation. Radiofrequency (RF) CA at the earliest retrograde atrial signal changed the retrograde activation pattern, without major change in the cycle length (*Figure 2*), while coronary sinus catheter maintained stable position. Ablation at the posterolateral mitral annulus resulted in termination of tachycardia and disappearance of pre-excitation (*Figure 1C*). After early arrhythmia recurrence, a second CA attempt was performed, 6 months after the first procedure, unsuccessfully.

Considering two failing attempts using conventional EP tools, the patient was scheduled for repeat CA using the DCDM system (AcQMap, Acutus Medical, Carlsbad, CA, USA).

The DCDM mapping system is a non-contact high-resolution charge density-based mapping technology that allows visualization of global atrial activation by combining highly accurate ultrasound-based 3D endocardial anatomy reconstruction with high-resolution propagation maps of electrical activation. The system is using an invasive diagnostic recording basket catheter (AcQMap catheter, Acutus Inc., 10F), which incorporates 48 biopotential electrodes and 48 ultrasound transducers. The real-time anatomy is rapidly created within 1.5–3 min based on point sets (115.000 surface points/minute) and corresponds to the end-diastolic shape and size. Activation maps are created within 2 min by measuring the non-contact unipolar voltage field (150.000 intra-cardiac unipolar voltages/second) to calculate cardiac activation as charge density and are displayed across the reconstructed 3D anatomy with a spatial resolution of 1 mm. The non-contact module of the DCDM system consists of two mapping modalities: single-position mapping and SuperMap. Single-position maps can be applied to assess global simultaneous cardiac activation in the chamber of interest using a single atrial beat, while SuperMap allows non-contact measurements by aligning different beats acquired at different locations and at different times.

The mapping basket catheter was advanced into the left atrium via intra-cardiac echocardiography guided trans-septal approach. Left atrial anatomy was built using non-contact ultrasound mapping. Next, single-position activation and super-map were performed during AVRT (similar ECG pattern and cycle length as first two CAs) using DCDM. The DCDM propagation maps identified two quasi-simultaneous early atrial activation sites at the left-lateral and left-anterolateral atrial aspects of the mitral annulus, consistent with the possibility of single AP with dual atrial insertion sites (*Figure 3A*). A Kent potential was not identified. Using remote magnetic navigation (MagnoFlush, Medfact, Germany; 45W), RF was applied at the left lateral mitral annulus targeting the earliest atrial activation fused with the ventricular electrogram (*Figure 4*), resulting in termination of tachycardia (*Figure 3B and C*). A new single-position DCDM activation map was performed during right ventricular pacing showing septal earliest atrial activation, resembling retrograde conduction using the atrioventricular node (*Figure 3D*) thus suggesting successful ablation of the mid-body of the AP. After 20-min waiting period, no AP conduction could be seen at adenosine test, and with isoproterenol challenge, tachycardia was non-inducible. Total procedure time was 128 min and fluoroscopy time 15.5 min. At 3-month follow-up, the patient was arrhythmia free, without pre-excitation on surface ECG and reported significantly improved quality of life.

Discussion

This case provides the first-in-human report of using DCDM for 3D visualization and successful RFCA of an AP with two atrial insertion sites.

Accessory pathways with multiple atrial insertion sites are frequently unrecognized and associated with initial CA failure. The real incidence of these APs is difficult to estimate considering that most of them are diagnosed during repeat CA, after being missed or misdiagnosed using conventional fluoroscopic approach.[2] Currently, data on the 3D electroanatomical properties of APs with multiple insertions are limited, relying on sequential mapping.[2,3] In this report, we present the successful use of a novel non-contact global chamber mapping system (DCDM) that allows diagnosis of these complex arrhythmias based on a single beat. Our centre's experience with DCDM comprises of 40–50 procedures per year, performed by five EP specialists. To our knowledge, this case reports the first-in-human use of the DCDM system for CA of an AP.

Dipole charge density mapping propagation maps identified two quasi-simultaneous early atrial activation sites at the left-lateral and left-anterolateral atrial aspects of the mitral annulus (*Figure 3A*). The most likely explanation for this finding is the presence of an AP with two atrial insertion sites. The alternating eccentric activation patterns without alteration in the tachycardia cycle length during the first ablation also support this finding (*Figure 2*).

Previously, few reports suggested the existence of single APs with multiple atrial insertion sites.[2–6] Currently, data on the 3D visualization of these APs are limited to two previous reports.[2,3] One of the most important advantages of DCDM is that a single beat is sufficient to acquire panoramic atrial activation. Due to its global chamber mapping capabilities, this leads to enormously decreased acquisition time. In

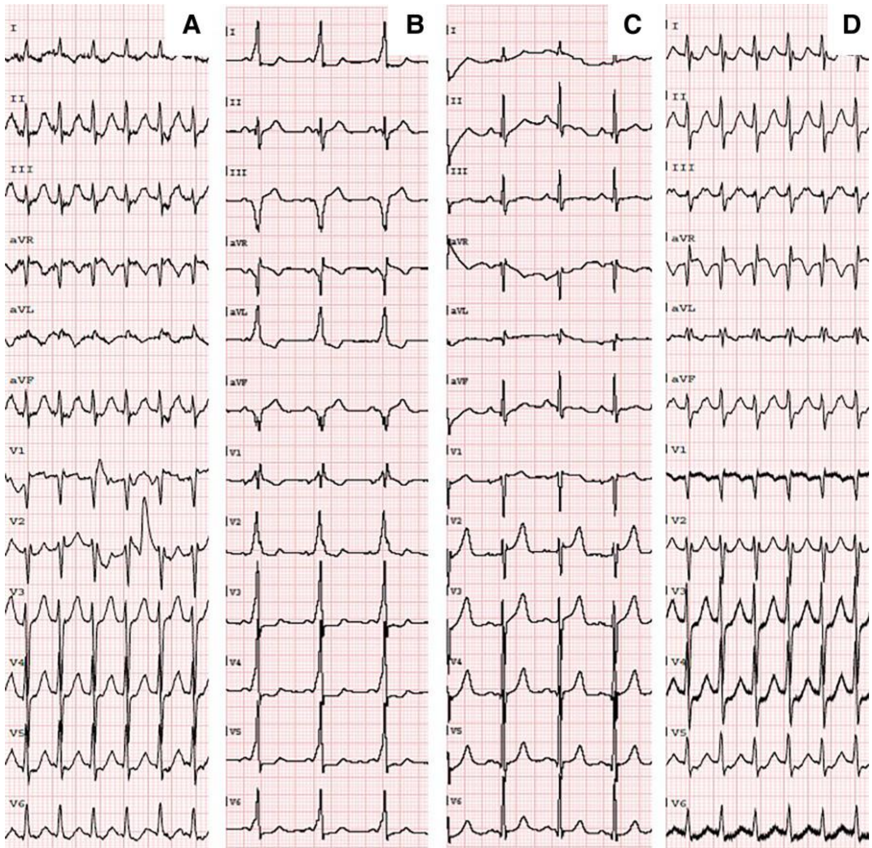

Figure 1 Twelve-lead surface ECG showing (*A*) supraventricular tachycardia and (*B*) sinus rhythm with pre-excitation before the first catheter ablation, (*C*) sinus rhythm without pre-excitation after first catheter ablation, and (*D*) tachycardia before the third catheter ablation procedure.

Figure 2 Change in retrograde activation pattern during radiofrequency catheter ablation at the anterolateral mitral annulus without major change in the tachycardia cycle length (arrows). Notice the possible double atrial component electrograms (A1 and A2) and earliness of the atrial potential (56 ms).

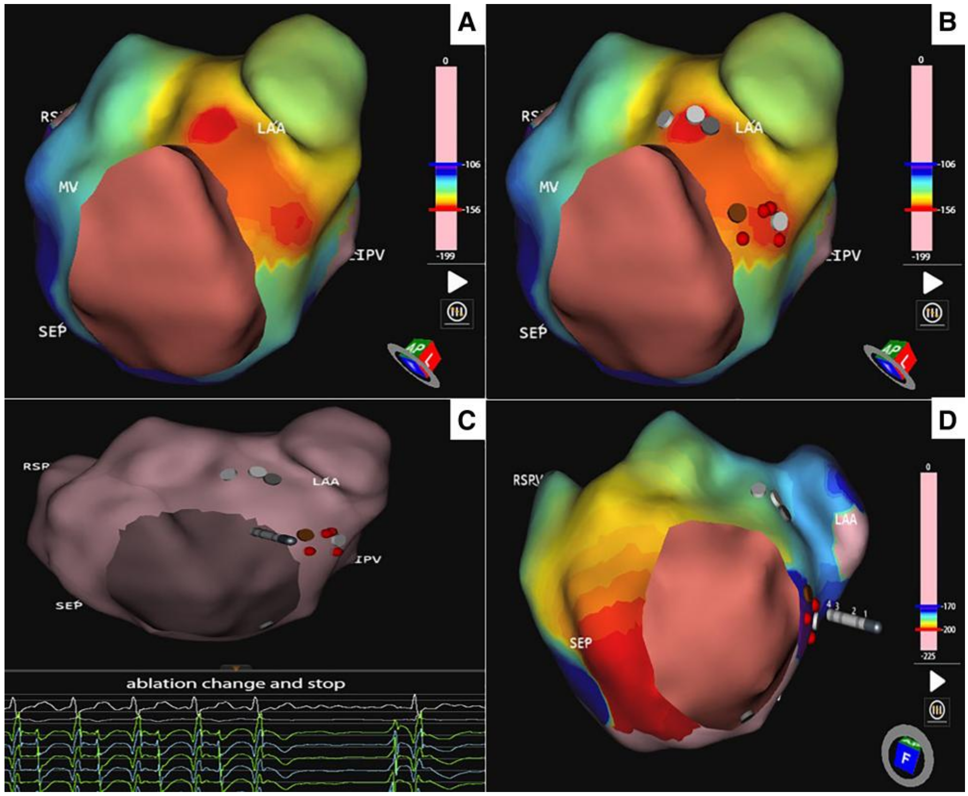

Figure 3 (*A*) Single-position (single-beat) activation map using dipole charge density mapping showing two quasi-simultaneous early atrial activation sites (red) at the left-lateral and left-anterolateral atrial aspects of the mitral annulus. The scales are representing the local activation time standard isochrone timing in milliseconds. (*B*) Ablation lesions overlaid on the single-beat activation map (red dots), (*C*) dipole charge density mapping system showing termination of tachycardia during radiofrequency catheter ablation at the left-lateral mitral annulus, and (*D*) single-position (single beat) activation map using dipole charge density mapping performed during right ventricular pacing showing septal earliest atrial activation, resembling retrograde conduction using the atrioventricular node. Grey dots represent manual annotations of early activation before radiofrequency delivery. LAA, left atrial appendage; LIPV, left inferior pulmonary vein; MV, mitral valve; RSPV, right superior pulmonary vein.

principle, it allows mapping a single beat in patients with complex APs with the potential of recreating new real-time maps with alternating propagation patterns or during pacing manoeuvres. Also, they could provide the possibility of mapping short-lived AVRT in patients with malignant APs unfeasible to map utilizing sequential mapping techniques due to recurrent atrial fibrillation.[7] In our case, single-position map repeated after ablation during right ventricular pacing showed septal earliest activation that proved retrograde conduction through the atrioventricular node.

Another potentially important advantage of non-contact DCDM is that the accuracy and resolution of the map are not dependent on the number of mapping points and less dependent on operator's experience, offering localized and high-resolution representation of endocardial activation.[8,9] As 3D mapping is routinely used only for CA of complex APs, DCDM can help add tremendous extra information about the underlying mechanism and propagation pattern of the arrhythmia, with the aim of improving clinical outcomes.

Finally, choosing an appropriate mapping and ablation technique should be personalized, each technique having its strengths and limitations. Dipole charge density mapping can provide accurate localization of APs using a single beat, which can come with advantages compared to conventional sequential mapping, especially after previous CA failure. A direct comparison of DCDM to sequential mapping would be very interesting in these patients; however, in our patient, both first and second procedures were performed without using 3D mapping. Also, the possible oblique course of the AP and previous ablations could have an impact on the atrial activation pattern. Further studies are suggested in order to confirm the feasibility and reproducibility of single-beat DCDM for patients with APs with multiple atrial insertions. Also, we highlight the necessity of conducting a registry on the use of novel mapping technologies in this group of patients.

Conclusion

This is the first-in-human report of 3D visualization of a single AP with two atrial insertion sites using high-resolution DCDM. Dipole charge density mapping allows the accurate localization of APs with multiple insertion sites based on a single beat.

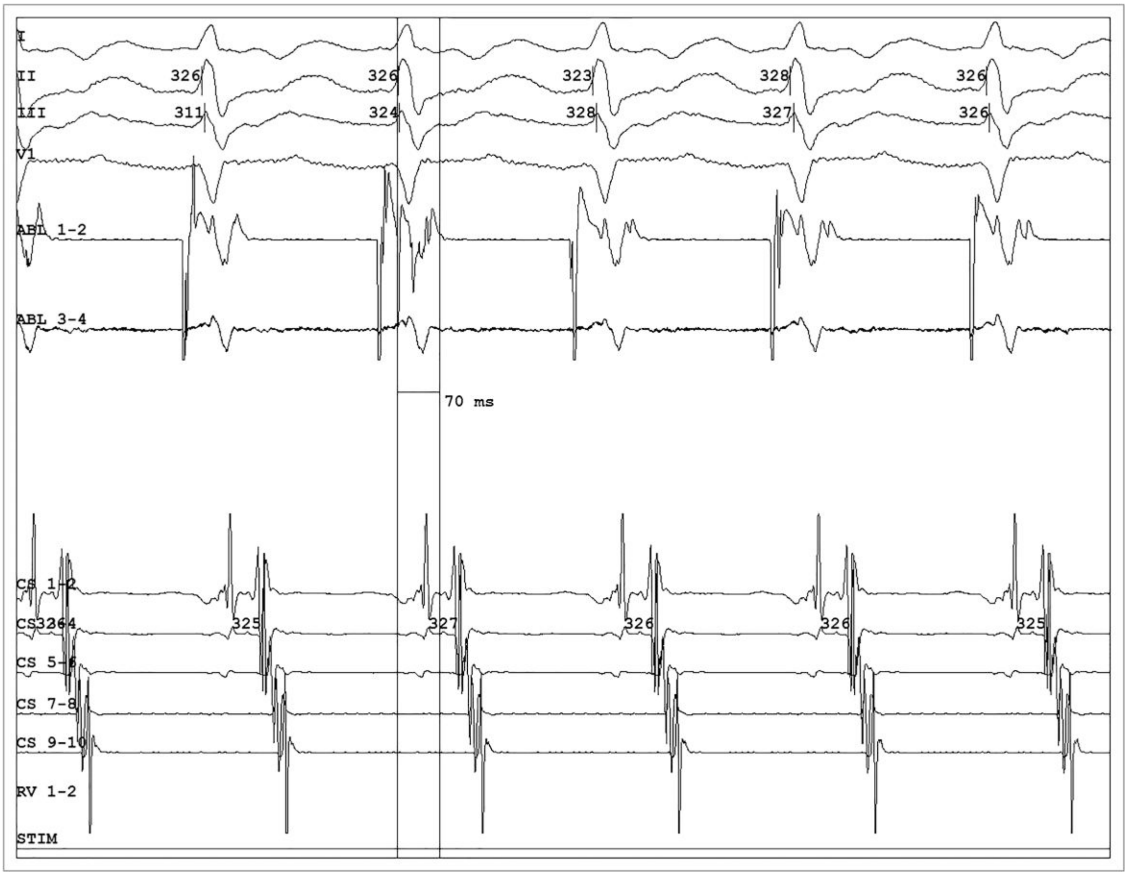

Figure 4 Electrograms of the site of successful catheter ablation showing earliest atrial activation (70 ms) and V–A fusion.

Lead author biography

Ioan A. Minciuna is a final-year cardiology resident physician who is currently completing his EHRA clinical electrophysiology training fellowship at Erasmus University Medical Center Rotterdam, the Netherlands. His areas of interest include catheter ablation of complex supraventricular and ventricular arrhythmias, with focus on novel mapping and ablation technologies.

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Ethics Approval: Patient informed consent was obtained prior to publishing in accordance with COPE guidelines.

Data availability

The full patient informed consent can be provided upon request.

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