

CASE REPORT

Novel SuperMap feature of dipole charge density mapping technique offers advantages for redo catheter ablation in highly symptomatic patients with inappropriate sinus tachycardia: A case series

Rita B. Gagyí  | Rohit E. Bhagwandien | Tamas Szili-Torok 

Department of Cardiology,
Electrophysiology, University Medical
Center, Erasmus MC, Rotterdam, the
Netherlands

Correspondence

Tamas Szili-Torok, Thoraxcenter,
Department of Clinical
Electrophysiology, Erasmus MC,
Postbus 2040, 3000 CA, Doctor
Molewaterplein 40, 3015 GD
Rotterdam, the Netherlands.
Email: t.szilitorok@erasmusmc.nl

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Abstract

Ablation procedures using classical sequential mapping systems may fail to eliminate IAST. The AcQMap dipole charge density mapping technique may offer improved accuracy and has a potential added value for the ultimate success of eliminating IAST. The use of the AcQMap should be considered for redo, as well as first line therapy for patients with symptomatic IAST.

KEYWORDS

catheter ablation, charge density, inappropriate sinus tachycardia, mapping

1 | INTRODUCTION

Three unique catheter ablation patients of symptomatic inappropriate sinus tachycardia underwent an initial ablation procedure using classical sequential mapping system (CARTO), and a redo procedure using a novel noncontact mapping system (AcQMap). We aim to demonstrate the crucial benefit of this novel technique for the ultimate success of eliminating IAST.

Inappropriate sinus tachycardia (IAST) is an uncommon form of supraventricular arrhythmia defined by inexplicably high sinus node frequency at rest or at minimal physical activity.¹ Although the prevalence of IAST is relatively low, in selected patients it may require catheter ablation (CA).² Mapping and CA of IAST results in reasonably good primary success, however, it has high recurrence rate among patients requiring multiple redo procedures.³

Beyond the very well protected epicardial anatomical position, recurrences could also be related to the suboptimal mapping of the targeted region. The major limitation of the currently used standard mapping techniques include suboptimal spatial and temporal resolution.

With the introduction of novel mapping technologies, such as dipole charge density mapping, the possibility of successful mapping and ablation in challenging arrhythmias are instantaneously improving.⁴ Due to the unique technological features, this mapping technology has the potential of increasing both short-term and long-term outcomes in patients even with uncommon arrhythmias. By offering a global endocardial three-dimensional anatomical map combined with high-resolution charge density maps of electrical activation, the AcQMap mapping system may offer advantages as compared with the currently used sequential mapping techniques.

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The aim of this case series draws attention to the possible benefit of using AcQMap mapping system in the mapping of IAST in highly symptomatic patients.

2 | CASE PRESENTATIONS

2.1 | Patient 1

A 29-year-old woman patient, presenting palpitations and vasovagal syncope, has been experiencing disabling symptoms since 2013 and received an ILR device (Medtronic, Reveal LINQ) in 2015. Due to a quasi-continuous sinus tachycardia, (average heart rate between 143 and 154 bpm) despite beta-blocker and ivabradine treatment she was referred for an EP study in 2020. All arrhythmia substrates (concealed bypass, slow pathway, atrial tachycardia) were excluded and she underwent sinus node modification using the CARTO system. Ablation was performed with 10 RF applications using the following power settings: 45W, 43C, and 17 ml/min. Unfortunately at the earliest activation site, the phrenic nerve was detected and no further ablations were applied to this area. Despite this, the procedure resulted in 10% reduction in sinus node frequency. Shortly after the procedure, the patient experienced recurrences and was rescheduled for ablation using the AcQMap system. The procedure was performed under local anesthesia. Under intravenous infusion of isoprenaline, a dipole change density map of the sinus node region using AcQMap mapping system was performed. The earliest site was assessed and ablation was performed using the following power settings: 55W, 43C, 30 ml/min, with a total number of 15 applications and a 7-min fluoroscopy time. Interestingly enough, at the earliest spot depicted by AcQMap, there was no phrenic nerve captured. This clearly highlights the advantages of an improved spatial resolution. Reduction of frequency was obtained with a maximal heart rate of 90 beats per minute under isoprenaline administration. After a 30-min waiting time, reduced frequency was maintained. A month after the procedure, the patient received a DDD pacemaker (St. Jude Medical, Assurity MRI) indicated by low heart rate and frequent vasovagal syncope. At the 3-months and 6-months follow-up visits the underlying rhythm during Holter monitoring was paced atrial rhythm.

2.2 | Patient 2

Our second redo patient is a 22-year-old woman with a past medical history of ADHD and asthma. She experienced palpitations from 2018 and received an implanted ILR device (Medtronic, Reveal LINQ +TruRhythm) after

a negative EP study in 2019. ILR recordings confirmed that her symptoms are associated with sinus tachycardia. In 2020, the patient underwent a second EP study and CA for IAST with the CARTO/ Stereotaxis system. Ablation was performed by applying 18 RF applications with the following power settings: 45W, 43C, and 17 ml/min. Sudden reduction of sinus node frequency was achieved with a heart rate of maximum 110 beats per minute under isoprenaline administration. Three months after CA, the patient complained about persisting palpitations despite metoprolol and her ILR confirmed recurrence of IAST. She was also rescheduled for ablation with the AcQMap mapping system. SuperMaps (Acutus, see below) were performed in the right atrium. Ablation with 13 RF applications targeted the earliest activation. Significant reduction of sinus node frequency was successfully achieved. Satisfying long-term results were recorded at 6-months and 12-months follow-up visits without recurrences.

2.3 | Patient 3

Similarly to the previous patients, a 50-year-old woman patient presenting palpitations from 2015 was referred for EP study and ablation procedure for IAST in 2018 using the CARTO system. Ablation was performed with 9 RF applications using identical power settings. Heart frequency showed only moderate decrease under isoprenaline administration. In the following months, the patient was experiencing persisting palpitations despite medical treatment with ivabradine and beta-blocker. In 2021, she was referred for a redo procedure with the AcQMap system. During the procedure, SuperMap was performed (see below). Ablation was performed using the following power settings: 50W, 43C, and 20 ml/min, with high number of applications (49). She developed significant sinus bradycardia during the procedure.

2.4 | AcQMap technology

In all of these patients, the AcQMap mapping system was used during the redo procedure. It is a novel 3D imaging and mapping system (Acutus Medical Inc.,) that provides highly accurate ultrasound-based anatomical reconstructions combined with high-resolution maps of electrical activation. The system is comprised of an invasive diagnostic recording basket catheter, the AcQMap 10F nondeflectable catheter, which is introduced into the chamber of interest over a 0.032-inch guidewire. The catheter and system are designed to acquire data using noncontact sensors that enable a continuous global view of the conduction of each beat and permits mapping of any atrial

arrhythmia. The endocardial surface is reconstructed based on point sets (115,000 surface points per minute) generated with the use of ultrasound imaging techniques. From the ultrasound point set, the 3D surface is algorithmically reconstructed (Figure 1A). The resulting chamber anatomy corresponds to the end-diastolic size and shape. Besides being used to navigate auxiliary catheters, the 3D anatomy is also key for the inverse solution to derive the location of charge sources on the endocardial surface. In addition, the AcQMap catheter has 48 biopotential electrodes measuring the noncontact unipolar voltage field (150,000 intracardiac unipolar voltages/second) to calculate cardiac activation as charge density via the inverse solution based on Poisson's Equation.⁵ Activation maps are created within approximately 2 min and displayed as a spatiotemporal window of activation history across the reconstructed 3D anatomical image with a spatial resolution of 1 mm (Figure). A propagation history map uses bands of colors to show the location and velocity of the leading edge of the activation wave front over a set duration of time. The noncontact module of the AcQMap system consist of two different mapping modalities, single position

mapping and superposition of multiple noncontact charge density mapping (SuperMap). In all of the three patients the SuperMap feature was utilized. It is a newly designed algorithm to map stable or transient rhythms with multiple morphologies. Due to the diagnostic error caused by signal attenuation over distance inherent to single position mapping, the SuperMap mapping modality was developed in order to acquire points in closer proximity to the endocardial wall. For the SuperMap algorithm, noncontact unipolar voltage electrograms were acquired by hovering the AcQMap catheter in the atria. A visual guided interface of surface illumination, when the noncontact electrodes were within 10-mm distance, assisted the operator in the data acquisition process. After roving around the AcQMap catheter in the chamber of interest, multiple noncontact catheter positions were time aligned based on coronary sinus (CS) activation. The CS channel with the least signal variability and largest peak-to-peak amplitude was automatically selected as the default primary reference. Subsequently, unipolar electrograms from CS were analyzed and binned based on morphology into beat groups. Selected beat groups were processed

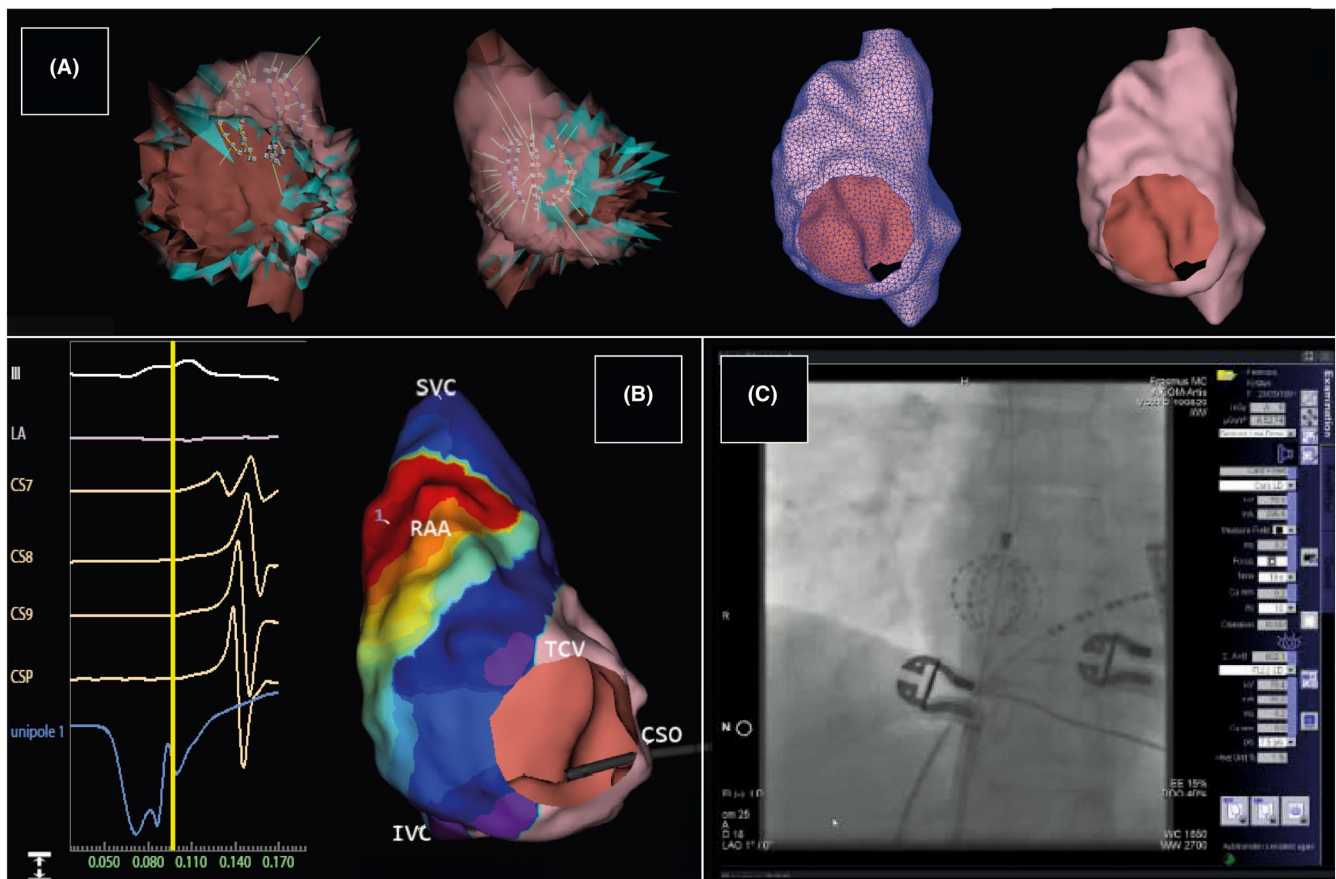


FIGURE 1 Panel A shows the 3D anatomy reconstruction of the right atrium (RA). The first two images show the collection of points with the basket catheter. After a minimal editing on the surface mesh, the final RA anatomy is reconstructed. In Panel B unipolar charge signal is presented, with the activation map showing the leading edge of the activation wave front. Fluoroscopy image showing catheter position is presented in Panel C

TABLE 1 Procedural characteristics

	CARTO					AcQMap				
	Procedure time (min)	RF time (s)	Fluoroscopy time (min)	Total mapping time (min)	Δ HR	Procedure time (min)	RF time (s)	Fluoroscopy time (min)	Total mapping time (min)	Δ HR
Patient 1	91	282	10	33	17	101	451	7	13	31
Patient 2	131	184	8	44	70	111	509	5	20	63
Patient 3	131	728	1	69	19	151	2081	14	6	43

Note: HR1, heart rate before procedure (bpm); HR2, heart rate 24h after procedure (bpm); Δ HR, reduction of heart rate calculated from HR1 – HR2, represented in percentage.

^apost ablation heart rhythm is not sinus rhythm, but atrial escape.

through the charge density inverse solution and presented as propagation history map. Simultaneously, relative unipolar charge amplitude maps can be generated from the same data acquisition and displayed side by side.

2.5 | Ablation procedure

Initial ablation procedures were performed using the NaviStar RMT ThermoCool (Biosense Webster) catheter, redo ablation procedures were performed using the MagnoFlush (MedFact) catheter with a power setting between 10 W and 50 W and temperature limit set to a maximum of 43°C with flow rate of 17–30 ml/min using the Stereotaxis remote magnetic navigation system (Stereotaxis). Acute procedural success was defined by the decrease of the sinus node frequency. Following the ablation procedure, all three patients were examined at the outpatient clinic at regular intervals. Follow-up visits were planned based on the institutional methodology plan.

3 | DISCUSSION

Catheter ablation for IAST has been a successful, despite a difficult approach, with the use of conventional sequential mapping techniques.⁶ Previous studies evaluating CA in highly symptomatic IAST patients observed inconsistent results on whether this approach is providing satisfying short-term and long-term outcomes.^{6–8} In recent literature, the recurrence rate varies between 16% and 30%.³ To the best of our knowledge, this is the first report of the use of the AcQMap novel noncontact mapping technique in the ablation of IAST. The SuperMap algorithm offered by AcQMap provides a global real-time anatomy of the cardiac chamber, and accurately creates a high-resolution propagation history map of electrical activation. Using this propagation history map, the site of earliest activation can be rapidly and precisely determined and successfully ablated. Due to its high spatial resolution, the system could successfully exclude the phrenic nerve implication in patient 1, which was the reason for cancellation of the initial procedure with the CARTO mapping system. Although these features do not shorten procedural times, they provide more sustained acute and long-term results compared with other sequential mapping techniques (Table 1). Additionally, the AcQMap system creates more complete anatomical reconstructions in significantly shorter mapping times compared with the CARTO mapping system. Interestingly enough, in all these three cases a first CA was attempted with the CARTO mapping system. The initial procedures failed to relieve symptoms in all three patients and there was no lasting effect on heart

rate, as assessed by Holter ECGs during the follow-up visits. Comparing the maps acquired using the CARTO system to the maps acquired with the AcQMap system, we observed a difference in the locations of activation sites in

all three patients (Figure 2). Consequently, we can affirm that the AcQMap mapping technique is more accurate in localizing early activation sites and it provides a crucial added value for the ultimate elimination of IAST.

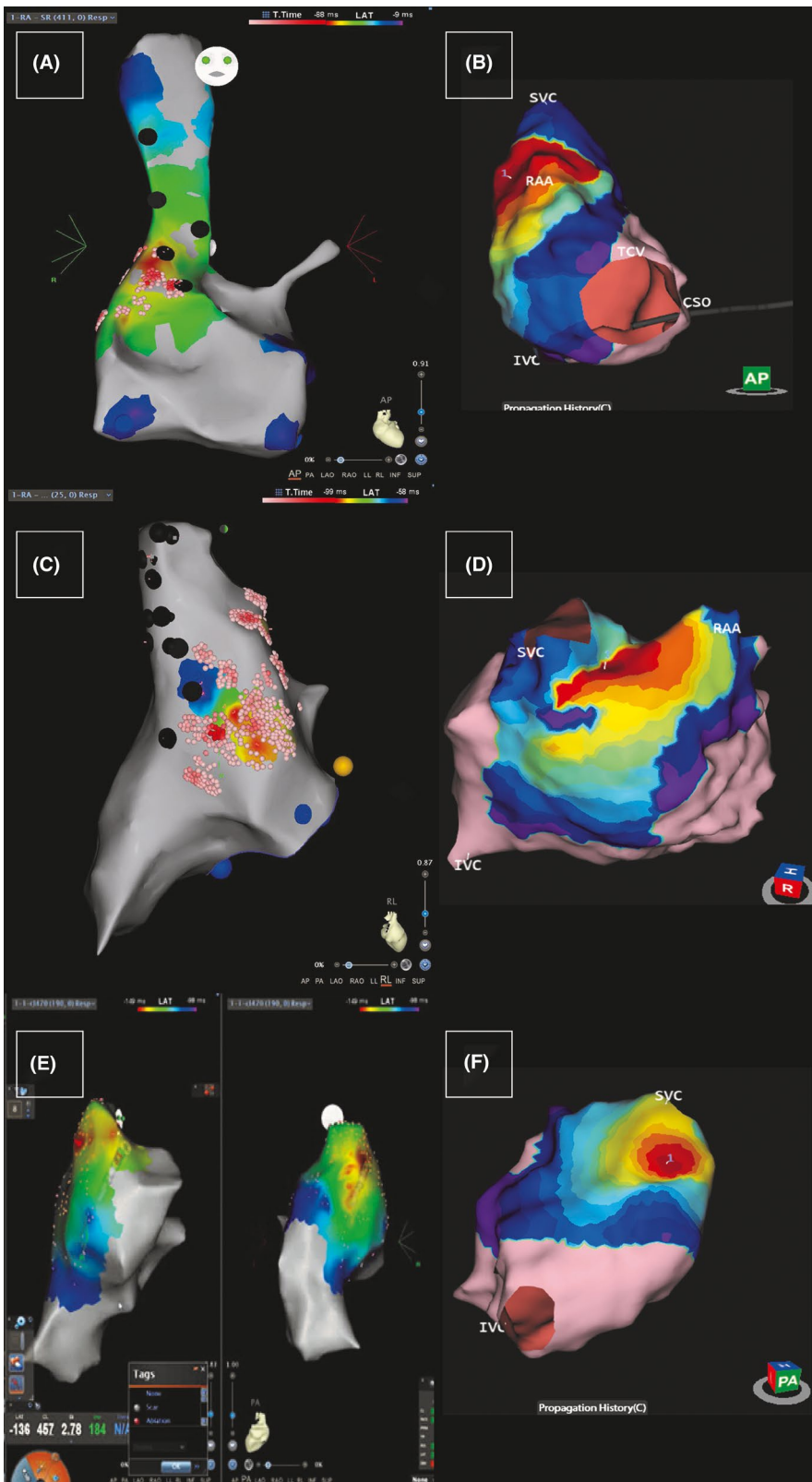


FIGURE 2 Panel A, C and E shows CARTO maps from the initial procedure for every patient. In panel B, D and F AcQMap acquisitions are presented for every patient. In all three patients, these ultrasound-based maps offer more realistic anatomical reconstruction than the CARTO maps showed in panel A, C and E. In every patient, a difference between the locations of the activation sites can be observed when comparing the CARTO to the AcQMap images

4 | LIMITATIONS

The small number of patients represents the major limitation of this report, which is due to the rare nature of the arrhythmia. Despite these promising results, future studies are required in order to prove the efficacy and efficiency of this novel mapping method in the treatment of IAST. Due to the small number of patients, data pooling should be considered. Considering that in all three patients the ablation procedures with AcQMap were redo procedures, we cannot exclude the possibility that the RF application in the first sessions may have shifted the earliest site of tachycardia. However, this is less likely in three consecutive patients. Further specific randomized studies are required for clarification.

5 | CONCLUSION

The current report suggests that the AcQMap mapping system may offer advantages over traditional sequential mapping systems in the treatment of symptomatic IAST. It may be considered for redo after failure of initial procedure, as well as for first-line therapy. Further research is needed to more rigorously demonstrate the advantages of this system.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

All authors contributed equally to the manuscript. TSZT substantially contributed to the conception, design of the work, and have drafted and revised the manuscript. RB acquired intraprocedural data and performed the procedures together with TSZT. RBG acquired clinical data and wrote the manuscript.

ETHICS APPROVAL

Written informed consent was obtained from all three patients for the publication of this case series.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Rita B. Gagyí  <https://orcid.org/0000-0003-4703-2897>

Tamas Szili-Torok  <https://orcid.org/0000-0002-7165-8243>

REFERENCES

1. Morillo CA, Klein GJ, Thakur RK, Li H, Zardini M, Yee R. Mechanism of 'inappropriate' sinus tachycardia. Role of sympathovagal balance. *Circulation*. 1994;90(2):873-877.
2. Lee RJ, Kalman JM, Fitzpatrick AP, et al. Radiofrequency catheter modification of the sinus node for "inappropriate" sinus tachycardia. *Circulation*. 1995;92(10):2919-2928.
3. Rodriguez-Manero M, Kreidieh B, Al Rifai M, et al. Ablation of inappropriate sinus tachycardia: a systematic review of the literature. *JACC Clin Electrophysiol*. 2017;3(3):253-265.
4. Bala G, De Asmundis C, Chierchia GB. A novel noncontact high-resolution charge density mapping system to guide ablation of complex atrial arrhythmias: overview of device technology and application. *Expert Rev Med Devices*. 2021;18(4):343-350.
5. Grace A, Willems S, Meyer C, et al. High-resolution noncontact charge-density mapping of endocardial activation. *JCI Insight*. 2019;4(6):126422.
6. Marrouche NF, Beheiry S, Tomassoni G, et al. Three-dimensional nonfluoroscopic mapping and ablation of inappropriate sinus tachycardia. Procedural strategies and long-term outcome. *J Am Coll Cardiol*. 2002;39(6):1046-1054.
7. Killu AM, Syed FF, Wu P, Asirvatham SJ. Refractory inappropriate sinus tachycardia successfully treated with radiofrequency ablation at the arcuate ridge. *Heart Rhythm*. 2012;9(8):1324-1327.
8. Koplán BA, Parkash R, Couper G, Stevenson WG. Combined epicardial-endocardial approach to ablation of inappropriate sinus tachycardia. *J Cardiovasc Electrophysiol*. 2004;15(2):237-240.

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