Stochastic Trajectory Analysis of Ranked Signals (STAR) Apollo mapping system approach to treat persistent atrial fibrillation: A case report

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Introduction

Atrial fibrillation (AF) is the most common arrhythmia encountered in clinical practice.[1] It affects close to 6 million individuals in the United States alone.[2] AF is considered persistent if it lasts continuously for 7 days and long standing if it lasts for more than 12 months, affecting more than 70% of the total cases.[3] The treatment of persistent AF requires ablation of additional targets in conjunction to pulmonary vein isolation (PVI) such as substrate modification, focal ablation of complex fractional atrial electrograms, and a hybrid approach combining epicardial with endocardial ablation.[4,5] Although there has been a significant improvement in mapping algorithms to identify focal drivers and drivers with rotational activity, there continues to be variability in outcomes.[6] In this case report we describe a novel mapping algorithm that uses a vector-based analysis to determine predominant wavefront direction and ranking of signals that identifies early sites of activation (ESA) to treat a patient with persistent AF.

KEY TEACHING POINTS

- There has been a significant improvement in mapping algorithms to identify focal drivers and drivers with rotational activity to treat persistent atrial fibrillation (AF): however, there continues to be variability in outcomes.
- The STAR system (Rhythm AI Ltd) identifies regions of the atrium with early electrical activation and does not seek to identify a particular mechanism, just a source.
- The logic for this is that identifying the mechanism is of limited clinical importance if the physician is going to deliver therapy to ablate it.
- Thus, STAR will aid the physician by identifying potential regions where AF is being driven from and thus may focus their attention on these regions.

History and physical

A 59-year-old female patient with a past medical history of paroxysmal AF status post radiofrequency isolation of all pulmonary veins (PVs) in 2019, hypertension, hyperlipidemia, and obstructive sleep apnea came to the clinic for recurrent increased palpitations and recording of recurrent symptomatic AF on her Apple watch.

After her ablation procedure in 2019, she was switched from amiodarone to sotalol, which was eventually stopped. Three years after the initial procedure, she presented to the emergency department for an abnormal electrocardiogram (ECG) and complaints of chest pain, shortness of breath, and fatigue. Her ECG showed sinus rhythm with premature atrial complexes. A Holter monitor placed on discharge showed intermittent symptomatic paroxysms of AF. A stress echocardiogram showed an ejection fraction of 60%, mild left ventricular hypertrophy, and mid distal inferoapical hypokinesis consistent with ischemia. An angiogram was recommended which showed mild non-obstructive coronary artery disease.

An ECG in the clinic on this visit showed AF with a ventricular rate of 122 beats/min. Her physical examination was unremarkable, and a decision was made to restart her sotalol in addition to being placed on a monitor. During her follow-up, a repeat ECG showed symptomatic persistent AF despite increasing the doses of sotalol, and she was deemed to require a redo AF ablation.

No cardiac magnetic resonance imaging was done for the patient because of her insurance. The patient was adequately vaccinated, with no side effects reported, and the patient did not have COVID-19.

KEYWORDS Artificial intelligence; Machine learning; Algorithm; Mapping; Atrial fibrillation; Ablation

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Procedural steps

The patient was prepped and draped in a sterile fashion. The right groin was anesthetized, and vascular access was obtained under ultrasound guidance. An esophageal temperature probe was inserted to monitor esophageal temperature throughout the case. Intracardiac echocardiography (ICE) was used during the entire procedure.

Vascular sheaths

An Agilis sheath along with an 8F and a 9F sheath were inserted in the right femoral vein.

Intracardiac echo and mapping

Three-dimensional (3-D) reconstruction of the left atrium (LA) was created using the EnSite X 3-D mapping system (Abbott, St.Paul, MN). The following structures were visualized with ICE: the right atrium, fossa ovalis, tricuspid valve, coronary sinus, crista terminalis, right atrial appendage, LA, mitral valve, left atrial appendage, left superior and inferior PVs, right superior and inferior PVs, aortic valve, left ventricular outflow tract, descending aorta, pulmonic valve, right ventricular outflow tract, and pulmonary artery.

Transseptal catheterization

A radiofrequency transseptal needle was used. Proper placement of the sheath was confirmed by ICE.

Mapping

A voltage and activation map of the LA was created using the grid mapping catheter and the EnSite X mapping system in AF. Three out of the 4 PVs were noted to be isolated distally but not proximally. There was an area of slow entry into the left inferior PV. The data were then analyzed using the STAR Apollo mapping system from Rhythm AI Ltd (London, England) to identify repetitive patterns of activation (RPA) and ESA (ESA – sites where the activation originates from within the footprint of the HD grid) to locate areas of the LA as potential targets for ablation. Three regions were identified by the STAR Apollo mapping system, 2 near the right PV and 1 on the roof between right PV and the left PV (Figure 1).

Algorithm of the STAR Apollo mapping system

The system uses unipolar electrograms recorded by the EnSite X mapping system. The electrograms are exported and filtered by STAR Apollo. Timing is determined by the maximum negative dV/dt. The timing of the

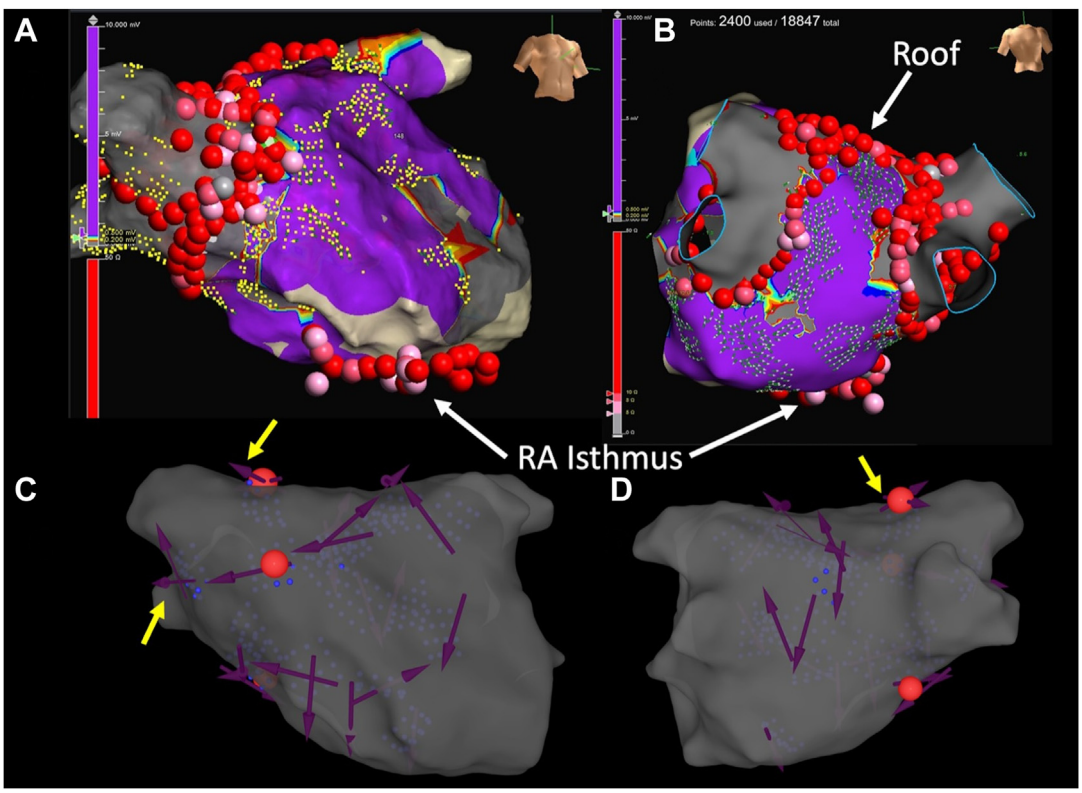

Figure 1 **A, B:** The postablation EnSite voltage maps (**A:** right anterior oblique; **B:** posteroanterior) showing the pulmonary vein (PV) encirclement and roof line (Roof) lesion set and right atrial isthmus line (RA Isthmus). **C, D:** The corresponding STAR Apollo maps showing 3 early sites of activation (*red spheres*). Repetitive patterns of action (*purple arrows*) are seen penetrating into the right PV, suggesting that repeating activations are moving from the right PV antrum into the veins rather than originating from within the veins (highlighted with *yellow arrows*) and that the right PVs were passive in the persistent atrial fibrillation (AF) mechanism. Inclusion of the antrum into the wide encirclement lesion set resulted in AF termination.

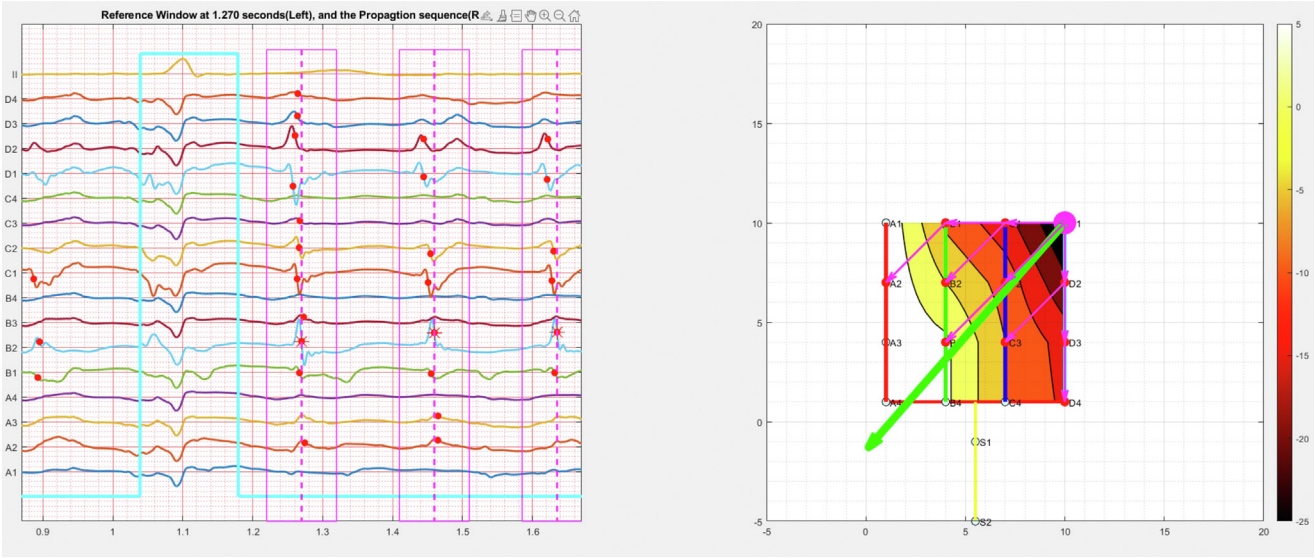

Figure 2 Sample of electrograms with the surface electrocardiogram at the top and electrograms from the HD grid. The reference window is marked as purple boxes and the R-wave blanking marked with blue boxes. The allocated timing from the STAR Apollo mapping system (Rhythm AI Ltd) is shown as red dots at the maximum negative dV/dt (right side) with the resultant vector represented by a green arrow.

electrograms have been validated by independent physician observers as part of the U.S. Food and Drug Administration clearance. The electrodes are timed relative to one another within a reference window that has a plausible duration for a single-activation wavefront of cardiac tissue for the area covered by the HD grid (Figure 2). If a signal is below a predetermined threshold, then no timing is allocated to that electrogram. The most common vectors of activation are calculated from a 30-second recording.

If the ESA is on a location at the edge of the HD grid footprint, then it will not be marked because there is no certainty that this is a truly local activation if it is not surrounded by simultaneously recorded electrodes that have late activation. However, if this is a repeating region with an AF driver, then the surrounding adjacent regions will have repeating patterns of activation emerging in all directions, which will be shown as an RPA in the STAR mapping system. ESA are therefore only marked if there is certainty that this is a true ESA, and other regions of drivers can be inferred by the distribution of RPA. This is a similar concept that one might use to identify the location of an accessory pathway where the location is inferred by the activation pattern of either the ventricle or atrium (during atrial pacing retrograde conduction). In AF, this pattern will vary from beat to beat but the most dominant or important activations will repeat themselves and be shown by the STAR mapping system. As the system uses unipolar electrograms to time signals, orientation of the grid catheter does not impact signals as it might do with bipolar signals. If the catheter is not near the endocardial surface/geometry, the system rejects that recording.

A voltage map was also performed as part of the baseline mapping to check whether the PVs were isolated and to what extent the PVI encirclement was made in the LA. In this case, the PVI was quite distal within the veins, which suggested that a wider encirclement would be useful. The STAR Apollo mapping system identified sites that activated earlier than those around them, and indicated a predominant activation direction, but did not assume any specific AF mechanism. The STAR Apollo mapping system can potentially be complementary to voltage mapping because it may give insight as to whether repetitive patterns of activation are progressing toward a passive area of low voltage or away from a low-voltage area that is supporting AF.

Ablation

Radiofrequency energy was applied using the Tactiflex ablation catheter (Abbott, St.Paul, MN) to include the regions of interest within a wider encirclement of the right PV antrum than would normally be considered. During enclosure of the second region within the right PV encirclement, AF organized into LA roof–dependent flutter, which terminated into sinus rhythm during ablation of the third region on the LA posterior roof. Bidirectional block was confirmed into the PVs and along the posterior roof line connecting the antrum of the left and right PVs.

Ablation was performed along the cavotricuspid isthmus for treatment of atrial flutter with confirmed bidirectional block.

Outcome

The patient is maintaining normal sinus rhythm without any antiarrhythmic medications. There is also improvement in her symptoms and ejection fraction 5 months post-ablation.

Discussion

This is the first description of the STAR Apollo mapping system, designed to supplement the EnSite X 3-D mapping system for persistent AF. The EnSite X 3-D mapping system can rapidly generate 3-D models of the cardiac chambers using a combination of skin patches and a single multielectrode mapping catheter. A system reference patch is placed on the patient's abdomen, making it the electrical reference for the mapping system. A set of 6 skin patches are placed over multiple sites to create an electrical field that is represented in the orthogonal axes (x, y, and z planes).[7]

A previous, research version of the STAR mapping method has been described and validated in vitro and in vivo as an effective method to terminate persistent AF and atrial tachycardia, with good long-term clinical outcomes.[6,8–10] The STAR Apollo mapping system described in this case report differs from previous versions because it is specifically designed to work with the EnSite mapping systems and HD grid catheter. There have also been some improvements in signal/noise differentiation, but the principal methodology remains unchanged.

The Topera system works on the assumption that all AF is driven by rotors and seeks to identify them. As such, it is vulnerable to missing other mechanisms of AF.[11] The STAR mapping system simply identifies regions of the atrium from which electrical activation is emerging and does not seek to identify a particular mechanism, just a source. The logic behind this is that identifying the mechanism is of limited clinical importance if the physician is going to deliver therapy to ablate it. Thus, the STAR mapping system will aid the physician by identifying potential regions from which AF is originating and thus may focus their attention on these regions.

Until now, methods to identify focal drivers and drivers with rotational activity in persistent AF have shown to be unreliable. However, in multiple small cohort studies, the STAR mapping system has demonstrated to be a reliable method with stable success rates.

These findings were confirmed in our patient, who presented with persistent recurrent AF to the electrophysiology lab and converted to sinus rhythm using targeted ablation. Areas that were identified as ESA and paths that coincided with wavefront activation were targeted and ablated. Widespread ablation was avoided in this patient and the patient remains asymptomatic 5 months post-procedure.

Conclusion

This case report highlights the utility of the STAR Apollo mapping system to successfully identify targets for ablation of persistent AF with optimal acute outcomes. Although this proof of concept has been reported as multiple small cohort studies, large-scale studies are needed to address its utilization as a standard of care in clinical practice in patients with persistent AF and atrial tachycardia.

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