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INVITED COMMENTARY

# The irresistible challenge of substrate mapping in atrial reentrant tachycardia

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In 1996, when Kalman et al. [1] reported in their seminal work the importance of localization of the critical isthmus (CI) to target intra-atrial reentry tachycardia by catheter ablation, it was clear that a milestone was set in the treatment of this form of arrhythmia in complex clinical settings, such as patients with surgically repaired congenital heart disease with long-lasting drug-refractory arrhythmias. During the procedure, multielectrode catheters were deployed in the atria, areas of electrical silence and of conduction block were defined by conventional mapping, and extensive entrainment was used to identify a narrow isthmus of slow conduction, critical for the reentry circuit. Arrhythmias were suppressed by a median of only 5 radiofrequency energy pulses. Although of relevance to the scientific community, the work clearly lacked in precise characterization of the whole reentry course, difficult to be obtained by the technology used at that time. Combined with non-irrigated radiofrequency energy delivery, this was probably responsible for a limited success rate at follow-up. Since then, the population of patients with atrial reentrant tachycardia/flutter amenable of catheter ablation has broadly increased and this has been paralleled by an increase in the development of technologies and techniques to better approach them. Electroanatomic mapping precisely identifies the whole reentry course: in most of the cases, a double-loop figure-of-eight reentry is present, although in some selected cases, more complex scenarios are observed [2]. Areas of atrial electrical silence and conduction block, as well as anatomic boundaries, are well characterized by contact force sensing catheters and by high-density mapping. Precise electroanatomic characterization of the CI by activation mapping during tachycardia, in terms of extension, bipolar voltage, and conduction velocity, is a discriminant to identify before ablation patients at risk of procedure failure or recurrences during follow-up, while clinical variables are unable to predict the procedure outcome [3]. Conversely, an atrial reentrant tachycardia/flutter exhibiting a narrow low-voltage slow-conducting CI can be permanently suppressed by limited ablation at the first procedure even in complex anatomies [3]. However, there are pitfalls in activation mapping of atrial reentrant tachycardia/flutter. When the arrhythmia is paroxysmal and cannot be induced by programmed electrical stimulation or the clinical tachycardia degenerates into atrial fibrillation or terminates during the electrophysiologic procedure, activation mapping may be inconclusive and insufficient to identify the CI and guide ablation. Currently, this represents the major limitation to extend this treatment to the large population of patients with this arrhythmia. On the other hand, there could be an increase in the need for substrate mapping during sinus rhythm (SR) to target both endocardial conduction gaps and/or areas of atrial myopathy, possible substrates for reentrant arrhythmias, in the increasing number of hybrid procedures for persistent or long-standing persistent atrial fibrillation [4].

In this issue of the *journal*, Tsai et al. [5] present their retrospective study on high-density mapping of scar-related atrial tachycardia performed during both arrhythmia and SR. Combining activation and entrainment mapping during atrial tachycardia, they found an average of 1.1 ± 0.3 CI per patient characterized by fractionated long-lasting electrograms with slow conduction. When re-mapped in SR, the area of the CI exhibited low voltage, slow conduction, and fractionated long-lasting electrogram in most of the cases. The authors conclude that based on the satisfactory spatial correlation between the abnormal substrate identified during SR and the sites of CI during

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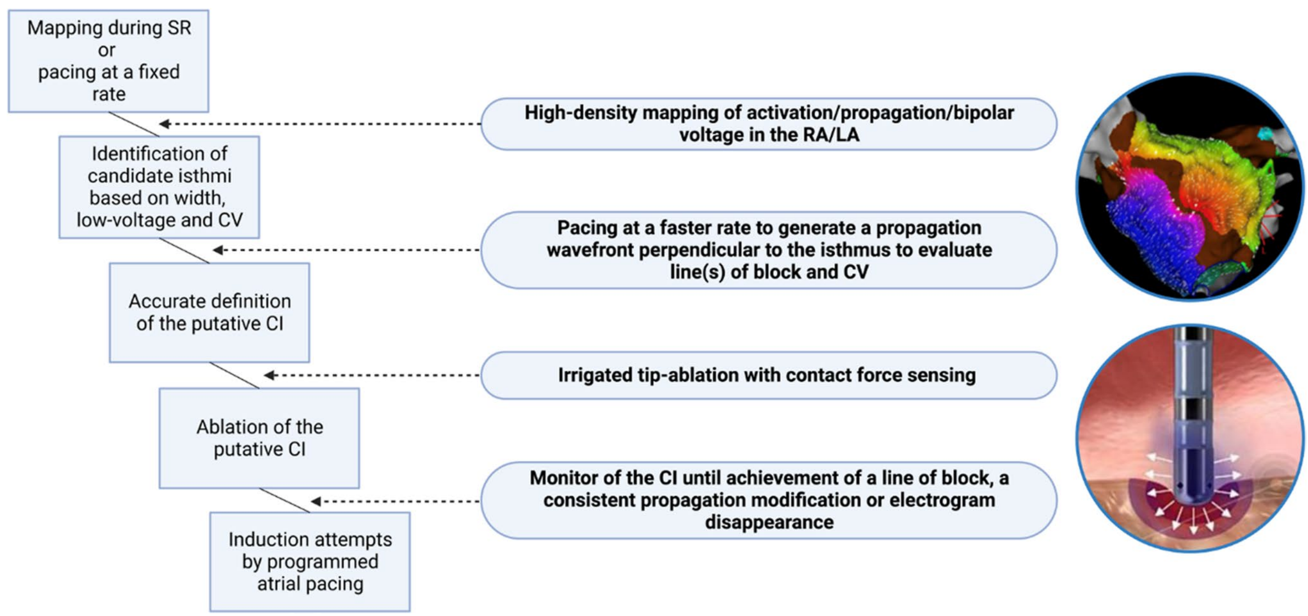


**Fig. 1** Proposed algorithm for substrate mapping during sinus rhythm in patients with unmappable atrial reentrant tachycardia. Abbreviations: CV, conduction velocity; CI, critical isthmus; LA, left atrium; RA, right atrium; SR, sinus rhythm

atrial tachycardia, high-density mapping in SR can be used to identify the arrhythmogenic substrate in patients with atrial reentrant tachycardia, obviating the need for activation mapping during the arrhythmia. This introduces the concept of empiric ablation in SR of the arrhythmogenic atrial substrate once it has been well characterized on a morpho-functional point of view, similar to what is performed in unmappable ventricular tachycardia. The limitations of this approach are well-acknowledged in this paper, and the authors should be congratulated for underlining once again that the arrhythmogenic substrate of reentrant tachycardia has peculiar morpho-functional characteristics and, therefore, a CI is not simply the narrower line between two scars or anatomic landmarks, but it is characterized by slow conduction, critical for reentry initiation, and maintenance. Similarly, in a retrospective study, other authors [6] had previously provided evidence also using another technology for high-density mapping that there is a clear spatial correlation between areas of delayed conduction in SR and the location of the CI of left atrial flutters.

If, on the one hand, high-resolution mapping is of great help, on the other operator's experience is essential in some cases for correct signal interpretation, especially in areas exhibiting low voltage and fractionation, where the automatic algorithms could mistakenly annotate normal-voltage far-field signals instead of low-voltage near-field signals [7]. Moreover, the extensive use of a technique based on high-density mapping in SR for substrate characterization of unmappable atrial reentrant tachycardia still needs further prospective investigation to assess its feasibility, safety, and efficacy. In fact, a strict workflow has to be planned for accurate morpho-functional characterization of the atrial arrhythmogenic substrate to avoid unsuccessful ablation or, worse, potentially pro-arrhythmogenic overtreatment. To this purpose, an algorithm is proposed in Fig. 1: on the left-hand side, the sequential steps to be followed are shown, while on the right, the methodologies to be adopted are listed. Moving from theory to practice, however, it appears clear that conceptualization is simpler than realization. In fact, when complex atrial substrates are approached, it should be taken into account that (1) SR may not be stable enough to allow accurate mapping; (2) low voltage does not necessarily correlates with conduction velocity [8]; (3) conduction velocity, in turn, may depend on wavefront direction and heart rate due to anisotropic conduction and functional phenomena; (4) the CI during atrial reentrant tachycardia may be delimited by lines of double potentials/conduction block which may not be evident in SR, being functionally determined by a given cycle length and/or wavefront direction; (5) in most of the cases, a single CI is responsible for reentry [3, 5] and therefore substrate mapping should discriminate among all candidate isthmi the most suitable to avoid overtreatment. All these factors may render difficult or even limit this approach but, however, represent an irresistible challenge to be accepted to further advance the treatment of these patients.

## Declarations

**Ethics approval** Not applicable.

**Informed consent** Not applicable.

**Conflict of interest** RDP. Financial interests: this author received honoraria from Biosense Webster and Medtronic for lectures and scientific collaboration; non-financial interest: none. CA. This author has no relevant financial or non-financial interests to disclose.

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