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Catheter ablation for atrioventricular nodal reentrant tachycardia: When all is not right, ablate what is left

Catheter ablation for atrioventricular nodal reentrant tachycardia (AVNRT) is commonly performed, due to the high rates of clinical success with a low risk of complications [1]. While the precise anatomic pathways involved in this reentrant arrhythmia are still elusive, there is increasing consensus that AVNRT involves reentry between various inputs to the atrioventricular node, and probably involves thin rims of working atrial myocardium between these. Improvements in understanding the mechanism of tachycardia led to the evolution of catheter ablation techniques, with the adoption of “slow pathway ablation” along the base of the triangle of Koch as the approach of choice for treatment of most forms of AVNRT. Despite the high rates of success with this approach, in <5% cases, ablation of left sided AV nodal inputs, either targeting the roof of the coronary sinus, or the inferoseptal mitral annulus using a transseptal approach, is required. Outcome data for left sided ablation is limited to large case series [2,3], and additional data helps elucidate the efficacy and safety of these approaches. In this issue of the Indian Pacing and Electrophysiology Journal, Narayanan et al. report their experience with left sided ablation for AVNRT from a large single center experience [4]. Out of 154 AVNRT ablations over 18 months, 5 patients required transseptal access and left sided ablation, with 80% mid-term success rates.

1. Understanding the substrate: anatomy of the atrioventricular node and its inputs

Since the description of the AV node and the conduction system by Tawara, there has been an increased appreciation of the inferior extensions of the AV node, which may serve as discrete inputs and participate in AVNRT [5]. The AV node has a fast pathway input which connects the septal atrium to the compact atrioventricular node (Fig. 1). In addition, there are multiple discrete inferior extensions, which likely form the anatomical basis for multiple slow pathway inputs into the compact AV node. The right inferior extension (RIE) extends from the base of the triangle of Koch to the compact AVN. The left inferior extension (LIE) likely extends from the roof of the coronary sinus or the inferoseptal mitral annulus to the compact AVN. An inferolateral left atrial input and superior input to the AVN have also been proposed.

A recent histological study elegantly demonstrated the presence of the RIE and LIE [6]. There was considerable variation in the inferior nodal extensions as well as the structure of the AV node, in terms of presence or absence of a left inferior extension and the relative size of the extensions. In this study, the anatomical basis

for the fast pathway was proposed as multiple connections between the working atrial myocardium in the interatrial septum to the compact AV node, and a transitional zone between these was uncommon.

It is important to clarify that when the terms “fast pathway” or “slow pathway” are used clinically during catheter ablation, the precise structures ablated may include these histologically demonstrated nodal extensions, or working atrial myocardium surrounding these extensions, and perhaps both based on the exact site [7].

2. Electrophysiological evidence: dual atrioventricular nodal physiology

The existence of discrete inputs to the AV node is demonstrable during electrophysiological study on patients with the so-called dual AV nodal physiology. During atrial extrastimulus testing, a sudden prolongation of the AH interval signals a shift in anterograde activation from the fast pathway to one of the slow pathways. Presence of multiple discrete “jumps” signals shift in anterograde activation between distinct slow pathways. The location of the insertion of these pathways into the atrium can be analyzed based on the earliest atrial activation during retrograde conduction [8]. During retrograde activation across the fast pathway, the earliest atrial activation occurs posterior to the tendon of Todaro. Retrograde activation across the RIE results in earliest atrial activation at the base of the triangle of Koch. Retrograde activation across the LIE results in earliest atrial activation at the roof of the coronary sinus, 1–2 cms into the CS or at the inferoseptal mitral annulus.

3. Typical versus atypical AVNRT: participation of left sided slow pathway

AVNRT has been classified into typical versus atypical based on the anterograde and retrograde limbs of the tachycardia circuit. It is generally accepted that typical AVNRT involves anterograde conduction through one of the slow pathways, and retrograde conduction through the fast pathway (“slow-fast” AVNRT). Typical AVNRT is usually associated with a short HA interval and earliest retrograde atrial activation in the region of the fast pathway. Atypical AVNRT could involve anterograde conduction through the fast pathway or one of the slow pathways, but retrograde conduction through a slow pathway, resulting in “fast-slow” or “slow-slow” AVNRT. The HA interval is usually long, and the earliest retrograde atrial activation depends on the retrograde slow pathway being activated.

In atypical AVNRT with an eccentric CS activation pattern, retrograde activation through the LIE can be suspected. However,

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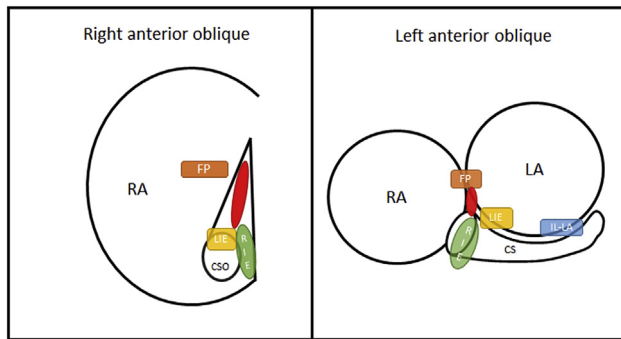


Fig. 1. Schematic for atrioventricular nodal inputs.

Red oval: compact AVN; RA: right atrium; LA: Left atrium; FP: fast pathway; RIE: right inferior extension; LIE: left inferior extension; IL-LA: infero-lateral left atrial extension.

eccentric activation in the CS may also be noted in typical AVNRT, if the fast pathway breakthrough is into the left atrium, and the wavefront has to conduct through the left atrial-coronary sinus connections to complete the circuit. A dedicated recording catheter in the region of the fast pathway would still be earlier than the CS and help clarify the diagnosis. In addition, it is important to appreciate that an eccentric pattern of CS activation is not a *sine qua non* for LIE participation in AVNRT. This is because in patients with typical AVNRT, with earliest retrograde activation at the fast pathway, anterograde activation could occur through either the RIE or the LIE. Thus, ablation failure at the usual location of the RIE may occur in typical AVNRT, if the anterograde limb of the tachycardia involves the LIE. This is also evident in the current study, where 4/5 patients requiring left sided ablation presented with typical AVNRT. The exact percentage of typical AVNRT utilizing the LIE instead of the RIE as the anterograde limb is unclear, since conventional ablation of the RIE may result in elimination of the LIE, especially more superiorly within the triangle Koch where the two pathways converge toward the compact AV node.

4. When to consider left sided ablation in AVNRT

In clinical practice, the need for a left sided approach is recognized in a few different scenarios. One is in patients with typical AVNRT, where ablation in the region of the RIE has produced a slow junctional rhythm, but typical AVNRT continues to be inducible. The tachycardia cycle length may be the same or different, based on whether the anterograde limb of the tachycardia was always the LIE, or shifted from the RIE to the LIE respectively.

A second scenario is when atypical AVNRT is induced, with earliest atrial activation within the coronary sinus or along the inferoseptal mitral annulus. Stavrakis et al. outlined two additional observations that are more common in patients with typical AVNRT utilizing the inferolateral left atrial slow pathway [3]. One is the presence of a “2 for 1” response during atrial extrastimulus testing. The second is an unusually short HA interval during tachycardia (<30 ms).

5. Resetting responses of late coupled premature atrial complexes

Current electrogram recording and mapping techniques do not permit direct recording of anterograde activation of AV nodal inputs during AVNRT. The technique of placement of late coupled premature atrial complexes (PACs) can help delineate the anterograde limb of tachycardia. PACs at varying coupling intervals could be placed from the base of the triangle of Koch, at the CS roof,

inferoseptal and inferolateral mitral annulus. The site where the latest coupled PAC resets the tachycardia is the anterograde pathway for AVNRT. This approach has been described in detail and elegantly by Stavrakis et al. and can help both diagnose AVNRT utilizing left sided input and treat AVNRT by catheter ablation at the site where PACs were delivered [3].

It is important to recognize certain caveats to this technique. First, the procedure could be time consuming due to the need for placement of multiple PACs at varying coupling intervals at various sites. It requires careful analysis of reset and clear recordings of electrograms. However, procedures where ablation in the RIE region has failed are anyways going to be time consuming, as evident from the current study, where left-sided ablation procedures were twice as long, and required almost three times as much fluoroscopy as conventional AVNRT ablations. Upfront utilization of this technique may help confirm the anterograde pathway and actually improve ablation efficiency once there is increased familiarity with the technique [3]. Second, due to the decremental nature of the AV node and its inputs, a premature atrial complex, even though late coupled, may result in *delay* of the next His EGM instead of advancing the next His EGM [9]. It may also result in termination of tachycardia, without conduction to the rest of the atrium, which is an extreme form of delay. This is analogous to placement of PVCs into orthodromic reciprocating tachycardia in patients with a decremental accessory pathway. Third, one must be certain that the PAC does not penetrate the fast pathway anterogradely, which may terminate the tachycardia. This is accomplished by recording the retrograde fast pathway activation, either on the His catheter, or with a dedicated catheter in the region of the fast pathway; and ensuring that the timing and the morphology of the retrograde fast pathway atrial activation is unchanged. Finally, the maneuver may still be challenging to perform and interpret due to lack of atrial capture, especially during AVNRT with shorter cycle length, or difficulties with EGM recording.

6. Left sided ablation for AVNRT

Once a conclusion to ablate left sided inputs is reached, there are a few approaches which could guide the exact site of ablation. First, if atypical AVNRT is present, with retrograde activation through a left sided slow pathway; or if retrograde conduction through the slow pathway is apparent during ventricular pacing, the earliest atrial activation in the CS, left atrium or right atrium could be mapped and targeted for ablation. Second, the response to late coupled PACs as detailed previously could guide the site for ablation. Finally, ablation can be empirically performed along the roof of the CS, 1–2 cms inside the CS ostium, or along the infero-septal mitral annulus after transseptal access is performed. As discussed in the current study, ablation in the CS is often attempted first, as transseptal access is not required for this approach.

When ablating inside the coronary sinus, it is important to be cognizant of the relation of the posterolateral branch of the right coronary artery and its proximity to the CS especially close to the ostium of the CS [10]. The catheter could be positioned 1–2 cm into the CS ostium and oriented toward the atrium to reduce the risk. Coronary angiography can also be performed to ensure the catheter is not adjacent to an artery.

When ablating along the inferoseptal mitral annulus, initial lesions must be placed below the level of the CS roof, since lesions above the roof may damage the AV node. As outlined by Narayanan et al., the EGMs at the ablation site should have a small atrial and large ventricular signal, analogous to ablation at the RIE. A far field His signal should not be present on the ablation catheter.

7. Endpoints for left sided ablation

Presence of a slow junctional rhythm during ablation, in addition to non-inducibility of AVNRT are considered endpoints for AVNRT ablation. Junctional rhythm was present in all cases during left sided ablation in all the cases in the large case series reported by Katritsis et al., and in 90% of cases reported by Stavrakis et al. [2,3]. In the current report, junctional rhythm was absent during ablation in 2/4 successful cases. It remains unclear whether junctional rhythm is a reliable marker for successful ablation of the LIE, and failure to reinduce AVNRT on isoproterenol is reasonable as an additional endpoint in patients undergoing LIE ablation, until additional data are available.

8. Conclusions

The exact circuit participating in AVNRT remains elusive, as activation mapping of AV nodal inputs is not possible with current recording systems, but may be possible in the future with development of systems with adequate sampling speed, dynamic range and advanced filtering techniques. Despite this, the current constructs for AVNRT permit catheter ablation with a high rate of long term success and safety. In <5% of cases, left sided ablation may be required in addition to the conventional “slow pathway” ablation targeting the right inferior extension. Narayanan et al. are to be commended for adding to the cumulative experience with left sided ablation for AVNRT and further demonstrate the efficacy and safety of this approach. Given the large volume of SVT ablations being increasingly performed in tertiary care centers in India, multicenter studies from India can further increase our knowledge of the efficacy and safety of left sided ablation, and outline optimal techniques and selection of end-points for favorable outcomes for our patients.

References

[1] Jackman WM, Beckman KJ, McClelland JH, Wang X, Friday KJ, Roman CA, et al.

- Treatment of supraventricular tachycardia due to atrioventricular nodal reentry by radiofrequency catheter ablation of slow-pathway conduction. *N Engl J Med* 1992;327(5):313–8.
- [2] Katritsis DG, John RM, Latchamsetty R, Muthalaly RG, Zografos T, Katritsis GD, et al. Left septal slow pathway ablation for atrioventricular nodal reentrant tachycardia. *Circ Arrhythm Electrophysiol* 2018;11(3):e005907.
- [3] Stavrakis S, Jackman WM, Lockwood D, Nakagawa H, Beckman K, Elkholey K, et al. Slow/fast atrioventricular nodal reentrant tachycardia using the infero-lateral left atrial slow pathway: role of the resetting response to select the ablation target. *Circ Arrhythm Electrophysiol* 2018;11(9):e006631.
- [4] Narayanan K, Omer M, Arif M, Sridhar P, Annarapu N, Naidu S, et al. Left sided ablation for atrioventricular nodal Re-entrant tachycardia: frequency, characteristics and outcomes. *Indian Pacing Electrophysiol. J.* 2020.
- [5] Inoue S, Becker AE. Posterior extensions of the human compact atrioventricular node: a neglected anatomic feature of potential clinical significance. *Circulation* 1998;97(2):188–93.
- [6] Anderson RH, Sanchez-Quintana D, Mori S, Cabrera JA, Back Sternick E. Re-evaluation of the structure of the atrioventricular node and its connections with the atrium. *EP Europace* 2020;22(5):821–30.
- [7] Hucker WJ, McCain ML, Laughner JI, Iuzzo PA, Efimov IR. Connexin 43 expression delineates two discrete pathways in the human atrioventricular junction. *Anat Rec (Hoboken)* 2008;291(2):204–15.
- [8] Sung RJ, Waxman HL, Saksena S, Juma Z. Sequence of retrograde atrial activation in patients with dual atrioventricular nodal pathways. *Circulation* 1981;64(5):1059–67.
- [9] Bera D, Sarkar R, Joshi RS, Kar A, Mukherjee SS. Reappraisal of resetting response to locate the antegrade pathway in slow-fast atrio-ventricular nodal re-entrant tachycardia. *Indian Pacing Electrophysiol J* 2020;20(6):290–2.
- [10] Contractor T, Swamy P, Prasad V, Bhardwaj R, Tung R, Mandapati R. Coronary artery injury during ablation of typical atrioventricular nodal reentrant tachycardia: report of a rare complication and review of literature. *HeartRhythm Case Rep* 2020;6(9):632–6.

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