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NEW RESEARCH PAPERS

Should the Aortic Root Be the Preferred Route for Ablation of Focal Atrial Tachycardia Around the AV Node?

Support From Intracardiac Echocardiography

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ABSTRACT

OBJECTIVES The purpose of this study was to determine the optimal approach to focal atrial tachycardia originating from around the atrioventricular node.

BACKGROUND Focal atrial tachycardia (FAT) demonstrating earliest activation around the atrioventricular (AV) node during right atrial (RA) mapping has been eliminated by ablation at the RA para-Hisian region, from the left atrium (LA) or the noncoronary aortic cusp (NCC). However the optimal approach has not been determined.

METHODS We conducted a retrospective analysis of a consecutive series of 148 patients undergoing catheter ablation for FAT between 2006 and 2014 in our institution.

RESULTS Earliest activation was recorded in the peri-AV nodal region during RA mapping in 34 patients (23%). Of these, 7 patients (20.5%) had successful ablation at the RA septum, using either radiofrequency (n = 4) or cryoenergy (n = 3). Seven FATs (20.5%) were ablated from the LA at the region of the aortomitral continuity, and 20 patients (59%) had successful ablation in the NCC, including 1 patient with a recurrence after a temporarily successful cryoablation from the RA. The proportion of the 3 approaches in this series showed a significant temporal evolution and overall frequency favoring ablation in the NCC ($p = 0.011$ for time trend and 0.013 for actual vs. expected frequencies). Intracardiac echocardiography proved superior catheter stability with the NCC approach. There were 2 cases of atrioventricular block and 1 recurrence after RA ablation versus no complications or recurrent FAT with NCC and LA approaches.

CONCLUSIONS Most peri-AV nodal FATs can be safely and effectively ablated from the NCC. The strategy of preferential NCC approach avoids RA para-Hisian ablation with the accompanying risk of AV block. (J Am Coll Cardiol EP 2016;2:193–9) © 2016 by the American College of Cardiology Foundation.

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Focal atrial tachycardia (FAT) often originates from predilection sites including the crista terminalis and coronary sinus (1). During development, these sites initially retain their primitive phenotype and have spontaneous pacemaker activity. Another region with an initially primary myocardium phenotype is the atrioventricular (AV) canal. Bundles of specialized myocardium surround the right and left AV rings, and the so-called retroaortic node is formed at their junction in the region of the right fibrous trigone (3). Later during development, the conduction system phenotype becomes confined to the AV node, but remnants of nodal-type AV canal myocardium may be found around the AV rings of adult hearts (4). These vestiges have been connected to the frequent localization of both FAT and

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ABBREVIATIONS AND ACRONYMS

AMC = aortomitral continuity

FAT = focal atrial tachycardia

ICE = intracardiac echocardiography

LA = left atrium

LCC = left coronary cusp

NCC = noncoronary cusp

RA = right atrium

RCC = right coronary cusp

ventricular tachycardia to the AV rings and especially around the AV node (4-6).

Peri-AV nodal FAT is amenable to catheter ablation from multiple approaches including right atrial (RA) or, by transseptal puncture, left atrial (LA) access (7). Recently, ablation from the centrally positioned noncoronary cusp (NCC) of the aortic root has been introduced with much success (8-10). However the optimal approach to peri-AV nodal FAT has not been determined.

METHODS

STUDY POPULATION. With Institutional Review Board approval (no. 3587/2015), we retrospectively studied 148 patients undergoing catheter ablation for FAT in our institution from the time of the publication of the first series of FAT cases ablated from the NCC of the aortic valve (2006) (9), until the end of 2014. Of these, origins of FAT in 34 patients (23%) were mapped to a site adjacent to the AV node (within 1 cm of the maximal His-potential recording site) during right-sided mapping, including the coronary sinus (CS). These patients were grouped according to the site of the ultimate, permanently successful ablation: RA, LA, or NCC. Their clinical characteristics are summarized in Table 1.

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TABLE 1 Clinical Characteristics of Patients

	RA (n = 7)	NCC (n = 20)	LA (n = 7)	p Value
Age, yrs	51 ± 18	66 ± 9	57 ± 19	0.04
% of females	71	80	100	NS
% with hypertension	57	82	57	NS
% with diabetes	14	21	14	NS
% with persistent/incessant FAT	0	10	29	NS
LVEF, %	67 ± 8	63 ± 7	59 ± 10	NS
LAd, mm	48 ± 13	44 ± 5	37 ± 6	NS

Values are mean ± SD or %.

FAT = focal atrial tachycardia; LA = left atrium; LAd = left atrial diameter; LVEF = left ventricular ejection fraction; NCC = noncoronary cusp; NS = not significant; RA = right atrium.

ELECTROPHYSIOLOGY PROCEDURE. After giving informed consent, patients underwent an electrophysiological (EP) study under light sedation (midazolam with or without fentanyl). After right and/or left femoral vein puncture, quadripolar EP catheters were positioned in the right ventricular apex and RA His bundle region, and a decapolar catheter was placed in the CS. A standard stimulation protocol at baseline and isoproterenol infusion (up to 5 μg/min), including atrial and ventricular burst, and extrastimulation was carried out to study AV and ventriculoatrial (VA) conduction, as well as induce tachycardia. The latter was diagnosed as FAT if it showed a centrifugal atrial activation pattern and overdrive pacing from the ventricle during tachycardia resulted in VAAV response (11). A steerable, roving EP catheter was used to map activation timing throughout the RA and exclude RA-free wall FAT. All FATs included in this study showed earliest RA activation in the para-Hisian region. Early during this 9-year experience, the LA was also mapped in most cases of peri-AV nodal FAT, and ablation was delivered to whichever atrium showed earlier activation. In the last 3 years, the approach changed, and the aortic root became the next area of mapping after the RA. After this time, the LA was mapped only when timing was considerably later or ablation failed in the NCC. The LA was approached through transseptal puncture and the aortic root through the right femoral artery. Intracardiac echocardiography (ICE) was used by advancing the ultrasound catheter (AcuNav, Biosense Webster, South Diamond Bar, California) to the RA for guiding catheter positioning in the NCC or LA. Coronary or aortic angiography was not performed. The surface p wave polarity in lateral (I, aVL) and inferior (II, III, and aVF) leads and in lead V_1 was classified as positive, negative, or isoelectric in relation to the baseline by an examiner blinded to procedural data. Local timing of atrial activation during FAT was determined relative to the CS ostium as a reference.

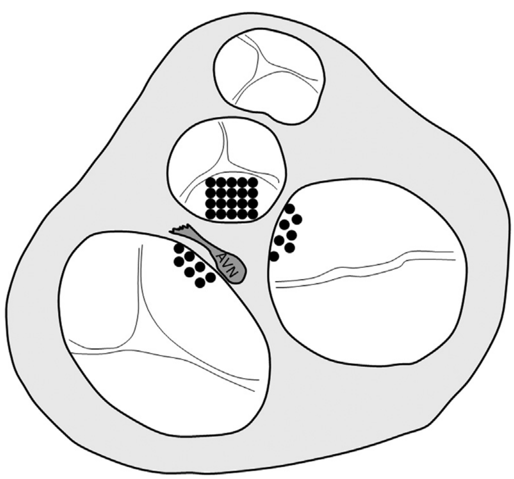
Radiofrequency (RF) ablation was performed using a 7-F 4-mm-tip ablation catheter (Celsius or Navistar, Biosense Webster or AlCath, Biotronik, Berlin, Germany) with a target temperature of 60°C and a maximal power output of 30 W for 60 s. Cryoablation was carried out using a 4- or 6-mm-tip cryoablation catheter (Freezor; Medtronic, Edgewater, Maryland), with a target temperature of −80°C, for 4 min. During ablation, AV conduction was carefully assessed, and any prolongation or block was noted, prompting halting of energy delivery. The choice of the ablation energy (RF or cryoablation) was made at the discretion of the operator.

STATISTICAL ANALYSIS. Continuous data are mean ± SD and were compared using Student's *t* test or 1-way ANOVA. Proportions were compared by using the chi-square test, with the Mantel-Haenszel method for temporal trend and assuming equal distribution of expected frequencies. All analyses were carried out using SPSS software (SPSS Inc., Chicago, Illinois). A p value of $<$0.05 was considered statistically significant.

RESULTS

CATHETER ABLATION. Right atrial ablation. Of the 34 patients with peri-AV nodal FAT, 14 (41%) had

FIGURE 1 Ablation Sites



Schematic representation shows successful ablation sites of focal atrial tachycardia originating from around the AV node (AVN).

an ablation attempt at the earliest RA site of activation in the para-Hisian region, and in 7 patients (20.5%) this led to lasting success (**Figure 1**, **Table 2**). Four of these patients received RF ablation, and 3 had cryoablation. One patient developed transient total AV block during RF delivery and subsequently underwent ablation from the NCC without further complications. At the earliest RA site, significant instability of the RF ablation catheter was encountered due to breathing and heart motion in all patients (**Figure 2A**, Online Video 1). Cryoadhesion stabilized the cryoablation catheter (Online Video 2); however, 1 patient developed transient PR prolongation during freezing, and another patient undergoing cryoablation had subacute recurrence and a subsequent successful ablation from the NCC. Seven RF ablation attempts in the RA were without lasting effect, one of these temporarily suppressed the FAT. Three of these cases were successfully treated by ablation in the LA and 4 from the NCC.

Left atrial approach. The LA was mapped in 17 patients (50%) by using ICE guidance. Eleven patients (32%) received RF ablation in the LA, at the anteroseptal mitral ring, in the region of the aortomitral continuity (AMC) (**Figure 3**). In 7 cases (20.5%), arrhythmia was eliminated, in 1 case it was temporarily suppressed, and in 3 cases LA ablation was without effect. The 4 FATs were ultimately ablated from the NCC (3 cases) and RA (1 case). One patient had previously undergone temporarily successful ablations during the same session from the NCC and then the left coronary cusp (LCC) before permanent

TABLE 2 Mapping and Ablation Data for Each Study Patient

	Activation Timing			Ablation Sites			
Patient #	RA	NCC	LA	RA	NCC	LA	Order of Ablation Sites
1	–	NA	–	Succ	NA	Fail	LA-RA
2	–	NA	NA	Succ	NA	NA	RA
3	–	NA	–	Fail	NA	Succ	RA-LA
4	−29	NA	−15	Succ	NA	NA	RA
5	−24	NA	NA	Succ	NA	NA	RA
6	−20	NA	−30	NA	NA	Succ	LA
7	−27	NA	−32	NA	NA	Succ	LA
8	−37	NA	NA	Succ	NA	NA	RA
9	−20	−24	−10	Tran	Succ	NA	RA-NCC
10	−20	NA	−27	Fail	NA	Succ	RA-LA
11	−31	NA	−25	Succ	NA	NA	RA
12	−21	−26	−20	NA	Succ	NA	NCC
13	−16	NA	−27	NA	NA	Succ	LA
14	−42	−46	−20	Fail	Succ	NA	RA-NCC
15	−30	−40	−33	NA	Succ	Tran	LA-NCC
16	−35	−28	−15	NA	Succ	NA	NCC
17	−34	NA	NA	Succ	NA	NA	RA
18	−19	−24	NA	NA	Succ	NA	NCC
19	−15	−18	NA	NA	Succ	NA	NCC
20	−21	−55	−20	NA	Succ	Fail	LA-NCC
21	−45	−39	NA	NA	Succ	NA	NCC
22	−25	−27	NA	NA	Succ	NA	NCC
23	−14	−15	NA	Fail	Succ	NA	RA-NCC
24	−24	−24	NA	NA	Succ	NA	NCC
25	−24	−23	NA	NA	Succ	NA	NCC
26	−51	−46	NA	NA	Succ	NA	NCC
27	−30	−35	−45	NA	Tran	Succ	NCC-LA
28	−27	−25	NA	Fail	Succ	NA	RA-NCC
29	−17	−20	−26	Fail	Tran	Succ	RA-NCC-LA
30	−33	−28	−24	NA	Succ	Fail	LA-NCC
31	−20	−20	NA	NA	Succ	NA	NCC
32	−30	−40	NA	NA	Succ	NA	NCC
33	−32	−36	NA	NA	Succ	NA	NCC
34	−17	−17	NA	NA	Succ	NA	NCC

Timing of earliest activation in the RA, NCC, and LA was measured relative to coronary sinus os activation in milliseconds.

– = missing data; Fail = failure to terminate tachycardia; LA = left atrium; NA = chamber was not mapped or ablation not attempted; NCC = noncoronary cusp; RA = right atrium; Succ = successful elimination; Tran = transient suppression.

elimination at the AMC, under the LCC (**Figure 3C**). One patient who was successfully treated by ablation at the AMC had a history of prior RF ablation from the RA in another institution, resulting in persistent total AV block requiring pacemaker implantation.

Transaortic approach. Twenty-two patients (65%) had an RF ablation attempt in the NCC, guided by ICE (**Figure 2B**, Online Video 3). Twenty of 34 patients (59%) had their arrhythmia eliminated by NCC ablation. The 2 remaining FATs, 1 of which was temporarily suppressed from the NCC, were ablated at the AMC. Although His potential was frequently recorded toward the junction of the NCC with the right cusp, it was never recorded at the more posterior

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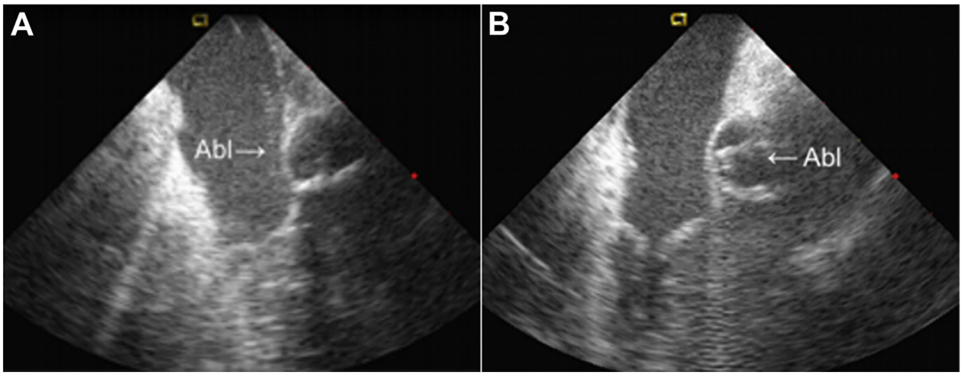
FIGURE 2 **Intracardiac Echocardiography**



Intracardiac echocardiographic (ICE) views from the right atrium (RA), with the ablation catheter (Abl) positioned at the site of earliest atrial activation during tachycardia in the RA para-Hisian region **(A)** and the noncoronary aortic cusp **(B)** in the same patient. See also Online Videos 1, 2, and 3.

successful site in the NCC. All cases of NCC ablation were guided by ICE without performing aortic or coronary angiography.

Intracardiac echocardiography. ICE was used in 28 of 34 cases (82%), including all patients who underwent retrograde aortic and transseptal approaches. ICE imaging revealed that the earliest activation site in the RA was within 5 mm from the lumen of the noncoronary aortic sinus (**Figure 2**). Furthermore, there was a very close anatomical relationship between the NCC and AMC (**Figure 3**). The mapping electrode positioned at the earliest site in the RA exhibited significant movement in relation to the myocardium (Online Video 1), while in the NCC catheter positioning was always stable (Online Video 3).

COMPLICATIONS AND OUTCOME. As mentioned above, 2 patients, 1 whose arrhythmia was ultimately ablated from the NCC and 1 from the LA, had previously had iatrogenic AV block during RF delivery from the RA, 1 during the same, the other during a previous session. No other patient developed AV block during or after energy delivery, and no further complications related to the mapping and ablation approach were observed. During 34 $\pm$ 19 months of follow-up after the ultimately successful ablation, no patient developed a recurrence of the targeted FAT.

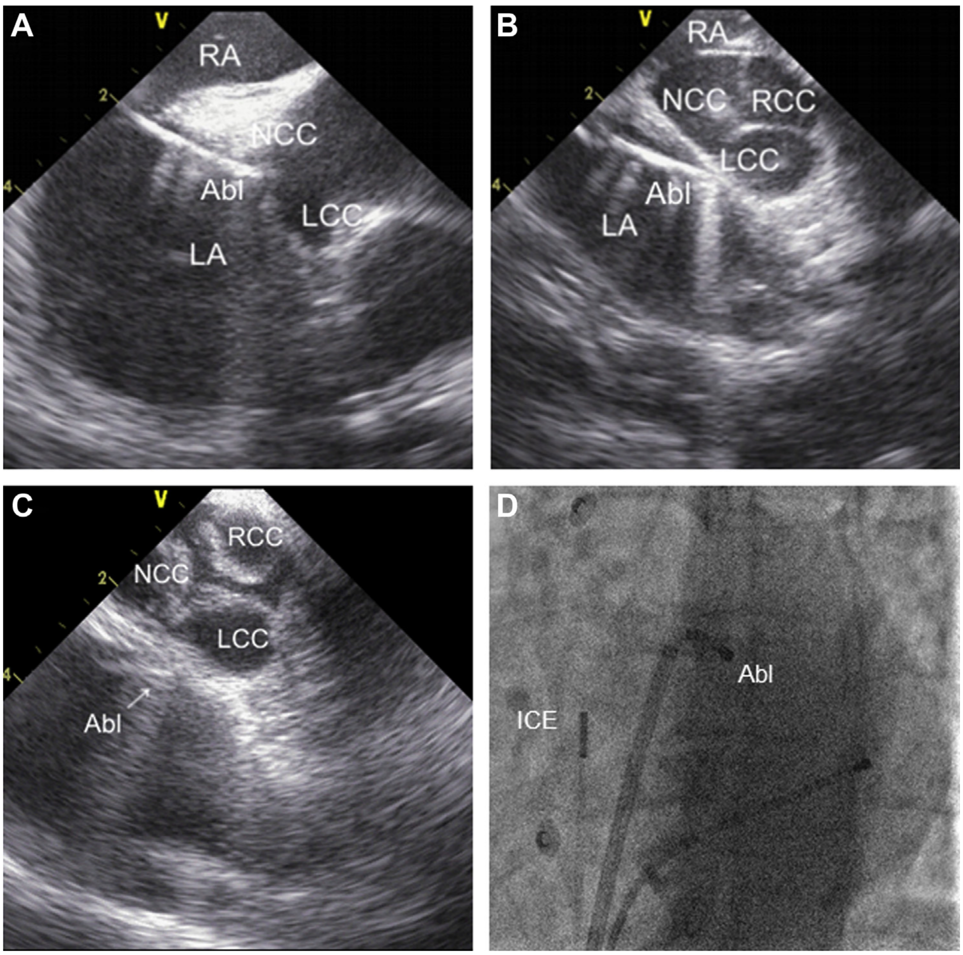
PROPORTION AND SUCCESS OF DIFFERENT ABLATION APPROACHES. In this series of patients, relative frequencies of different approaches leading to successful elimination of peri-AV nodal FAT included the RA, LA, or NCC (20.5%, 20.5%, and 59%, respectively), which showed significant differences from an expected equal distribution ($p = 0.007$). Regarding all ablation attempts, the success of the 3 approaches was, in ascending order: RA at 50%, LA at 64%, and NCC at 91% ($p = 0.021$). There was a significant time trend over the years toward more common ablations from the NCC and complete disappearance of RA ablation ($p = 0.008$) (**Figure 4**). The percentage of cases undergoing transseptal puncture for LA mapping also decreased from 70% during the first 6 years to 29% in the last 3 years ($p = 0.017$) in this population.

COMPARISON OF GROUPS. There were no significant differences in clinical characteristics between groups, except that patients ablated from the RA were slightly younger, owing to the presence of one 17-year-old patient. All 3 groups showed a striking female predominance (**Table 1**). All patients had a p wave during FAT that was shorter in duration than the one during sinus rhythm. However, no differences in surface p wave polarity in the lateral or inferior leads or lead V_1 were observed between groups ($p > 0.3$). Atrial activation was not significantly earlier during FAT in the NCC (-29 ± 12 ms) than that in the RA (-27 ± 12 ms; $p = 0.56$) in 22 patients receiving ablation from the NCC (**Table 2**).

DISCUSSION

In this single-center experience, most cases of peri-AV nodal FAT were ablated from the NCC without complications or recurrence. A strategy of preferential transaortic approach led to the complete disappearance of RA para-Hisian ablation from our armamentarium over the years, and the frequency of LA mapping decreased, whereas the prevalence of FAT ablated from the LA remained stable. Intracardiac echocardiography showed that the NCC

FIGURE 3 Mapping the Aortomitral Continuity



Ablation catheter (Abl) is positioned trans-septally in the left atrium (LA), at the aortomitral continuity. Long- **(A)** and short-axis **(B)** intracardiac echocardiographic (ICE) images in the same patient. Short-axis ICE image **(C)** and fluoroscopy **(D)** in another patient. LCC = left coronary cusp; NCC = noncoronary aortic cusp; RCC = right coronary cusp.

provides a safe and effective vantage point for ablation of these FATs, where catheter deployment is more stable and farther from the AV node, as opposed to the RA approach, rendering ablation from the NCC safer and more effective. However, a few cases of peri-AV nodal FAT still require a slightly more leftward catheter position at the AMC.

FREQUENCY OF PERI-AV NODAL ATRIAL TACHYCARDIA. The prevalence of FAT originating from around the AV node among all instances of FAT in this report (23%) was similar to that in previous studies (12–14). However, there are differences in the proportion of different approaches for the ablation of these FATs. Although Wang et al. (12) reported ablation from the NCC in 35 of 48 cases (73%), Ju et al. (14) ablated 15 of 20 (75%) from the RA.

ORIGIN OF PERI-AV NODAL ATRIAL TACHYCARDIA. Previous studies demonstrated a lack of supravalvular myocardium in the NCC (10) and no differences in p wave morphology or EP characteristics between FAT ablated from the RA and the NCC (14–16). Transient suppression by ablation at the RA para-Hisian region of FAT ultimately ablated from the NCC has been demonstrated in this and previous series (13,14). These data suggest that, instead of separate entities of para-Hisian FAT and NCC FAT, different ablation approaches exist for peri-AV nodal FAT, originating from the region of the embryologic retroaortic node (2,3). We corroborated these findings by showing similar demographic characteristics, a lack of difference in local activation timing, close proximity of earliest activation sites in the RA and NCC on ICE, and the

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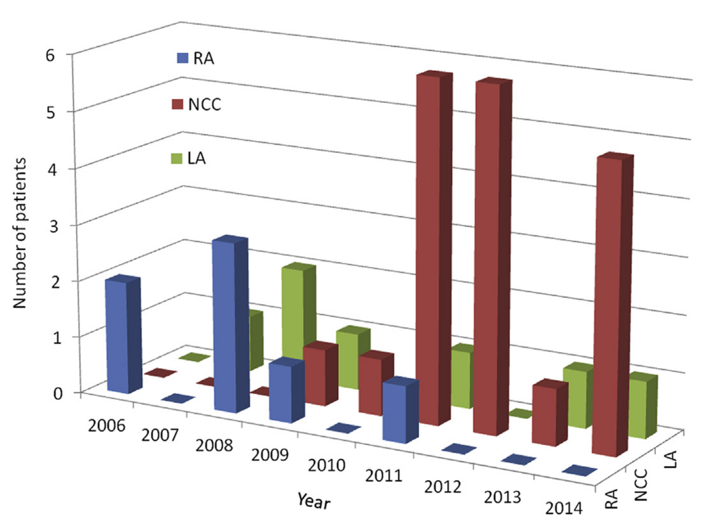
FIGURE 4 Evolution of the Approach to Perinodal Atrial Tachycardia



Yearly numbers of patients undergoing ablation from the right atrium (RA), noncoronary aortic cusp (NCC), and left atrium (LA) are shown.

ability to totally abandon the RA para-Hisian approach without compromising efficiency. These observations suggest that the NCC merely enables better catheter positioning to ablate a common peri-AV nodal focus.

OPTIMAL APPROACH TO PERI-AV NODAL ATRIAL TACHYCARDIA. The risk of AV block is high during RA anteroseptal RF ablation (17–19). Cryoablation appears safe, but this and previous experience suggest that the long-term success rate may be limited in this region (20,21). Ju et al. (14) advocated careful, low-energy RF ablation at the RA para-Hisian region before attempting aortic root mapping; however, they observed junctional rhythm and transient PR prolongation in 7 and 4 of 20 patients, respectively, during this maneuver. The population Ju et al. (14) treated might have been different from that of this study, as the RA ablation site was without a His potential in 17 of 20 of their patients, whereas most of our cases showed at least a far field His at the earliest RA site. We have seen 2 patients with AV block (1 permanent and 1 transient) with attempted para-Hisian RF ablation for FAT. On the other hand, we have seen no AV block occur, nor has it been reported previously as a consequence of NCC ablation (8–10,12–15). Vascular complications (dissection, coronary injury, thromboembolism), potential limitations of the transaortic approach, were not encountered in this series.

The utility of ablation from the NCC has been advocated before (12,13,22), whereas other investigators prefer RA ablation (14). In our experience, the transaortic approach is safer and more efficacious and can completely replace the RA para-Hisian ablation as well as eliminate the concomitant risk of AV node damage; therefore, we consider it the preferred first approach to peri-AV nodal FAT. Currently, whenever earliest atrial activation during FAT is recorded in the RA para-Hisian region, we map and ablate in the NCC, even if local activation is not earlier than in the RA. Left atrial mapping is reserved for patients in whom this is ineffective. Energy delivery in the RA is avoided.

Similar to previous case reports (23), we found that mapping and ablation in the NCC can safely and effectively be accomplished with ICE guidance, without the need for angiography. ICE has shown that catheters positioned at the earliest site of activation in the RA and the NCC are separated by only a few millimeters, but we have seen striking differences in catheter stability favoring the NCC approach.

ATRIAL TACHYCARDIA FROM THE AMC. A slightly leftward continuation of the right fibrous trigone is known as the AMC (**Figures 1 and 3**). When the focus of perinodal FAT is located in this region, RF energy delivery from the NCC can be ineffective or provide transient suppression, as seen in this and previous studies (12,15). Ablation can be delivered to this region through transseptal puncture. However, the need for LA access may be difficult to predict before attempting ablation in the NCC, given the lack of differences in findings during right sided mapping and p-wave morphology between these and FATs amenable to ablation from the NCC in this study. This is contrary to the findings by Wang et al. (12), who found negative p waves in leads I and aVL in all 3 patients, but in accordance with Wong et al. (24), who registered isoelectric or positive p waves in lateral leads in most patients. However, the frequency of AMC origin is relatively low in both the above-mentioned series and this series, so it seems prudent to consider LA access only after NCC ablation has failed.

STUDY LIMITATIONS. This was a retrospective analysis, thus, the approach was neither randomized nor systematic but chosen by the operator. Nevertheless during the last 3 years, all operators agreed on preferential use of the NCC approach and avoidance of RA ablation.

Given the relatively low number of such cases presenting to a single center, it would be difficult to execute a randomized comparison of approaches. The small sample size also limits the interpretation of differences between the groups.

Although most instances of FAT were ablated from the NCC, multiple approaches may be effective for a single focus. This was suggested specifically in cases where we observed transient suppression from multiple sites.

CONCLUSIONS

Atrial tachycardia originating from around the AV node can be in most instances safely and effectively eliminated by ablation in the NCC. The RA para-Hisian approach carries a higher risk of AV block because of closer proximity to the conduction system and instability of the ablation catheter, as shown by ICE, and can be totally avoided by a strategy of preferential transaortic approach. Our findings suggest that cases of RA para-Hisian and NCC FAT have a common origin, corresponding to the embryological retroaortic node, enriched with specialized myocardium and that the more favorable outcome with the transaortic approach is due to the optimal anatomical vantage point provided by the NCC.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: This retrospective, single-center experience provided evidence supporting the preferential utilization of the transaortic route upon approaching focal atrial tachycardia originating from around the AV node.

TRANSLATIONAL OUTLOOK: Further studies are needed to confirm the findings in a prospective, multicenter fashion and to explore the relationship between remnants of the embryologic conduction system and "annular" atrial tachycardias.

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KEY WORDS aortic root, aortomitral continuity, catheter ablation, focal atrial tachycardia, intracardiac echocardiography, noncoronary cusp

APPENDIX For supplemental videos, please see the online version of this article.