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AH jump duration is associated with elimination of slow pathway during ablation of atrioventricular nodal reentrant tachycardia

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ABSTRACT

Introduction: Ablating the slow pathway (SP) is the superior treatment for atrioventricular nodal reentrant tachycardia (AVNRT) with a low complication rate. However, the ablation of the SP could result in either complete *elimination* or *modification* of the SP. We aimed to investigate whether the duration of AH jump pre-ablation associated with the outcome of elimination of SP.
Methods: We included 56 patients with typical AVNRT (slow-fast), 20 males and 36 females, aged 44.2 ± 15.1 years. Slow pathway ablation was performed using classical approach. Univariate and multivariate analysis was performed for potential predictors of SP elimination.
Results: Typical AVNRT was inducible in all patients. Post-ablation, non-inducibility of AVNRT was obtained in all 56 (100%) patients, with SP elimination in 33 (61%) patients and SP modification in 23 (39%) patients. Patients with SP elimination had significantly longer AH jump than patients with SP modification. Cox regression analysis showed that AH jump duration was the independent predictor of SP elimination, in which every 20 ms increase in AH jump duration was associated with 1.30 higher rate of SP elimination. Furthermore, ROC curve analysis indicated that the AH jump duration of ≥100 ms had 6.14 times higher probability for complete elimination of the SP with a sensitivity of 79%, specificity of 70%, PPV of 79% and NPV of 70%.
Conclusions: AH jump duration pre-ablation is associated with complete elimination of slow pathway during AVNRT ablation.

1. Introduction

Atrioventricular nodal reentrant tachycardia (AVNRT) is the commonest regular supraventricular tachyarrhythmia [1]. Targeting the slow pathway (SP) has emerged as the superior form of treatment for AVNRT for more than two decades [2]. This technique has been found effective and is associated with a low complication rate. However, the ablation of the SP could result in either complete elimination or only modification of the SP. Although SP modification has already been accepted as a reliable end-point of successful AVNRT ablation [3,4], some studies have shown that in the long-term observation, the recurrence rate was higher in patients with only modification of SP [5,6]. It could be due to the incomplete radiofrequency injury in SP modification that the conduction over SP may resume in months or years [5]. Therefore it was strongly suggested that complete SP elimination should be the preferred ablation end-point.

Unfortunately, data on predictors of SP elimination or modification are still scarce. A study conducted by Kulakowski et al. [5] found that AVNRT characteristics were different in patients with complete SP elimination versus modification, in which the latter had a shorter cycle of AVNRT that may suggest smaller reentry circuits. That study also found that the presence of a typical jump was an independent predictor for favorable long-term outcomes, indicating that those patients had more standard and easier to ablate substrate for arrhythmia than those without typical jump.

Although typical AH jump was considered as a hallmark of dual

Abbreviations: AUC, area under the curve; AV, atrioventricular; AVNRT, atrioventricular nodal reentrant tachycardia; NCCHK, National Cardiovascular Center Harapan Kita; NPV, negative predictive value; PPV, positive predictive value; RF, radiofrequency; SP, slow pathway.

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AV node physiology, the presence of dual AV node physiology itself does not imply the presence of AVNRT. A study conducted by Gonzales et al. found that a jump of 50 ms or longer was present in 83% of patients with AVNRT and in 77% of patients without AVNRT, although the difference between the two groups was not statistically significant [6]. However, the magnitude of AH jump duration was greater in patients with AVNRT (93 ± 7 versus 61 ± 7 ms, $p < 0.05$), suggesting that the slow AV nodal pathways are probably "slower" in those patients. Despite the fact that AH jump duration was an important electrophysiological characteristic of AV node, there has been no data regarding its association with the outcome of ablation. Hence, this study sought to investigate whether the AH jump duration pre-ablation associated with the outcome of elimination/modification of SP.

2. Methods

2.1. Patients and ablation protocol

This was an observational and cross-sectional study that included patients with typical AVNRT who underwent successful radiofrequency ablation in National Cardiovascular Center Harapan Kita (NCCHK) in 2018. All demographic, clinical and periprocedural parameters (AH jump, sinus cycle length, tachycardia cycle length, junctional rhythm cycle length, cumulative junctional beat) were collected retrospectively.

All patients (>18 years old) gave written informed consent. Patients were admitted to undergo an electrophysiological study and were weaned off of all anti-arrhythmic drugs for at least five half-lives. The procedure was performed with local anesthesia or under conscious sedation according to the patient age and preference, and at the discretion of the operator. All ablation procedures were performed by the same team using a conventional method [7] of intracardiac recording and stimulation (EP Workmate™ Recording System, St. Jude Medical Inc., USA).

The diagnosis of AVNRT was based on the presence of AH jump and echo initiating tachycardia during programmed atrial stimulation and/or during incremental atrial pacing close to the Wenckebach point. Typical AVNRT was diagnosed when the earliest retrograde atrial activation during tachycardia was <70 ms from the ventricular activation and was concentric (recorded from coronary sinus), matching that during RV pacing [8,9].Typical jump was defined as a sudden prolongation of AH interval >50 ms with a decrease of 10 ms of S1–S2 interval during programmed atrial pacing [5,10]. Patients were excluded if there were more than one jump (multiple AH jumps) or no AH jump at all.

Ablation was performed using a 4 mm radiofrequency (RF) ablation catheter (Cordis Webster or St. Jude Medical Inc.) with power set at 30–35 Watts and temperature at 50–55 °C. We always started the ablation from the low Koch triangle (close to the ostium of the coronary sinus) and subsequently placed the ablation catheter in a higher position (mid to high Koch triangle) towards the His area if previous applications had been ineffective.

2.2. Study outcomes

The primary outcome of this study was successful radiofrequency ablation, defined as non-inducibility of AVNRT without the presence of residual jump and/or echo (SP elimination), or the presence of only a single jump and/or echo (SP modification). In patients in whom isoproterenol was needed to induce AVNRT at baseline, post-ablation pacing was also performed after drug infusion. In patients in whom isoproterenol was not necessary to induce AVNRT at baseline, the post-ablation use of isoproterenol was left to the operator's discretion.

2.3. Statistical analysis

Numerical variables are presented as the mean ± standard deviation, or median (minimum-maximum) if not normally distributed. Categorical variables are presented as percentages. Differences in analyzed parameters were assessed using the t-test for numerical variables and the chi-square test for categorical variables. A multivariate logistic regression analysis was performed to identify parameters that predicted the outcome of ablation. The optimal cut-off value for the prediction of primary outcome was determined by a receiver operator characteristic (ROC) curve. A p-value of <0.05 was considered statistically significant. Results are presented as odds ratios (OR) with a confidence interval of 95%.

3. Results

3.1. Patient characteristics

The study group consisted of 56 typical AVNRT patients with a mean age of 44.2 ± 15.1 years. The majority of the patients (36/64%) were female and all had a history of palpitations due to AVNRT. History of syncope and near syncope were experienced in only 1 patient (1.7%). AVNRT was inducible in all patients and induction of junctional rhythm during radiofrequency ablation procedure was occurred in 46 (82%) patients. Non-inducibility of AVNRT was achieved in all patients, with SP elimination in 33 (59%) patients and SP modification in 23 (41%) patients. Anterograde atrioventricular conduction was preserved in all patients after the ablation procedure.

Baseline demographic, clinical characteristics, and periprocedural parameters are presented in Table 1.

3.2. AH jump duration and outcome of ablation

In Table 2, the periprocedural parameters were compared between patients with SP modification versus elimination. There was no significant difference in terms of age, sex, sinus and tachycardia cycle lengths, junctional beat numbers and duration between the two groups. Importantly, patients with SP elimination had significantly longer AH jump duration ($p = 0.001$).

Multivariate logistic regression analysis was performed in order to identify independent predictors for SP elimination (Table 3). Five

Table 1
Baseline characteristics of the patients.

Variable (N = 56)	Mean +SD/Number (%)
Demographic parameters	
Age (years)	44.2 + 15.1
Sex, female	36 (64%)
Symptoms	
Palpitations	56 (100%)
Near syncope	1 (1.7%)
Syncope	1 (1.7%)
Electrophysiological parameters	
JR during ablation	46 (82%)
SP elimination	33 (59%)
SP modification	23 (41%)
AH jump duration, ms	152.8 + 92.1
FP ERP, ms	346 .7 + 257.7
SP ERP, ms	278.4 + 82.6
SCL, ms	711.7 + 110.1
TCL, ms	353.1 + 47.0
JRCL, ms	530.8 + 106.5
CJB, beats	23.2 + 19.9
JB duration, ms	11941.9 ± 11113.7

FP: fast pathway; SP: slow pathway; ERP: effective refractory period; SCL: sinus cycle length; TCL: tachycardia cycle length; JRCL: junctional rhythm cycle length; CJB: cumulative junctional beat; JB: junctional beat.

Table 2
Comparison of periprocedural data between patients with SP modification vs SP elimination.

Variable	SP modification n = 23	SP elimination n = 33	p
Age (years)	42.4 ± 16.8	45.4 ± 14.0	0.463
Sex, female	14 (61%)	22 (67%)	0.656
AH jump duration	104.5 ± 56.4	186.5 ± 97.7	**0.001**
SCL	738.4 ± 105.5	693.2 ± 111.1	**0.127**
TCL	340.3 ± 47.2	361.9 ± 45.5	**0.086**
JRCL	536.5 ± 91.0	526.8 ± 117.2	0.375
CJB	18.5 ± 16.8	26.4 ± 21.7	**0.138**
JB duration	9028.4 ± 8209.9	13972.6 ± 12473.8	**0.098**
SCL - JRCL ratio	1.4 ± 0.3	1.3 ± 0.4	0.814

Table 3
Multivariate analysis of SP elimination.

Variable	Odds Ratio	95% CI		p
		Lower	Upper	
AH jump duration (20 ms)	1.30	1.06	1.61	0.012
SCL	0.99	0.99	1.00	0.069
TCL	1.01	1.00	1.03	0.108
CJB	0.91	0.77	1.08	0.272
JB duration	1.00	1.00	1.00	0.188

variables with $p < 0.25$ from univariate analysis were included in the model. Results of the multivariate analysis revealed that the duration of AH jump was the sole independent predictor of SP elimination, in which every 20 ms increase in AH jump duration was associated with 1.30 higher rate of SP elimination (OR 1.30; 95% CI 1.06–1.61; $p < 0.05$).

ROC analysis (Fig. 1) was then performed to determine the optimal cut-off value for the AH jump duration. The area under the curve (AUC) was the primary efficacy measurement. If the lower 95% CI of the AUC was >0.5, we considered that the parameter might be suitable in predicting the primary outcome. The optimal cut-off value from ROC analysis was 100 ms, with a sensitivity of 79%, a specificity of 70%, a PPV of 79% and an NPV of 70%. Further analysis by dividing the AH jump duration based on its cut-off value showed that patients with AH jump duration of ≥100 ms have 6.14 times higher probability to have complete SP elimination compared to patients with AH jump duration of <100 ms (OR 6.14; 95% CI 1.47–25.62; $p < 0.05$) (Table 4).

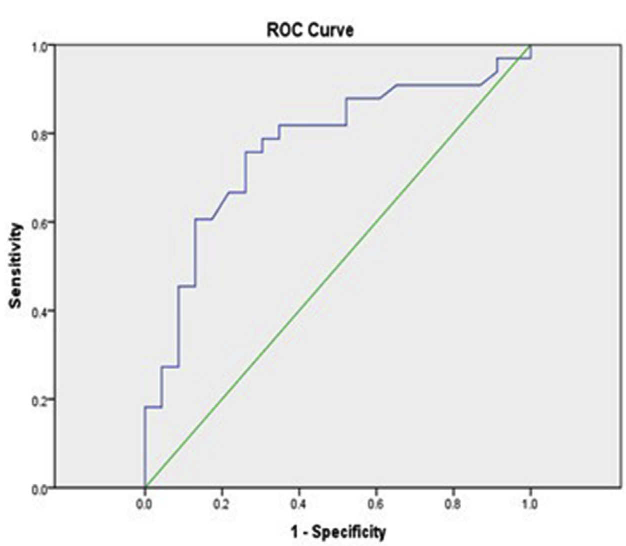

Fig. 1. ROC curve analysis for the optimal cut-off value of AH jump duration.

Table 4
Multivariate analysis of SP elimination.

Variable	Odds Ratio	95% CI		P
		Lower	Upper	
AH jump duration (≥ 100 ms)	6.14	1.47	25.62	0.013
SCL	0.99	0.98	0.99	0.012
TCL	1.01	1.00	1.03	0.022

4. Discussions

This study showed for the first time that the duration of AH jump pre-ablation is an independent predictor of SP elimination during AVNRT ablation. Every 20 ms longer AH jump, the higher probability for complete SP elimination during AVNRT ablation, with the OR of 1.30 (95% CI 1.06–1.61; $p < 0.05$). Further analysis by dividing the length of AH jump based on its cut-off value showed that patients with the length of AH jump of ≥100 ms had 6.14 times higher probability for complete SP elimination as compared to patients with AH jump of <100 ms (95% CI 1.47–25.62; $p < 0.05$).

Our study showed that patients with SP elimination and modification had similar age, sinus and tachycardia cycle length, and duration of junctional rhythm. This result is slightly different from the study by Kulakowski et al. [5] that reported patients with SP elimination were older and had longer AVNRT cycle length as compared to those with SP modification. Furthermore, the study conducted by Iakobishvili et al. [11] found that the higher amount and longer duration of junctional rhythm are correlated with complete SP elimination. The differences of the periprocedural parameters indicated that AVNRT characteristics and electrophysiological profile in patients with SP elimination might differ from that of the patients in whom only SP modification was achieved.

AH jump represents the change of anterograde activation from the fast pathway to the slow pathway conduction due to dual AV nodal physiology [12]. The length of the AH jump was determined by anatomical factors such as slow pathway length and functional factors such as cellular electrophysiology characteristics and autonomic nervous activity [13]. Several studies [14,15] found that the AH interval during tachycardia was correlated with the site of successful ablation. Slow pathways with longer conduction times have a more inferior location in the triangle of Koch when compared with locations producing a shorter AH interval. The site near the posteroinferior base of the triangle of Koch between the coronary sinus ostium and tricuspid annulus has become the target of ablation and has proven to be effective and safe [16]. In this study, we also have the impression that the longer the AH jump, the more posteroinferior location of the successful ablation site. Unfortunately, we can not make such a conclusion because the fluoroscopic images are not readily available for all patients.

Our study strengthens the previous observation that patients with complete SP elimination had different electrophysiology characteristics, specifically the length of AH jump pre-ablation. The longer AH jump the higher the probability for complete SP elimination during AVNRT ablation, probably due to its location in the posteroinferior base of triangle Koch. The observation of the longer AH jump would encourage a posterior approach, away from His bundle. While the finding of the shorter AH jump would be indicative of an increased risk of AV nodal injury.

4.1. Study limitations

This is a cross-sectional study, and the data were collected retrospectively. Therefore, we could not provide follow-up data regarding the recurrences rate post-ablation in both groups of patients (elimination/modification). In addition, we exclude the patients with multiple AH jump, therefore the results cannot be applied in such a population of patients.

5. Conclusions

This study proved that the length of AH jump pre-ablation is an independent predictor of slow pathway elimination during AVNRT ablation. Patients with the length of AH jump of ≥100 ms had a 6.14 times higher probability for a complete elimination of the slow pathway as compared to patients with AH jump of <100 ms.

Authors' contributions

- "SBR contributed to the research idea formulation, design of the study and writing the manuscript. BT carried out the proposal development and data collection. HA conceived of the study and participated in the funding of the study. DAH and YY participated in the coordination of data collection and statistical analysis."
- "All authors read and approved the final manuscript."

Declaration of competing interest

All authors declare no conflict of interests for this article.

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