



Prediction of Primary Slow-Pathway Ablation Success Rate According to the Characteristics of Junctional Rhythm Developed during the Radiofrequency Catheter Ablation of Atrioventricular Nodal Reentrant Tachycardia

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Abstract

Background: Nowadays, developed junctional rhythm (JR) that occurs during slow-pathway radiofrequency (RF) catheter ablation of atrioventricular nodal reentrant tachycardia (AVNRT) has been focused upon as a highly sensitive surrogate end point for successful radiofrequency ablation. This study was conducted to assess the relationship between the presence and pattern of developed JR during the RF ablation of AVNRT and a successful outcome.

Methods: Seventy-five patients aged between 14 and 88 who underwent slow-pathway RF ablation due to symptomatic AVNRT were enrolled into the study and received a total of 162 RF energy applications. Combined anatomic and electrogram mapping approach was used for slow-pathway RF ablation. The ablation procedure consisted of 60-second, 60 °C temperature-controlled energy delivery. After each ablation pulse, successful ablation was assessed according to the loss of AVNRT inducibility via isoproterenol infusion. Four different patterns were considered for the developed JR, namely sparse, intermittent, continuous, and transient block. Success ablation rate was assessed with respect to the position, pattern, and number of junctional beats.

Results: Successful RF ablation with a loss of AVNRT inducibility was achieved in 43 (57.3%) patients using 119 RF energy applications (73.5%). JR developed in 133 of the 162 (82.1%) applications with a given sensitivity of 90.8% and low specificity of 41.9% as an end point of successful RF ablation, with a negative predictive value of 62.1%. The mean number of the developed junctional beats was significantly higher in the successful ablations (p value < 0.001), and the ROC analysis revealed that the best cut-off point of the cumulative junctional beats for identifying accurate AVNRT ablation therapy is 14 beats with 90.76 % sensitivity and 90.70% specificity. There were no significant differences in terms of successful ablation rates according to the four different patterns of JR and its positions (p value=0.338, p value=0.105, respectively) in the univariate analyses.

Conclusion: JR is a sensitive but non-specific predictor of the successful RF ablation of AVNRT. Nevertheless, according to the results, its specificity could increase with the presence of more than 14 cumulative junctional beats. Although the development of JR during slow-pathway RF ablation seems not to be reliable as a success end point, its absences could be a marker of requiring more energy application to ablate the slow pathway.

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Introduction

Atrioventricular nodal reentrant tachycardia (AVNRT) has long been regarded as the most common supra-ventricular arrhythmia with the highest rate of occurrence in the young and especially female population.¹ Following several clinical trials and studies, nowadays radiofrequency (RF) ablation, not least slow-pathway RF ablation and modification, is established as the first-line interventional treatment for AVNRT.¹⁻⁶ Its success rate has been reported to be more than 90% with up to 70% freedom from recurrence in three years and less than 1% risk of complete heart block.^{1,3,4,7} Thus far, the most conventional marker and end point for successful RF ablation has been considered the loss of the inducibility of AVNRT; be that as it may, it has been reported to be not inducible in up to 10% of patients.^{8,9} This disadvantage has prompted scientists to focus on identifying an accurate alternative end point for predicting the success rate of the slow-pathway RF ablation of AVNRT. Developed junctional rhythm (JR) during this procedure with a reported sensitivity of up to 99.5% seems to be the accurate sensitive surrogate end point.^{3,9,10} Still, its specificity has not been desirable, and there is still a great deal left to evaluate for clarifying the controversies regarding its specificity in conjunction with determining the role of its patterns and even its absence in successful RF ablation.^{3,9,11,12}

In this study, we assessed the association between developed JR and its characteristics and the successful RF ablation of AVNRT.

Methods

This cross-sectional study, conducted from April 2007 to December 2008, recruited 75 patients aged between 14 and 88 who underwent slow-pathway RF ablation due to symptomatic and documented spontaneous AVNRT. None of the patients had congenital heart disease. The patients received a total of 162 RF energy applications, and cases with more than 5 RF energy applications were excluded from the study. Written informed consent was obtained from the patients, and the study was approved by the Ethics Committee of our hospital.

The incidence of JR developed during ablation with respect to the characteristics and its relationship with successful RF ablation was assessed in addition to an evaluation of the sensitivity and specificity of developed JR as the end point for successful RF ablation.

The baseline variables were comprised of gender;

underlying disease such as hypertension, coronary heart disease, dilated cardiomyopathy, congestive heart failure, and ventricular heart disease; presenting symptoms; and concomitant arrhythmias. The concomitant arrhythmias mostly included atrial tachycardia (AT), atrial fibrillation (AF), and Wolff-Parkinson-white syndrome (WPW).

The JR pattern was divided into the following five different groups: 1. Continuous JR: A JR span of more than 95% of the total RF ablation time that could last more than 15 seconds; it could persist after the interruption of the RF application, 2. Intermittent bursts: At least one burst of JR and at least 5 beats per burst with more than a 5-second duration, 3. Sparse: The appearance of single junctional ectopy in a sparse pattern with more than 5 ectopies during each burst, 4. Transient block: The interruption of the RF energy delivery after the appearance of ventriculoatrial block or atrioventricular block during JR, and 5. No junction: The non-appearance of any junctional beat during the RF energy delivery.

RF ablation was carried out utilizing a combined anatomic and electrogram-guided technique via a 7-Fr gauge and a 4 mm tip electrode catheter (Dr. Osypka) with temperature-controlled energy delivery (60 °C and maximum 60 watts) by the HAT 300 system (Dr. Osypka, Inc. USA). The distal electrode of the ablation catheter was first positioned in the lower posteroseptal region, where the slow-pathway potentials were recorded. The RF energy with the mentioned setting was delivered up to 60 seconds. After each ablation pulse, the inducibility of AVNRT by isoproterenol infusion was assessed. The delivery of the RF energy was repeated until AVNRT could not be more inducible. If required, the catheter tip was gently replaced more anteriorly to the upper posteroseptal and then midseptal areas until successful ablation had been achieved. The presence or absence of JR and its pattern during each RF application was recorded. The criterion for a success end point was the loss of AVNRT inducibility.

The data are presented as mean \pm standard deviation (SD) for the numeric variables and are summarized by absolute frequencies and percentages for the categorical variables. The continuous variables were compared using the Student t-test or nonparametric Mann-Whitney U test whenever the assumption of normality was not met, while the categorical variables were compared using the chi-square or Fisher exact test as appropriate. The Spearman rank-order correlation coefficient (r_s) was employed to evaluate the relationship between the JR beats and successful ablation.

As the second effort, a Receiver Operating Characteristic (ROC) analysis was conducted in the subgroup of successful ablations to identify the optimal cut-off point of the

cumulative junctional beats that could be considered an end point for successful ablation.

For the statistical analysis, the statistical software SPSS version 16.0 for Windows (SPSS Inc., Chicago, IL) was used. All the *p* values were 2-tailed, with statistical significance defined by a *p* value ≤ 0.05 .

Results

The study population comprised of 75 patients with a mean age of 42.07 ± 16.29 years (age range = 14-88 years old); 41 (54.7%) cases were women and 34 (45.3%) were men. Palpitation was the most common (62.7%) symptom during AVNRT among the patients followed by pre-syncope and syncope (2.7%) and dyspnea (2.7%). Additionally, 31.9% of the patients had more than one symptom. All the patients had antegrade AH jumps, demonstrating the presence of dual AV nodal conduction.

There were 162 RF energy applications with a mean number of 2.16 ± 0.92 per patient. Initial successful RF ablation with the loss of AVNRT inducibility was achieved in 43 (57.3%) patients using a total of 119 (73.5%) RF energy applications.

The distribution of the symptoms and underlying diseases between the patients with and without successful ablation was not significant (*p* value < 0.05). The baseline characteristics of the patients according to the initial successful ablation are shown in Table 1.

JR developed during 133 (82.1%) of the 162 RF energy applications with a mean number of junctional beats of 15.70 ± 9.91 . JR occurrence was significantly higher during successful ablation (*p* value < 0.001) (Table 2).

Most of the JR ectopies (64 [39.5 %]) occurred at the low posterolateral position; there was, however, no significant difference between the development site of JR and successful RF ablation (*p* value = 0.105) (Table 2).

JR developed in 82.1% of the RF energy applications; the rate was significantly higher in the successful ablations (*p* value < 0.001). Sparse was the most common pattern of developed JR and it occurred in 37.6% of the ablations, followed by intermittent (27.8%), transient block (19.5%), and continuous (15.0%). All the patterns occurred more, albeit not significantly, in the successful ablations.

Also, the Fisher exact test revealed no significant difference in terms of the successful RF ablation rates between the four different patterns of JR (*p* value = 0.338) (Table 2).

JR sensitivity as an end point for the successful RF ablation of AVNRT was 90.8%. Its specificity was 41.9% with a positive predictive value of 81.2%, negative predictive value of 62.1%, and accuracy of 77.8%.

The mean of the developed junctional beats was 19.13 ± 8.13 in the successful ablations and 6.23 ± 8.13 in the unsuccessful ablations; the mean was significantly higher in

the successful cases (*p* value < 0.001).

A ROC analysis was performed to find the best cut-off point of the cumulative junctional beats for identifying an accurate success end point in AVNRT ablation therapy. The area under the ROC curve was 0.868, and the value of the cumulative junctional beats cut-off point was 14 beats with 90.76% sensitivity and 90.70% specificity. The likelihood ratio (LR) reached 9.75 for a positive test (LR+) and 0.10 for a negative test (LR-).

Other developed arrhythmias were AF, WPW, and AT with the occurrence rates of 11.1%, 1.2%, and 0.6%, respectively. There was no significant difference with respect to these arrhythmias between the successful and unsuccessful ablations (*p* value = 0.641) (Table 2).

Discussion

Loss of the inducibility of AVNRT has been considered the end point for successful slow-pathway RF ablation; however, AVNRT is not inducible in up to 10% of patients during ablation.^{8, 9} Nowadays, JR developed during the slow-pathway RF ablation of AVNRT has been identified as a sensitive surrogate end point for successful AVNRT ablation. Nevertheless, there are still some controversies in the literature over this predictive role.^{3, 9-11}

In recent years, some studies have assessed the observed JR during RF energy applications and revealed that although JR develops significantly more in successful RF ablation with a sensitivity of up to 99.5%, it has a low specificity with a wide range of less than 80% in addition to a low positive prediction value, which renders cardiologists more reluctant to utilize it as an end point for successful RF energy applications.^{9, 11, 13} Our results showed the sensitivity (90.8%) and specificity (41.9%) of JR as an end point for successful AVNRT ablation; these rates chime in with those reported in the existing literature.^{3, 9, 11, 13} On the other hand, the positive predictive value in our study was 81.2%, which is notably higher than that in previous reports and seems to be a satisfying result.⁹ It means that the misclassification of unsuccessful cases as successful ones using a JR end point is under 20%, but it is still not a desirable outcome, especially with low specificity and negative predictive values of 62.1% in terms of misclassifying about 40% of successful cases as unsuccessful ones. These results totally confirm previous studies reporting the low specificity of JR occurrence as a surrogate end point for successful AVNRT ablation.^{9, 11, 13}

In recent years, further studies have been performed to assess the characteristics of JR that could affect the specificity of JR as a successful predictor of RF ablation. The JR that is mostly developed during the slow-pathway RF ablation of AVNRT is thought to be a result of increased automaticity of thermally injured cells of the perinodal region and Koach triangle during energy application.^{14, 15} It is evident that



Table 1. Successful RF ablation according to the patients' characteristics*

Patients' Characteristics	With successful RF applications n=43	With at least one unsuccessful RF application n=32	Total n=75	p value
Age (y)	42.86±16.13	41.00±16.71	42.07±16.29	0.628
Gender				
Male	21 (48.8)	13 (40.6)	34 (45.3)	0.480
Female	22 (51.2)	19 (49.4)	41 (54.6)	
Underlying diseases	9 (20.9)	6 (18.8)	15 (20)	0.815
Mean number of RF applications	1.77±0.75	2.69±0.86	2.16±0.92	<0.001
Total number of RF applications	119 (73.45)	43 (26.55)	162	

*Data are presented as mean ± SD or n (%)
RF, Radiofrequency

Table 2. Successful RF ablation according to the characteristics of junctional rhythm*

Characteristics of JR	Successful RF applications n=119	Unsuccessful RF applications n=43	Total n=162	p value
JR development	108 (81.20)	25 (18.80)	133	<0.001
Mean number of JR beats	19.13±8.13	6.23±8.13	15.70±9.91	<0.001
Position of developed JR				0.105
Low posteroseptal	42 (35.3)	22 (51.2)	64 (39.5)	
High posteroseptal	44 (37.0)	9 (20.9)	53 (32.7)	
Mid septal	33 (16.3)	12 (27.9)	45 (27.8)	
Pattern of developed JR				
Sparse	41 (38.0)	9 (36.0)	50 (37.6)	0.338
Intermittent	31 (28.7)	6 (24.0)	37 (27.8)	0.100
Continuous	18 (16.7)	2 (8.0)	20 (15)	0.105
Transient block	18 (16.7)	8 (32.0)	26 (19.5)	0.704
Other developed arrhythmias				0.594
AF	15 (12.6)	3 (7.0)	18 (11.1)	0.641
WPW	2 (1.7)	0	2 (1.2)	0.999
AT	1 (0.8)	0	1 (0.6)	0.314

*Data are presented as mean ± SD or n (%)

RF, Radiofrequency; JR, Junctional rhythm; AF, Atrial fibrillation; WPW, Wolff-Parkinson-white syndrome; AT, Atrial tachycardia

if JR originates from some unplanned thermally injured surrounding cells out of the Koch triangle like annular cells, RF application would be misclassified as successful and that would relatively decrease the specificity and positive predictive value.

A number of studies have demonstrated that some patterns and behaviors of JR that could be classified according to the onset, number, and duration of JR beats or even temperatures that induce JR have a significant correlation with successful RF ablation.^{3, 12} As Wagshal¹² and Nikoo³ stated, sinus-junction-sinus, sinus-junction-junction, and sinus-junction-block patterns as well as the JR pattern that starts and ends abruptly during the energy delivery are the statistically specific indicators of successful ablation. Our study, however, detected no difference between JR patterns and successful ablation rates, which could be due to different pattern classifications. The cumulative number of junctional beats, JR ectopy duration, and JR cycle-length are the other

demonstrated JR characteristics that are significantly in correlation with successful RF ablation.^{3, 13, 16, 17}

Jimenez-Candil¹⁷ found that the specificity of JR for predicting the success of slow-pathway ablation is increased with cumulative junctional beats more than 10 and cycle-length ratio higher than 1.26 (pre-RF cycle-length divided by JR cycle-length). However, Nikoo and colleagues³ found that cumulative junctional ectopies of more than 20 were significantly associated with successful RF ablation. Our result, albeit in line with both of these studies, revealed cumulative junctional ectopies of more than 14 as a cut point for effective ablation.

In our study, most of the junctional ectopies developed at the low posteroseptal area. Still, in line with the majority of previous reports, there were no significant differences between the positions of JR development and successful RF ablation.

Conclusion

Our study confirms JR as a sensitive, albeit non-specific, predictor of a successful RF ablation of AVNRT. Also, cumulative number of more than 14 junctional beats could significantly increase the specificity of the role of JR as an end point in predicting an effective RF ablation of AVNRT. Furthermore, according to the results, if the predictability of successful slow-pathway RF ablation with respect to the presence of JR is still not reliable enough, its absence could be a reliable marker of requiring more energy application delivery to abolish the pathway.

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