Changes in electrophysiologic properties of the conductive system of the heart in children with atrioventricular nodal reentrant tachycardia after 2–8 years following radiofrequency catheter ablation of the slow pathway

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Key words: *atrioventricular nodal reentrant tachycardia; ablation.*

Summary. *Radiofrequency ablation of the slow pathway is an effective method of treatment in children with atrioventricular nodal reentrant tachycardia.*

The aim of our study was to evaluate anterograde conduction properties in children before and after radiofrequency ablation of the slow pathway and to determine the efficacy and safety of this method.

Material and methods. Noninvasive transesophageal electrophysiological examination was performed in 30 patients at the follow-up period (mean duration, 3.24 years) after radiofrequency ablation of the slow pathway.

Results. The slow pathway function was observed in 13 patients one day after ablation, in 26 patients during the follow-up period, and in 28 patients after administration of atropine sulfate. Atrioventricular node conduction was significantly decreased the following day after ablation and at the follow-up versus the preablation (165.2 [30.2] bmp and 146.3 [28.5] bpm versus 190.9 [31.4] bpm; P<0.001). The atrioventricular node effective refractory period prolonged significantly the following day after ablation and at the follow-up versus the preablation (319.3 [55.3] ms and 351.0 [82.1] ms versus 248.3 [36.6] ms; P<0.001). Effective refractory period of the fast pathway prolonged significantly as compared with the preablation (from 408.0 [60.4] ms to 481.2 [132.9] ms; P=0.005). The prolongation of effective refractory period of the slow pathway was more significant than effective refractory period of the fast pathway at the follow-up (P<0.001).

Two late recurrences occurred; one patient had atrial tachycardia.

Conclusion. Children with atrioventricular nodal reentrant tachycardia can be effectively and safety cured by ablative therapy. The end-point during slow pathway ablation should be the abolition of tachycardia with preservation of dual atrioventricular nodal physiology.

Introduction

Atrioventricular nodal reentrant tachycardia (AVNRT) is one of the most common supraventricular tachycardias in childhood (1–3). It occurs very rarely in infants. This clear relation with age is unexplained. The heart size and changes in autonomic activity may play a role in it.

The substrate of the tachycardia is not completely understood. Although the circuit in AV node reentry has been shown to generally include "fast" and "slow" AV node pathways, only the slow pathway (SP) region has become the target for catheter ablation (4, 5).

Radiofrequency (RF) ablation as the method of treatment of cardiac arrhythmias has been used since late 1980s (in our clinic starting 1991, including children), and a selective RF ablation of the SP is a safe and effective method of treatment in children with AVNRT (5–7). However, the lesions created by RF energy can change the electrophysiological parameters of the conductive system of the heart.

Investigators have previously described the electrophysiological characteristics of antegrade AV nodal pathways in children with AVNRT during electrophysiological study after recently done RF ablation (8–10).

However, the long-term follow-up data of electrophysiological changes of the conductive system of the heart after SP RF ablation in children are limited.

The aim of our study was to define the electrophysiological properties of the conductive system of the

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heart in children 2–8 years after RF ablation of SP due to AVNRT and to determine the efficacy and safety of this method.

Patients and methods

After the approval of regional Ethics Committee, 48 consecutive pediatric patients who underwent an invasive electrophysiological examination and RF ablation due to typical AVNRT at the Hospital of Kaunas University of Medicine during 1999–2005 were subjected to noninvasive transesophageal electrophysiological testing (during this period, 48 pediatric patients underwent RF ablation). The diagnosis of typical AVNRT was confirmed during transesophageal and intracardiac electrophysiological examination (the narrow QRS complex tachycardia lasting more than 30 s; short ventriculoatrial time – less than 40 ms at earliest atrial activation site; tachycardia can be evoked and interrupted by atrial pacing).

The indications for ablation were as follows: patients' and their parents' preference (68%), symptoms refractory to antiarrhythmic medication (31%), adverse effects of antiarrhythmic medication (1%). The SP ablation was performed at the right inferoseptal to midseptal region.

Thirty children were enrolled into the study, and informed consent for the noninvasive transesophageal electrophysiological testing was obtained from children (>18 years) or their parents (<18 years). The mean (SD) age of patients was 17.5 (2.9) years (range, 8.5–20.2); there were 14 boys and 16 girls. Two of them had recurrences the following day after the first RF ablation, and RF ablation was repeated after one to three months. The mean follow-up duration was 3.24 years (range, 2–8). The late ablation follow-up data of conductive system of the heart was compared with preablation data and early (first day) postablation data.

Transesophageal electrophysiological examination

All the investigations were performed without sedation. A transesophageal multicontact electrode (not less than 4 contacts) was used, and electrogram was recorded by controlling the electrode at the highest amplitude of atrial activation. The Cardiolab (General Electric) electrophysiological computerized system was used for electrocardiogram recordings according to protocols during electrophysiological investigation, and EP MedSystems computerized stimulator EP-4 – for cardiac pacing.

The standard protocol included the following steps:

1. Electrocardiogram recording, measurement of sinus cycle length, PR interval.
2. Atrial incremental pacing for evaluation of sinus node recovery time, atrioventricular (AV) conduction, AV conduction time, prolongation of AV conduction time by a jump (≥50 ms, which represents the manifestation of antegrade dual AV nodal pathways) in order to induce supraventricular tachycardia.
3. The AV conduction time, the prolongation of AV conduction time by a jump, AV node effective refractory period (ERP), the fast pathway (FP) and the SP ERP were estimated by programmed atrial pacing decreasing coupling intervals 10 ms until AV node refractory period occurred. The "echo" reentrant atrial evocation following by long AV interval was estimated too.
4. If AVNRT could not be provoked during the baseline stimulation protocol, atropine was used intravenously at a concentration of 0.02 mg/kg, and AV conduction, AV conduction time, AV node ERP, the fast and slow pathways ERP were assessed.

Statistical analysis. All parametric data were expressed as the mean (standard deviation). The continuous data of the clinical and electrophysiologic characteristics were compared by using unpaired or paired *t* test. Relationships between continuous variables were evaluated by Pearson correlation. Statistical significance was set at P value of <0.05.

Results

Following ablation, complete elimination of the SP was noted in 18 patients and modification – in 12 patients. In the latter, the prolongation of AV conduction time by a jump or single "echo" beats (as a single complex of tachycardia) was observed after immediately performed RF ablation. In both cases, AVNRT was not inducible.

The following day after ablation, the absence of the SP function was confirmed in 17 patients. At the follow-up of 2–8 years, SP was not observed only in 4 patients. During the follow-up, atropine sulfate was prescribed intravenously for 27 patients, except 3 patients (two of them had recurrences, and one patient developed atrial tachycardia). The SP function was not observed only in two patients after administration of atropine sulfate. In the case of proved SP function, SP ERP prolonged significantly at the follow-up in comparison with preablation data. There was no significant difference in SP ERP before ablation and the following day after ablation. In addition, there were no significant differences in SP ERP before ablation and after atropine sulfate injection at the late follow-up period (Table 1).

FP ERP was unchanged early after ablation (the following day after it), but it prolonged significantly by 73.2 (130.2) ms by incremental pacing and by 53.6 (102.6) ms by programmed pacing after follow-up period of 2–8 years (Table 2).

At the follow-up period of 2–8 years, more significant prolongation of the SP ERP than FP ERP was seen; it was prolonged more than 129.0 (144.0) ms (r=0.6; P<0.001) by incremental pacing and 104.8 (109.7) ms (r=0.55; P<0.001) by programmed pacing versus the prolongation of FP ERP.

Standard electrophysiological study revealed two late recurrences, which occurred at the follow-up period of 2 to 5 years; both patients had modification of SP, and one of them had concomitant atrial tachycardia.

There were no significant changes in PR interval and sinus node recovery time before and after RF ablation of the SP (Figs. 1 and 2).

Sinus cycle length before RF ablation of SP and after RF ablation at the 2–8-year follow-up differed significantly (P<0.05) (Fig. 3). It shortened from 738.6 (134.3) ms in preablation state in comparison with 664.4 (179.5) ms at the late follow-up.

Significant alterations (P<0.05) in anterograde conduction properties before and after RF ablation of SP were documented (Table 3). AV conduction was significantly decreased the following day after ablation and during 2–8-year follow-up (26.0 [29.7] bpm and 43.9 [37.3] bpm, respectively). The AV ERP was significantly prolonged the following day after RF ablation of the SP and at the 2–8-year follow-up (71.0 [54.8] ms and 102.7 [79.4] ms, respectively). The prolonged AV ERP was recorded too during 2–8-year follow-up even after intravenous administration of atropine sulfate at a concentration of 0.02 mg/kg.

Discussion

Although elimination of the SP conduction was the original paradigm for treatment of AVNRT by RF ablation, it has become clear that elimination of the SP conduction is not necessary for good outcome (11–13).

SP conduction after ablation can be observed in 31–69% of cases (11, 14–16).

In our long-term observation, we have found the SP conduction in 86.6% of cases, and only two recurrences of AVNRT were documented. It raises the question: what actually changes during ablation? The SP ERP increased significantly at the follow-up after RF ablation. Existence of the anatomic circuit remained but access of premature beats to the reentrant circuit was impaired, decreasing the possibility of spontaneously occurring AVNRT.

Table 1. **Effective refractory period of the slow pathway before and after ablation**

Time point	SP ERP1, ms	SP ERP2, ms
Before RF ablation (n=30)	321.8 (53.8)	246.0 (36.0)
The following day after RF ablation (n=13)	326.9 (51.5)	283.1 (44.6)
At 2–8-year follow-up (n=26)	406.3 (123.4)*	334.5 (74.1)*
At 2–8-year follow-up + atropine (n=25, n=28-3)	302.9 (92.0)	284.4 (63.3)

*Statistically significant difference (P<0.05) comparing the data before and after ablation.
All values are expressed as mean (standard deviation). SP ERP – effective refractory period of the slow pathway; 1 – atrial incremental pacing; 2 – programmed atrial pacing.

Table 2. **Effective refractory period of the fast pathway before and after ablation**

Time point	FP ERP1, ms	FP ERP2, ms
Before RF ablation (n=30)	408.0 (60.4)	351.3 (40.15)
The following day after RF ablation (n=30)	409.0 (55.6)	354.7 (39.98)
At 2–8-year follow-up (n=30)	481.2 (132.9)*	405.0 (105.9)*
At 2–8-year follow-up + atropine (n=27)	385.9 (104.0)	340.4 (87.2)

*Statistically significant difference (P<0.05) comparing the data before and after ablation.
All values are expressed as mean (standard deviation). FP ERP – effective refractory period of the fast pathway; 1 – atrial incremental pacing; 2 – programmed atrial pacing.

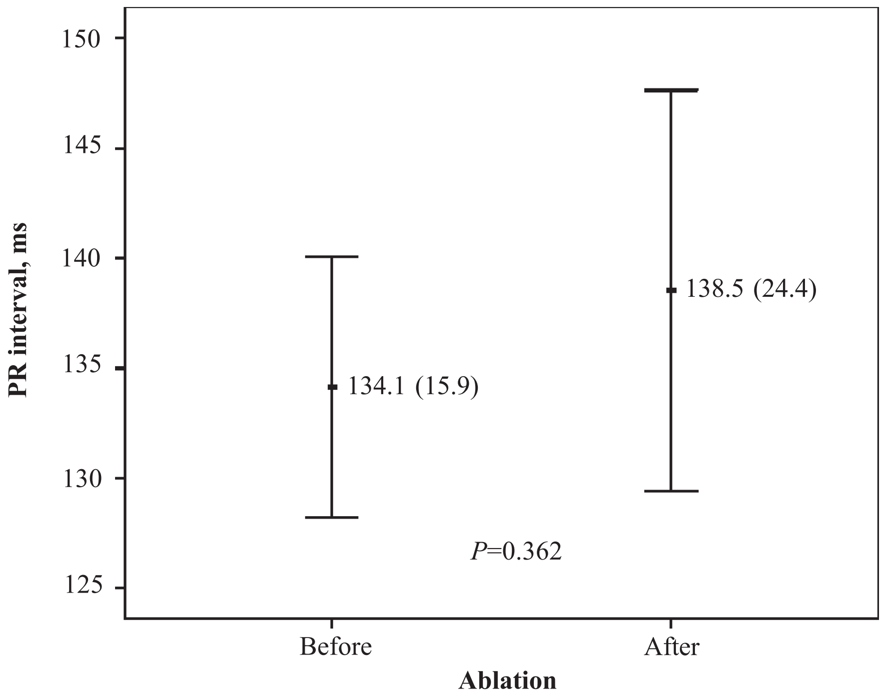

Fig. 1. **PR interval before radiofrequency ablation of the slow pathway and at the follow-up period of 2–8 years**

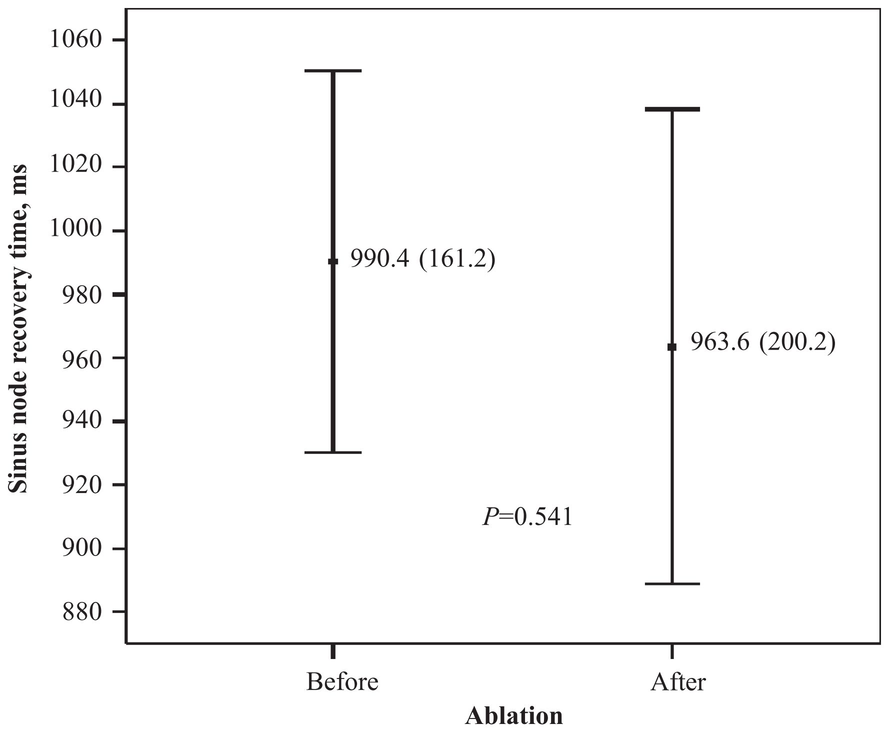

Fig. 2. **Sinus node recovery time before radiofrequency ablation of the slow pathway and at the follow-up period of 2–8 years**

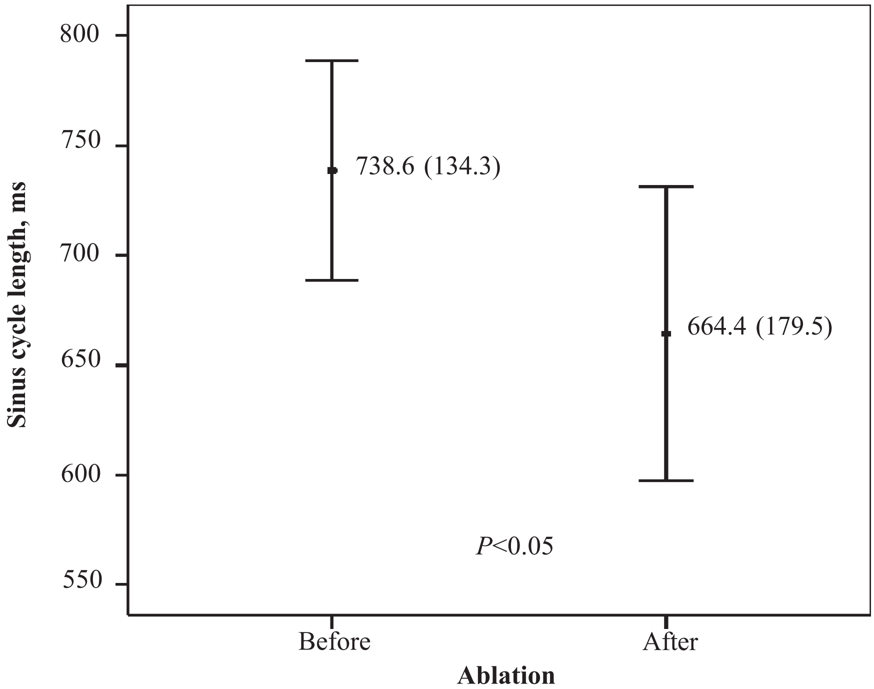

Fig. 3. **Sinus cycle length before radiofrequency ablation of the slow pathway and at the follow-up period of 2–8 years**

Table 3. **Atrioventricular conduction, atrioventricular effective refractory period before and after radiofrequency ablation of the slow pathway**

Time point	AV conduction, bpm	AV ERP, ms
Before RF ablation (n=30)	190.9 (31.4)	248.3 (36.6)
Following 1 day after RF ablation (n=30)	165.2 (30.2)*	319.3 (55.3)*
At 2–8-year follow-up (n=30)	146.3 (28.5)*	351.0 (82.1)*
At 2–8-year follow-up + atropine (n=27)	190.6 (25.9)	284.8 (62.4)*

*Statistically significant difference ($P<0.05$) comparing the data before and after ablation.
All values are expressed as mean (standard deviation). AV – atrioventricular;
AV ERP – atrioventricular effective refractory period; bmp – beats per minute.

Some possible mechanisms may lead to elimination of tachycardia despite the persistent SP conduction. SP may be injured and rendered, unable to sustain tachycardia. SP may remain unchanged, but interaction with FP may be disrupted in a manner that prevents further tachycardia (16–18).

After RF ablation and modification of SP, significant changes in anterograde conduction were noted: atrioventricular conduction was decreased by 43.9 (37.3) bpm and atrioventricular ERP was prolonged by 102.7 (79.4) ms on the average. This finding retrospectively shows the importance of SP to atrioventricular conduction.

Our study showed that at the follow-up after RF ablation of SP, FP ERP prolonged significantly in comparison with preablation FP ERP. Many previous studies (9, 19) showed a significant shortening of FP ERP after SP ablation. The reason of this phenomenon is unclear, but changes in autonomic activity may play a certain role, and the shortening is seen only when there is no residual evidence of the SP conduction after ablation (20). Furthermore, all the electrophysiological parameters were obtained immediately after RF ablation procedure, when patient is in deep sedation or general anesthesia. Our data were obtained during transesophageal electrophysiological examination without sedation during 2–8-year follow-up. The SP conduction was observed in 26 patients out of 30. We suggest that prolongation of the FP ERP may be associated with the functionality of SP at the postablation long-term follow-up period, when the electronic interactions between the FP and SP appears, but without inducible AVNRT.

The actual anatomic details how the SP makes physical contact with the fast pathway and, therefore, the distance over which electronic interactions take place are largely unknown. From many changes that occur during cardiac growth and development of the human, an increase in heart size is most obvious. Development of autonomic innervation must be an important factor too (9, 20).

Conclusions

Children with atrioventricular nodal reentrant tachycardia can be effectively and safely cured by radiofrequency ablation. Ablative therapy can be considered as the initial treatment for these patients. However, the ideal end-point during slow pathway ablation should be the abolition of tachycardia with preservation of dual atrioventricular nodal physiology.

Vaikų širdies laidžiosios sistemos elektrofiziologinių parametrų pokyčiai praėjus 2–8 metams po perkateterinės lėtojo tako radiodažninės abliacijos esant atrioventrikulinio mazgo reciprokinei tachikardijai

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Raktažodžiai: atrioventrikulinio mazgo reciprokinė tachikardija, abliacija.

Santrauka. Lėtojo tako radiodažninė abliacija veiksminga gydant vaikų atrioventrikulinio mazgo reciprokinę tachikardiją.

Tyrimo tikslas. Įvertinti anterogradinio laidumo pokyčius prieš ir po atrioventrikulinio mazgo lėtojo tako radiodažninės perkateterinės abliacijos procedūros praėjus 2–8 metams bei įvertinti metodo efektyvumą ir saugumą gydant atrioventrikulinio mazgo reciprokinę tachikardiją.

Tyrimo medžiaga ir metodai. 30 vaikų atliktas perstemplinis elektrofiziologinis širdies tyrimas, praėjus vienai dienai ir 2–8 metams po lėtojo tako radiodažninės abliacijos.

Rezultatai. Iškart po operacijos lėtojo tako funkcija išliko 13 vaikų. Po operacijos praėjus 2–8 metams, lėtojo tako funkcija užregistruota 26 vaikams, po atropino mėginio – 28 vaikams. Atrioventrikulinio mazgo laidumas sumažėjo statistiškai reikšmingai nuo 190,9 (31,4) k/min. prieš abliaciją iki 165,2 (30,2) k/min. iškart po operacijos ir iki 146,3 (28,5) k/min praėjus 2–8 metams. Atrioventrikulinio mazgo efektyvus refrakterinis laikotarpis pailgėjo statistiškai reikšmingai nuo 248,3 (36,6) ms prieš abliaciją iki 319,3 (55,3) ms iškart po operacijos ir iki 351,0 (82,1) ms praėjus 2–8 metams. Lėtojo tako efektyvus refrakterinis laikotarpis pailgėjo statistiškai reikšmingai nuo 321,8 (53,8) ms prieš abliaciją iki 406,3 (123,4) ms po abliacijos praėjus 2–8 metams. Greitojo tako efektyvus refrakterinis laikotarpis pailgėjo statistiškai reikšmingai nuo 408,0 (60,4) ms prieš abliaciją iki 481,2 (132,9) ms po abliacijos praėjus 2–8 metams. Dviem pacientams užfiksuoti du vėlyvieji atkryčiai, vienam pacientui – prieširdinė tachikardija.

Išvados. Daugumai vaikų, gydytų dėl atrioventrikulinio mazgo reciprokinės tachikardijos, po 2–8 metų užregistruota lėtojo tako funkcija nesant tachikardijos priepuolių. Tai rodo metodo efektyvumą ir saugumą, išsaugant dviejų takų funkciją pakankamai ilgai.

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