Atrio-ventricular conduction following radiofrequency ablation for atrio-ventricular node reentry tachycardia in children

Michal J. Kantoch1*, Joseph Atallah1, and Reeni N. Soni2

1Stollery Children’s Hospital, 4C2 WMC Health Sciences Centre, University of Alberta, Edmonton, Alberta, Canada T6G 2B7; and 2Variety Children’s Heart Centre, University of Manitoba, Winnipeg, Manitoba, Canada

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Aims
The study was designed to assess atrio-ventricular (AV) conduction with non-invasive methods at least 1 year after radiofrequency ablation (RFA) of the slow pathway for AV node reentry tachycardia.

Methods and results
Medical records of all patients who underwent RFA before their 18th birthday were reviewed. Patients were brought back for clinical evaluation, an electrocardiogram, an exercise stress test, and ambulatory Holter monitoring. Radiofrequency ablation of the slow pathway above the ostium of the coronary sinus was done in 106 children. No procedure resulted in high degree AV block. Follow-up evaluation was possible in 67 patients (63% of the total cohort) who were brought back to the clinic 1–13.7 years, mean 4.7 ± 3.0 years after the procedure. Dizzy spells were reported by 36% of examined patients and 2 patients reported syncope. PR intervals were normal in all but two patients when compared with published normal values. One patient presented with persistent, post-procedural first-degree AV block and another developed new onset, symptomatic second degree AV block 2 years after the procedure and required pacemaker implantation.

Conclusion
Non-invasive testing showed normal PR intervals in a cohort of patients who underwent RFA of the slow pathway in childhood or adolescence. Late AV block occurred in one child. Clinical evaluation more than a year after the procedure is warranted in symptomatic patients.

Keywords
Atrio-ventricular reentry tachycardia • Radiofrequency ablation • Atrio-ventricular node • PR interval • Atrio-ventricular block • Children

Introduction
Radiofrequency ablation (RFA) of the slow pathway is an accepted treatment for atrio-ventricular node reentry tachycardia (AVNRT) in children and adolescents.1–4 The procedure is associated with a small risk of atrio-ventricular (AV) block from inadvertent injury to the AV node. There is limited data on the long-term effect of perinodal ablation on AV conduction. The purpose of this study was to assess AV conduction based on patient symptoms and non-invasive testing at mid-term follow-up.

Methods
Medical records of all patients who underwent RFA for AVNRT before their 18th birthday during the period from 1994 to 2006 were reviewed. Patients were contacted by telephone, informed of the reason for follow-up, and brought to the clinic for evaluation with a 12-lead electrocardiogram (ECG), a 3-channel ambulatory Holter monitor (Del Mar Avionics), and a treadmill stress test (Quinton Q-Stress) using a standard Bruce protocol. Clinical evaluation included an enquiry regarding lightheadedness, syncope, palpitations, and exercise tolerance. PR interval measurements by the ECG equipment algorithm were accepted after manual verification in limb lead II. All PR intervals recorded by ambulatory monitoring (pre-cordial lead V5) and by exercise stress testing (limb lead II) were measured manually to the nearest 10 ms. Results were tabulated along with the published normal values for age.

Statistical analysis
Continuous variables are presented as means with standard deviation and categorical variables are presented as counts with percentages.

* Corresponding author. Tel: +1 780 407 3963; fax: +1 780 407 3954, Email: michal.kantoch@albertahealthservices.ca

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A two-sample t-test was used to compare our data set with normal values published by Lue.\textsuperscript{5}

\section*{Results}

Radiofrequency ablation for AVNRT was performed in 106 patients. All patients had normal hearts except for one child with documented viral myocarditis in the past and another with non-obstructive hypertrophic cardiomyopathy. All patients underwent RFA of the slow pathway at or above the ostium of the coronary sinus (CS) with a 4 mm tip electrode catheter. The endpoint for RFA was non-inducibility of AVN reentry of more than one echo beat. No RFA procedure resulted in AV conduction defect or any other ECG abnormality except for one patient with new I\textsuperscript{A} AV block and two patients with new right bundle branch block (RBBB). These three patients are included in the follow-up group.

\section*{Follow-up group}

Sixty-seven patients at the age of 10–28.7 years (mean 17.7 ± 4.9 years) were brought back to the clinic for evaluation (63\% of the total cohort). Twelve patients could not be reached because of unavailable contact information, 9 refused to enter the study, and 18 could not present to the study centres for investigations due to a long distance to travel. The follow-up time was 1–13.7 years, mean 4.7 ± 3.0 years.

Seven patients underwent two procedures and one patient underwent three procedures. At follow-up, two patients gave a history of rapid paroxysmal tachycardia. Atrio-ventricular node reentry tachycardia was documented in one patient and new ectopic right atrial tachycardia in another. No patient presented with recurrent tachycardia more than 6 months after the procedure. Junctional rhythm was induced by RFA application in 68/77 (88\%) procedures.

All six patients with transient AVB from RFA or catheter trauma to the AV node at the time of the procedure had normal ECGs prior to discharge home. None of them gave history of syncope or dizzy spells and all PR intervals were normal at the time of follow-up evaluation.

Table 1 shows characteristics of the study group and the total cohort.

\section*{General symptoms}

Syncope was reported by two patients. One patient reported syncope with recurrent paroxysmal tachycardia and one child presented with syncope produced by new onset AV block.

Lightheadedness or dizzy spells were reported by 24 patients (36\%). These symptoms accompanied recurrent paroxysmal tachycardia (two), palpitations (three), anxiety (one), migraine headaches (one), and new onset AV block (one). Sixteen patients (24\%) gave history typical for orthostatic or vasovagal hypotension.

Exercise tolerance was reported as normal by 58 patients (87\%), better than average by 8 patients, and worse than average by 1 patient.

\section*{PR interval evaluation}

ECG, Holter, and stress test PR interval measurements are summarized in Table 2.

An ECG was normal in 57 patients (85\%). The PR interval was normal in 65 patients (97\%). Radiofrequency ablation induced I\textsuperscript{A} AVB persisted in one patient (PR 260 ms) and RBBB in two patients. There were no new ECG abnormalities when compared with the post-procedural recordings except for the child with new onset AVB and syncope (PR 210 ms).

A treadmill exercise stress test was done in 55 patients (82\%). Five patients refused stress testing and seven patients missed a scheduled test. All but two patients reached 85\% predicted maximum heart rate for age. The PR interval was normal in all patients except for the patient with persistent post-procedural I\textsuperscript{A} AVB (PR 260–270 ms at baseline and in recovery, and 150 ms at peak exercise), and the child with new AVB and syncope (PR 240 ms at baseline and in recovery, and 120 ms at peak exercise).

An ambulatory Holter monitor was done in 57/67 patients (85\%). Seven patients refused testing and three patients missed a scheduled test. Holter monitors showed minimum heart rates 35–63 bpm (51 ± 8 bpm), maximum heart rates 125–202 bpm (156 ± 21 bpm), and average heart rates 64–104 bpm (82 ±

\begin{table}[h]
\centering
\caption{Characteristics of the study group and the total atrio-ventricular node reentry tachycardia cohort}
\begin{tabular}{|l|c|c|}
\hline
 & Study group (n = 67) & Total cohort (n = 106) \\
\hline
Male gender & 22 (33\%) & 39 (37\%) \\
Age range (mean) & 5.1–18 (13.1) & 4–18 (13.5) \\
Patients younger than 10 years & 14 (21\%) & 17 (16\%) \\
Number of RFA procedures (per patient) & 77 (1.15) & 119 (1.12) \\
RFA success after redo procedures & 94\% & 93\% \\
Number of RFA applications (mean ± SD) & 1–28 (9 ± 7) & 1–28 (9 ± 6) \\
Intra-procedural complications & & \\
Complete AV block & 0 & 0 \\
I\textsuperscript{A} AV block & 1 (1.5\%) & 1 (1\%) \\
Right bundle branch block & 2 (3\%) & 2 (2\%) \\
Transient AV block & 6 (9\%) & 8 (8\%) \\
\hline
\end{tabular}
\end{table}
10 bpm). These values were normal for age in all patients. Infrequent, brief periods of Wenckebach AV block during sinus bradycardia while asleep were recorded in five patients. One of them, a competitive hockey player, presented with infrequent orthostatic lightheadedness. All five patients had normal PR measurements by all diagnostic tests.

The only patient with abnormal Holter results and PR prolongation by all diagnostic tests was the young boy presenting with new onset daily lightheadedness and syncope 2 years after RFA at 9 years of age (weight 32 kg). The underlying cardiac anatomy was significant for a dilated coronary sinus (CS) draining a left superior vena cava (SVC). Three Holter monitors showed frequent episodes of I° and II° type I AVB and 2:1 AVB which correlated with symptoms. Symptoms resolved after implantation of a dual chamber pacemaker.

**Discussion**

This study evaluated patient symptoms and PR intervals at mid-term follow-up after RFA of the slow pathway for AVNRT in children and adolescents. Results showed normal resting PR intervals in 65/67 patients when compared with the published standard values for adolescents. Based on normal PR intervals recorded by non-invasive testing, we conclude that AV node conduction was normal in 97% enrolled patients.

One female patient had persistent, asymptomatic, RFA produced I° AV block 4.7 years after the procedure. Wang et al. showed that a prolonged PR interval following RFA for AVNRT in adults was not associated with late development of high grade AV block at 38 ± 12 months follow-up. Adult patients with PR prolongation prior to the procedure are not at risk of progression to higher grade AV conduction defect following RFA for AVNRT. Six patients had documented type I second degree AV block by Holter monitoring. In all but one patient, infrequent brief periods of Wenckebach AV block could have been produced by increased parasympathetic tone. Only one patient presented with syncope and new onset I° and II° AV block recoded by all diagnostic tools 2 years after RFA. In this child, clinical evaluation with an ECG, a Holter monitor, and an exercise stress test 10 weeks after the procedure showed normal PR intervals. By that time, healing of all RFA lesions should have been complete. The child had a persistent left SVC draining into a large CS. Anderson and Latham showed that a large CS draining a left persistent SVC may alter the anatomy of the triangle of Koch, the position of the compact AV node, and the conduction axis on the fibrous trigone. The conduction axis was found to be arranged more superficially compared with hearts with a small CS. It is possible that a more superficial location of the conduction axis might make it vulnerable to RFA applications or encroachment by the post-ablation scar tissue although successful and uncomplicated RFA was reported in three adult patients with a left SVC by Okishige et al. Coronary sinus abnormalities are unusual in patients with AVNRT; in 175 patients reported by Chiang et al., only one had a major coronary sinus abnormality (CS angulation).

Acute AV block is a recognized complication associated with right septal ablation in children as reported by the Pediatric Radiofrequency Ablation Registry in 1996. Late onset II° AV block was reported in two children at 24 h and 2 months after RFA for the right mid-septal accessory pathways. Apparently neither of these two patients presented with any AV conduction defect at the time of the procedure and neither required pacemaker implantation. In patients who underwent RFA in adulthood, occurrence of AV block was reported in isolated cases within a week following RFA or from a month to more than a year later. Presence of a left SVC was not mentioned in any case.

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**Table 2 PR interval measurements compared to published normal values**

<table>
<thead>
<tr>
<th>Test</th>
<th>Study group</th>
<th>Davignon et al.</th>
<th>Garson</th>
<th>Lue</th>
<th>t-test</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Davignon et al.</td>
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<tr>
<td>ECG</td>
<td></td>
<td>Davignon et al.</td>
<td></td>
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<tr>
<td>PR range</td>
<td>80–172</td>
<td>92–175</td>
<td>80–220</td>
<td></td>
<td></td>
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<tr>
<td>Mean ± SD</td>
<td>134 ± 17</td>
<td>135</td>
<td>140</td>
<td>140 ± 17.94</td>
<td>ns</td>
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<tr>
<td>Holter</td>
<td></td>
<td>Davignon et al.</td>
<td></td>
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<tr>
<td>PR minimum</td>
<td>80–140</td>
<td>109 ± 17</td>
<td>120–220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>109 ± 17</td>
<td>120–220</td>
<td>155 ± 22</td>
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<tr>
<td>PR maximum</td>
<td>80–140</td>
<td>109 ± 17</td>
<td>120–220</td>
<td></td>
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<tr>
<td>Mean ± SD</td>
<td>109 ± 17</td>
<td>120–220</td>
<td>155 ± 22</td>
<td></td>
<td></td>
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<tr>
<td>Stress test</td>
<td></td>
<td>Davignon et al.</td>
<td></td>
<td></td>
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<tr>
<td>Resting PR</td>
<td>90–180</td>
<td>81–207</td>
<td>130</td>
<td>137 ± 18.53</td>
<td>ns</td>
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<tr>
<td>Mean ± SD</td>
<td>137 ± 18</td>
<td>130</td>
<td>137</td>
<td>137 ± 18.53</td>
<td>ns</td>
</tr>
<tr>
<td>Peak stress PR</td>
<td>80–120</td>
<td>57–138</td>
<td>108b</td>
<td>111b</td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>96 ± 12</td>
<td>108b</td>
<td>111b</td>
<td></td>
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<tr>
<td>Recovery PR</td>
<td>110–200</td>
<td>138 ± 19</td>
<td>138 ± 19</td>
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</tbody>
</table>

ns, not significant by an independent two-sampled t-test.

*Both patients with I° and II° AV block were excluded from this group.

PR intervals at different heart rates were not obtained by exercise stress testing.
None of our six patients with transient AVB from catheter trauma or trauma to the AV node during RFA presented with syncope or PR prolongation at follow-up. A prospective study on catheter trauma in patients aged 9–92 years showed that such trauma is relatively common especially in younger patients.22 Transient AV conduction block at the time of RFA was not associated with late onset AV block in the report by the Pediatric Radiofrequency Ablation Registry.15 However, late occurrence of high-grade AV block following RFA trauma to the AV node was described in an adult patient.23

Conclusions

Non-invasive testing showed normal PR intervals in a cohort of patients who underwent RFA of the slow pathway for AVNRT in childhood or adolescence. Late onset AV block occurred in one child. Clinical evaluation more than a year after the procedure is warranted in symptomatic patients.

Limitations

Partial enrolment of the target study cohort might not have allowed for identification of all patients with AV conduction defects. Nevertheless the total patient cohort and the study group were very similar in regards to demographic and procedural characteristics. Not all patients in the study group had all diagnostic tests done. Function of the AV node was inferred from PR interval measurements by non-invasive methods only.

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Conflict of interest: none declared.

References