Evolution Of The Paced And Non-paced Qrs Duration With Chronic Right Ventricular Pacing In Pediatric Patients With And Without Structural Heart Disease

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**Article ID:** WMC001076
**Article Type:** Original Articles
**Submitted on:** 26-Oct-2010, 05:02:29 AM GMT  **Published on:** 26-Oct-2010, 11:38:19 AM GMT
**Article URL:** http://www.webmedcentral.com/article_view/1076
**Subject Categories:** CARDIOLOGY
**Keywords:** QRS duration, Right ventricular pacing, Cardiac resynchronization therapy, Congenital heart disease

**How to cite the article:** Nikolov Shalganov T, Paprika D, Kornyei L, Mihalcz A, Bodrogi G, Vatasescu R, Szatmari A, Szili-Torok T. Evolution Of The Paced And Non-paced Qrs Duration With Chronic Right Ventricular Pacing In Pediatric Patients With And Without Structural Heart Disease. WebmedCentral CARDIOLOGY 2010;1(10):WMC001076

**Competing Interests:**
There is no conflict of interests in publishing this paper.
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Abstract

Background: Right ventricular (RV) pacing creates artificial left ventricular (LV) dyssynchrony and thus can be used as a surrogate for left bundle branch block (LBBB). Assuming this, our aim was to assess the evolution of the QRS width in chronically paced pediatric patients with and without structural heart disease (SHD).

Methods: A group of 99 pediatric patients with a previously implanted pacemaker was studied retrospectively. Forty-three patients had isolated atrioventricular block (IAVB) and the remaining 56 patients had SHD. Patients were followed up for an average of 52.83±41.42 months. QRS duration was measured in lead V5 or II on ECG recordings with paper speed of 50 or 25 mm/sec. Data on QRS width were analyzed in six age groups (group I: Results: Paced QRS duration showed progressive widening during the follow-up (group I: 109.3±23.4 ms, group VI: 155±27.9 ms, p Conclusions: Chronic RV pacing in pediatric patients with or without structural HD does not cause widening of the QRS complex over 120 ms until the end of the first year of life. Paced QRS duration of 130 ms is not reached until the age of 3 to 4 years. The presence of structural HD results in a wider paced and intrinsic QRS complex.

Introduction

Cardiac resynchronization therapy (CRT) has emerged as a powerful tool for improving symptoms and quality of life in patients with advanced heart failure and for reducing heart failure-related morbidity and hospitalizations. [1-3] There is also some evidence that cardiac resynchronization reduces heart failure-related and all-cause mortality. [4-6] The abundance of data led to the formal inclusion of CRT in recent guidelines. QRS duration of at least 130 msec is among the criteria for selecting optimal candidates for cardiac resynchronization. [7] Although there is growing body of evidence that other markers for left ventricular (LV) mechanical dyssynchrony are better predictors for positive response to this treatment modality [8-10], the QRS duration is still a formal criterion for patient selection.

Cardiac resynchronization is increasingly performed and reported also in pediatric patients. [11-14] However, current selection criteria are derived from trials that included adult patients only and therefore cannot automatically be applied to the pediatric population. As right ventricular (RV) pacing creates artificial LV dyssynchrony it can be used as a surrogate for left bundle branch block (LBBB). The primary aim of the present study was to assess the evolution of the QRS duration across different age groups in pediatric patients with and without structural heart disease (SHD) paced chronically in the right ventricle. Furthermore, these data were also compared to the current cut-off value for cardiac resynchronization in adult patients.

Methods

Patient population
A group of 99 pediatric patients (55 males) with a previously implanted pacemaker was studied retrospectively. Forty-three of the patients (21 males) had isolated complete or advanced atrioventricular block (IAVB), the remaining 56 patients (34 males) had pacing indication in the presence of SHD - congenital cardiac malformations or some other type of SHD (hypertrophic obstructive cardiomyopathy - 3 patients; arrhythmogenic right ventricular dysplasia/cardioimopathy - 1 patient). Nine patients (all with SHD) had also bundle branch block (BBB) - 8 of them had right BBB and 1 had LBBB. All patients had received a VVI or DDD pacemaker device with or without rate-response with a ventricular pacing lead placed in the region of the RV apex. Forty-one of the patients had received initially an epicardial lead. 28 of
the patients with initial epicardial lead and 55 of the patients with initial endocardial lead kept it throughout the entire follow-up. Patients with DDD devices pacing only the atrium were not included in the study group.

Data collection
ECGs from follow-up visits or repeat hospitalizations were used for measurements. Measurement of the intrinsic and paced QRS complexes were performed using manual calipers on paper ECG recordings at a speed of 50 or 25 mm/sec. QRS width was assessed in lead V5. If lead V5 was not available, lead II was used instead. The width of the paced QRS was measured from the pacing spike to the end of last deflection. The duration of the intrinsic QRS complexes was measured in the same manner after temporary reprogramming of the device for follow-up measurements of pacing and sensing parameters. The above-described measurements were repeated in all patients during the follow-up period, which was divided into six age groups (group I:

Statistics
Data are presented as mean ± standard deviation (SD). Differences in different age groups were determined by means of Student’s T test. QRS values in different patient populations in the same age group were compared using Mann-Whitney test for non-parametric data. A p value of

Results

Changes of QRS duration within the age groups
Paced QRS duration showed progressive prolongation during the follow-up period from age group I to age group VI, p
Paced QRS duration did not show any significant difference between the 2 subgroups (IAVB vs. SHD patients) irrespective of exclusion or inclusion of patients with BBB in the analysis.
Patients with IAVB had narrower intrinsic QRS complex compared to patients with SHD, but this difference became significant only after the age of 7 years. This was true even after excluding the patients with BBB (all of them with SHD).

Discussion

The major finding of this study is that the paced QRS duration shows progressive widening with age, following the natural course of the native QRS. Assuming that paced QRS is equivalent to LBBB, one can say that QRS duration is a suboptimal selection parameter for cardiac resynchronization until certain age in a pediatric population.

Importance of cardiac resynchronization
In recent years cardiac resynchronization proved to be a powerful adjunct in the treatment of adult patients with advanced heart failure. Although it is a potential treatment option also for pediatric patients [11-14], selection criteria for this age group are not yet implemented.

As RV pacing creates artificial LV dyssynchrony, it can be used as a surrogate for LBBB. Assuming this, measurement of the paced QRS duration would permit to study how reliable the ECG is for selection of optimal pediatric candidates for cardiac resynchronization.

Progression of the paced QRS duration
Our data suggest that the paced QRS duration follows the natural widening of the intrinsic QRS – a known phenomenon in the pediatric population [15], which is due to the growth of the cardiac muscular mass. Nevertheless, although the paced QRS is wider than the intrinsic one, it can still be at the upper limit of the normal in infants and very small children. According to our results the cut-off value of 120 ms discriminating narrow from wide QRS was not reached in chronically paced children until the end of the first year of life. This happened in the next age group. This result was irrespective of whether intraventricular conduction delay was present or not.

Paced QRS width of 130 ms, which currently is the cut-off value for selection of adult cardiac resynchronization patients [7], was reached in age group III, i.e. after the second year of life. Again, this was irrespective of the presence or absence of BBB.

When patients were divided into subgroups according to epicardial or endocardial stimulation site, the values of 120 and 130 ms respectively were reached one age group later by patients paced endocardially (Table 5). Paced QRS duration and mechanical dyssynchrony

It would be interesting to know how the paced QRS width correlates to pacing-induced LV mechanical dyssynchrony in pediatric patients. In our series a QRS width of 150 ms was reached in age group V or VI (Tables 1 and 3). Bearing in mind that adult patients with QRS duration between 120 and 150 ms are a heterogeneous group regarding the presence of LV mechanical dyssynchrony, probably for pediatric patients under 8-15 years of age the QRS is not at all a good identifier for this condition and other methods allowing direct measurements of mechanical dyssynchrony should be used. Recently tissue Doppler imaging emerged as a better tool than ECG for selecting candidates for cardiac resynchronization,
especially in heart failure patients with mildly widened or narrow QRS complex. [8-10,16] Paced QRS duration and structural heart disease

Not unexpectedly, patients with SHD had the widest intrinsic QRS, even after excluding patients with BBB (Tables 2 and 4). The paced QRS duration in patients with SHD became more prolonged than in IAVB patients after the age of 7 years, probably reflecting the time of corrective heart surgery performed, although this difference was not significant except for age group V (Tables 1 and 3).

Conclusion(s)

In conclusion, our data suggest that RV apical pacing causes widening of the QRS complex that follows the natural progression of the QRS duration. The presence of SHD results in a wider paced QRS complex. Patients paced endocardially reach specific wide QRS values later than patients receiving epicardial leads. With the assumption that RV apical pacing is equivalent to LBBB, these data strongly suggest that QRS width derived from adult studies cannot be used as a selection parameter identifying pediatric candidates for cardiac resynchronization. Alternative methods such as tissue Doppler imaging should probably be the method of choice for young patients.

Abbreviation(s)

RV - right ventricular
LV - left ventricular (LV)
LBBB - left bundle branch block (LBBB)
SHD - structural heart disease (SHD)
IAVB - isolated atrioventricular block (IAVB)
CRT - cardiac resynchronization therapy (CRT)

Limitations of the study

The study is retrospective and although every effort was made to collect all available data, the time for obtaining ECGs was inevitably varying across the age groups. There is some heterogeneity in the subgroup with SHD – this can be regarded as a limitation, but also as an advantage for our aim was to evaluate not a highly selected, but a more “general” population. Likewise some of the patients had undergone palliative or totally corrective heart surgery, which may have confounded the natural progression of the QRS complex. On the other hand, for these patients heart surgery may be regarded as a “natural” and probably inevitable event that improved the prognosis and prolonged life. Measurements were done manually and at different paper speeds, which may have introduced errors. On the other hand all measurements were done by a single cardiologist, which eliminated interobserver variability.

Authors Contribution(s)

We hereby certify that all of the co-authors participated in the preparation, have read the manuscript and agree with its content and the conclusions of the work. This manuscript is not under consideration by any other publication and has not been published elsewhere. There is no conflict of interests in publishing this paper.

Reference(s)


Illustrations

Illustration 1

Tables 1-5.

Table 1. Progression of the paced QRS duration in the entire group and in the subgroups.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Overall*</th>
<th>IAVB*</th>
<th>SHD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>109.3±23.4</td>
<td>110±25.3</td>
<td>108.2±21.4</td>
</tr>
<tr>
<td>II</td>
<td>125.5±21.9</td>
<td>130±21.6</td>
<td>121±22.3</td>
</tr>
<tr>
<td>III</td>
<td>132.7±18.8</td>
<td>130.6±15.7</td>
<td>134.3±21.1</td>
</tr>
<tr>
<td>IV</td>
<td>140.8±22.8</td>
<td>140±16.6</td>
<td>141.3±26.2</td>
</tr>
<tr>
<td>V</td>
<td>147.3±18.1</td>
<td>141±14.8§</td>
<td>152.2±19.1</td>
</tr>
<tr>
<td>VI</td>
<td>155±27.9</td>
<td>147.5±18.2</td>
<td>159.1±31.6</td>
</tr>
</tbody>
</table>

QRS duration data are presented in milliseconds. IAVB – patients with isolated AV block; SHD – patients with structural heart disease; * p<0.05 for age group I vs. age group VI; § p<0.05 for IAVB vs. SHD.

Table 2. Progression of the non-paced QRS duration in the entire group and in the subgroups.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Overall*</th>
<th>IAVB*</th>
<th>SHD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>58.8±16.7</td>
<td>54.7±12.8</td>
<td>61.6±18.6</td>
</tr>
<tr>
<td>II</td>
<td>76.1±22</td>
<td>68±11</td>
<td>77.8±23.5</td>
</tr>
<tr>
<td>III</td>
<td>86.1±24.1</td>
<td>73±18.3§</td>
<td>91.7±24.4</td>
</tr>
</tbody>
</table>
Table 3. Progression of the paced QRS duration in the entire group and in the subgroups after excluding patients with bundle branch block.

<table>
<thead>
<tr>
<th></th>
<th>Overall*</th>
<th>IAVB*</th>
<th>SHD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group I</td>
<td>108.1±23</td>
<td>110±25.3</td>
<td>105±19.6</td>
</tr>
<tr>
<td>Age group II</td>
<td>125.8±22.4</td>
<td>130±21.6</td>
<td>121.1±23.7</td>
</tr>
<tr>
<td>Age group III</td>
<td>131.9±19.1</td>
<td>130.6±15.7</td>
<td>133.1±22.4</td>
</tr>
<tr>
<td>Age group IV</td>
<td>140.3±23</td>
<td>140±16.6</td>
<td>140.5±27</td>
</tr>
<tr>
<td>Age group V</td>
<td>144.4±16.5</td>
<td>141±14.8</td>
<td>147.7±17.7</td>
</tr>
<tr>
<td>Age group VI</td>
<td>149.7±23.7</td>
<td>147.5±18.2</td>
<td>151.2±27.4</td>
</tr>
</tbody>
</table>

QRS duration data are presented in milliseconds. IAVB – patients with isolated AV block; SHD – patients with structural heart disease; * p<0.05 for age group I vs. age group VI. Values for IAVB patients are the same as in Table 1 because no patient in this subgroup had bundle branch block.

Table 4. Progression of the non-paced QRS duration in the entire group and in the subgroups after excluding patients with bundle branch block.

<table>
<thead>
<tr>
<th></th>
<th>Overall*</th>
<th>IAVB*</th>
<th>SHD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group I</td>
<td>58.8±17.1</td>
<td>54.7±12.8</td>
<td>61.7±19.5</td>
</tr>
<tr>
<td>Age group II</td>
<td>74.6±22.5</td>
<td>68±11</td>
<td>76.3±24.5</td>
</tr>
<tr>
<td>Age group III</td>
<td>80.4±22.6</td>
<td>73±18.3</td>
<td>84.7±24.3</td>
</tr>
<tr>
<td>Age group IV</td>
<td>87.3±26</td>
<td>80±12.6</td>
<td>90±29.4</td>
</tr>
<tr>
<td>Age group V</td>
<td>87±24</td>
<td>79.1±28.8</td>
<td>92.1±19.6</td>
</tr>
</tbody>
</table>

Non-paced QRS duration data are presented in milliseconds. IAVB – patients with isolated AV block; SHD – patients with structural heart disease; * p<0.05 for age group I vs. age group VI.
QRS duration data are presented in milliseconds. IAVB – patients with isolated AV block; SHD – patients with structural heart disease; * \( p<0.05 \) for age group I vs. age group VI; § \( p<0.05 \) for IAVB vs. SHD; † \( p<0.05 \) for IAVB vs. SHD. Values for IAVB patients are the same as in Table 2 because no patient in this subgroup had bundle branch block.

### Table 5. Progression of the paced QRS duration in patients with endocardial and epicardial leads.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Endocardial pacing lead</th>
<th>Epicardial pacing lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>NA</td>
<td>105.5±16.4</td>
</tr>
<tr>
<td>II</td>
<td>110±20</td>
<td>121±13.7</td>
</tr>
<tr>
<td>III</td>
<td>128.9±14.9</td>
<td>130±17.7</td>
</tr>
<tr>
<td>IV</td>
<td>143.8±20.6§</td>
<td>120±14.1</td>
</tr>
<tr>
<td>V</td>
<td>150±17.6</td>
<td>NA</td>
</tr>
<tr>
<td>VI</td>
<td>159.3±25.3</td>
<td>NA</td>
</tr>
</tbody>
</table>

NA – not applicable (insufficient number of data). § \( p<0.05 \) for patients with endocardial vs. epicardial pacing leads.
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