Cardiac Index and Exercise during VDD/DDD versus VVIR Pacing in Children

The Effects of Atrioventricular Delay

Osman Baspinar  Alpay Celiker  Tevfik Karagöz
Department of Pediatric Cardiology, Hacettepe University, Faculty of Medicine, Ankara, Turkey

Key Words
Atrioventricular sequential pacing • Atrioventricular delay • Cardiac index • Children

Abstract
Twelve children with a VDD/DDD pacemaker during 100, 125, 150, 200 ms atrioventricular delays and VVIR pacing, cardiac index was measured at rest and evaluated by endurance time during exercise stress test. The optimal atrioventricular delay, which provides highest cardiac index, was 100 ms in three, 125 ms in two, and 150 ms in four and 200 ms in three patients. VDD/DDD pacing with different atrioventricular intervals resulted in a significantly higher cardiac index (6.70 ± 3.06, 6.49 ± 2.51, 6.15 ± 2.35, 6.37 ± 2.69 l/min/m², respectively) than VVIR pacing (5.25 ± 2.39 l/min/m²) at the rest. However, endurance times to treadmill exercise were similar in both the optimal atrioventricular delay (21.6 ± 3.7 min) and VVIR mode (22.4 ± 3.4 min) (p > 0.05).

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Atrioventricular sequential pacing with dual chamber pacemakers, which preserves physiological atrioventricular synchrony, improves ventricular filling, and thus also ventricular contraction, while at the same time reducing wall stress and myocardial oxygen consumption, is considered superior to single chamber ventricular demand pacing for the treatment of atrioventricular conduction disturbance [1–5]. Small changes in the programmed atrioventricular delay have a significant effect on cardiac function at rest. Also, the studies have indicated that optimization of cardiac hemodynamics, particularly in terms of cardiac index and workload, can only be obtained at optimal atrioventricular delay setting [6–10].

Physiological pacing with preservation of the atrioventricular synchrony may be important in the pediatric patients. These beneficial effects are especially important in children with heart failure. But this effect may not be apparent at rapid rates. At the exercise, the rate-responsive ventricular pacing is an acceptable alternative to the dual chamber pacing mode [11–13].

In this study, we evaluated the cardiac index at rest in children with atrioventricular sequential pacing, during different atrioventricular delays to detect the optimal atrioventricular delay and during VVIR pacing. Also, we compared the endurance time during exercise test with atrioventricular sequential pacing with optimal atrioventricular delay versus VVIR pacing.

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After 15 min of pacing at each atrioventricular delay at VDD/DDD pacing mode and VVIR mode, echocardiography was performed. Each patient examined in a supine position or in a lateral decubitus position during the ultrasound examination at each one atrioventricular delay changing and VVIR pacing mode. Doppler echocardiography was performed using a GE Vivid 7 ultrasonography with 2.5 and 3.5 MHz transducers. The transducer was positioned at the cardiac apex to give a standard five-chamber view. The Doppler sample volume was placed in the middle of the left ventricular outflow tract just below the aortic valves at the five-chamber position or upper level of the valves at the supraventricular position for the aortic flow measurement [14]. The aortic time-velocity integral was measured and results were expressed in cm. The aortic valve area was derived by measuring the diameter of aortic valve using an M-mode echocardiographic image. We took average values from 3 to 5 beats.

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Results

Cardiac Index at Rest

VDD/DDD pacing with 100, 125, 150 and 200 ms atrioventricular intervals resulted in a significantly higher mean cardiac index (6.70 ± 3.06, 6.49 ± 2.51, 6.15 ± 2.36, 5.37 ± 2.69 l/min/m², respectively) than VVIR pacing (5.25 ± 2.39 l/min/m²) at the rest (p < 0.05). But no statistically significant difference was found among different atrioventricular delay settings during atrioventricu-
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NS = p > 0.05, atrioventricular sequential pacing in all atrioventricular delays.

Atrioventricular sequential pacing (table 2). The optimal atrioventricular delay which provides highest cardiac index was 100 ms in three, 125 ms in two, 150 ms in four and 200 ms in three patients during atrioventricular sequential pacing. The optimal atrioventricular delay value at the VDD/DDD pacing mode was 6.96 ± 2.86 l/min/m².

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No patients experienced chest pain, shortness of breath, dizziness or hypotension during the exercise test. Some patients with VDD pacing had brief period of sense and capture problems during exercise test without negative effect on mean heart rate. Their rate responsive features were not activated. All patients (except two, both of them during VVIR pacing mode) showed a chronotropically competent sinus node. Their heart rates were 60 and 71 beats/min before and 62 and 77 beats/min at the end of the exercise testing. During exercise test heart rate was increased from 94.4 ± 20.4 to 142.5 ± 28.1 beats/min with the optimal atrioventricular delay in atrioventricular sequential pacing and from 90.1 ± 22.7 to 130.1 ± 38.5 beats/min with the VVIR pacing. Exercise time was 21.6 ± 3.7 (range: 17.8-27.9) min with the optimal atrioventricular delay and 22.4 ± 3.4 (range: 15.4-27.8) min VVIR pacing (p > 0.05) (fig. 1).

Discussion

Atrioventricular sequential pacing is the preferred method of cardiac pacing in children, since atrial contribution to ventricular filling causes a ≥20% increase in cardiac index [16]. Cardiac index may change with different atrioventricular delay settings in these pacing modes. Optimization of the cardiac index of VDD/DDD patients requires that atrial and ventricular contraction be appropriately timed [6-8, 10, 17]. Although, VVIR pacing in patients with congenital atrioventricular block could adequately respond in their physiological needs [18], the present study documented hemodynamic benefit proven by Doppler-echo measurements of cardiac index, at the atrioventricular sequential pacing mode compared to VVIR pacing at the rest.

Doppler echocardiographic measurement of cardiac index is a simple, satisfactory noninvasive method for the evaluation of hemodynamic changes when assessing the optimal atrioventricular delay in patients with atrioventricular sequential pacing. Though a controversial issue, the effects of various atrioventricular sequential pacing on cardiac hemodynamics are supported by some reports showing that a reduction in atrioventricular delay can be used in the treatment of dilated cardiomyopathy in advanced functional class [9, 19, 20]. In our study, atrioventi-
tricular delay value is not important since there was no statistical difference between the different atrioventricular delay adjustments at rest during atrioventricular sequential pacing. There is no data comparing cardiac index during rest and exercise Doppler derived atrioventricular delay. The optimal atrioventricular delay, determined by Doppler echocardiographic measurement of cardiac index, changed between 100 and 200 ms and was not predictable for the individual patient. These findings are also shown by the other investigators [6, 7, 21]. Programming of atrioventricular delay should be performed individually in every patient because of personal variability of optimal values of this parameter. Although, we do not know anything optimal atrioventricular delay can be sustained during long-term follow-up. We thought that this especially may be clinically important for children with heart failure and cardiac sequel.

Pacemakers should prevent sudden death and also they are helpful regarding improvement in quality-of-life. This has shown different clinical techniques, e.g. quality of life questionnaire, exercise test, 6-min exercise test, shuttle walking test, measurement of cardiac output with ultrasonography, oxygen uptake, indicator dilution, radionuclide cardiology, and to assess cyclic adenosine monophosphate and atrial natriuretic peptide levels [17]. Most pacemaker recipients were elderly and not particularly active. But exercise is very important in children regarding physical performance. Therefore, we compared total exercise time in both the optimal atrioventricular delay setting and VVIR pacing mode to evaluate the physical performance. Endurance times to treadmill exercise were similar in both of them. The benefits of atrioventricular sequential pacing, proven at rest with echocardiography, were not clear during conventional exercise test. We can say that dual chamber pacing does not improve effort tolerance compared with rate-adaptive ventricular pacing. The ability of VVIR to increase heart rate in response to exertion appears to minimize the benefit of dual chamber over ventricular pacing. These results may be evaluated further with the metabolic parameters during exercise tests, since conventional exercise tests may not reflect true exercise performance. Long-term follow-up would be very useful to detect the beneficial effects of dual chamber pacing, which was not apparent during exercise testing. The optimal atrioventricular sequential pacing might not be the same at rest and during exercise, the optimal atrioventricular delay as programmed at rest may not be necessary to improve exercise tolerance and also the important factor for maximal physical performance is ability to increase the ventricular rate [7].

Conclusion

In conclusion, dual chamber pacing with optimized atrioventricular sequential pacing may be helpful in children regarding cardiac index values. Doppler echocardiography seems indispensable for the noninvasive optimization of the atrioventricular interval. Thus, atrioventricular delay should be programmed separately for each patient. Atrioventricular sequential pacing with VDD/DDD pacemakers with the optimal atrioventricular delay seems superior to VVIR pacing with respect to cardiac index at rest. The benefits of atrioventricular sequential pacing were not occur during conventional exercise test. However, long-term randomized studies are required to determine the long-term effects of the optimal atrioventricular sequential pacing on growth and development at rest and exercise.

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No patients experienced chest pain, shortness of breath, dizziness or hypotension during the exercise test. Some patients with VDD pacing had brief period of sense and capture problems during exercise test without negative effect on mean heart rate. Their rate responsive features were not activated. All patients (except two, both of them during VVIR pacing mode) showed a chronotropically competent sinus node. Their heart rates were 60 and 71 beats/min before and 62 and 77 beats/min at the end of the exercise testing. During exercise test heart rate was increased from 94.4 ± 20.4 to 142.5 ± 28.1 beats/min with the optimal atrioventricular delay in atrioventricular sequential pacing and from 90.1 ± 22.7 to 130.1 ± 38.5 beats/min with the VVIR pacing. Exercise time was 21.6 ± 3.7 (range: 17.8–27.9) min with the optimal atrioventricular delay and 22.4 ± 3.4 (range: 15.4–27.8) min VVIR pacing (p > 0.05) (fig. 1).

Discussion

Atrioventricular sequential pacing is the preferred method of cardiac pacing in children, since atrial contribution to ventricular filling causes a ≥20% increase in cardiac index [16]. Cardiac index may change with different atrioventricular delay settings in these pacing modes. Optimization of the cardiac index of VDD/DDD patients requires that atrial and ventricular contraction be appropriately timed [6–8, 10, 17]. Although, VVIR pacing in patients with congenital atrioventricular block could adequately respond in their physiological needs [18], the present study documented hemodynamic benefit, proven by Doppler-echo measurements of cardiac index, at the atrioventricular sequential pacing mode compared to VVIR pacing at the rest.

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Discussion
Atrioventricular sequential pacing is the preferred method of cardiac pacing in children, since atrial contribution to ventricular filling causes a >20% increase in cardiac index [16]. Cardiac index may change with different atrioventricular delay settings in these pacing modes. Optimization of the cardiac index of VDD/DDD patients requires that atrial and ventricular contraction be appropriately timed [6–8, 10, 17]. Although, VVIR pacing in patients with congenital atrioventricular block could adequately respond in their physiological needs [18], the present study documented hemodynamic benefit, proven by Doppler-echo measurements of cardiac index, at the atrioventricular sequential pacing mode compared to VVIR pacing at the rest.

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Conclusion

In conclusion, dual chamber pacing with optimized atrioventricular sequential pacing may be helpful in children regarding cardiac index values. Doppler echocardiography seems indispensable for the noninvasive optimization of the atrioventricular interval. Thus, atrioventricular delay should be programmed separately for each patient. Atrioventricular sequential pacing with VDD/ DDD pacemakers with the optimal atrioventricular delay seems superior to VVIR pacing with respect to cardiac index at rest. The benefits of atrioventricular sequential pacing were not occult during conventional exercise test. However, long-term randomized studies are required to determine the long-term effects of the optimal atrioventricular sequential pacing on growth and development at rest and exercise.

References


Cardiac Index and Exercise during VDD/DDD versus VVIR Pacing in Children

The Effects of Atrioventricular Delay

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* Between VVIR and atrioventricular sequential pacing in all atrioventricular delays.
NS = p > 0.05, atrioventricular sequential pacing in all atrioventricular delays.

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Baspinar/Celiker/Karagoz


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<tr>
<td>With 125 ms atrioventricular delay</td>
<td>6.49 ± 2.51 (4.02 ± 12.84)</td>
<td>NS</td>
</tr>
<tr>
<td>With 150 ms atrioventricular delay</td>
<td>6.15 ± 2.35 (3.86 ± 12.50)</td>
<td>NS</td>
</tr>
<tr>
<td>With 200 ms atrioventricular delay</td>
<td>6.37 ± 2.69 (3.69 ± 12.88)</td>
<td>NS</td>
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* Between VVIR and atrioventricular sequential pacing in all atrioventricular delays.
NS = p > 0.05, atrioventricular sequential pacing in all atrioventricular delays.

ular sequential pacing (table 2). The optimal atrioventricular delay which provides highest cardiac index was 100 ms in three, 125 ms in two, 150 ms in four and 200 ms in three patients during atrioventricular sequential pacing. The optimal atrioventricular delay value at the VDD/ DDD pacing mode was 6.96 ± 2.86 l/min/m².

Exercise Testing
No patients experienced chest pain, shortness of breath, dizziness or hypotension during the exercise test. Some patients with VDD pacing had brief period of sense and capture problems during exercise test without negative effect on mean heart rate. Their rate responsive features were not activated. All patients (except two, both of them during VVIR pacing mode) showed a chronotropically competent sinus node. Their heart rates were 60 and 71 beats/min before and 62 and 77 beats/min at the end of the exercise testing. During exercise test heart rate was increased from 94.4 ± 20.4 to 142.5 ± 28.1 beats/min with the optimal atrioventricular delay in atrioventricular sequential pacing and from 90.1 ± 22.7 to 130.1 ± 38.5 beats/min with the VVIR pacing. Exercise time was 21.6 ± 3.7 (range: 17.8–27.9) min with the optimal atrioventricular delay and 22.4 ± 3.4 (range: 15.4–27.8) min VVIR pacing (p > 0.05) (fig. 1).

Discussion
Atrioventricular sequential pacing is the preferred method of cardiac pacing in children, since atrial contribution to ventricular filling causes a >20% increase in cardiac index [16]. Cardiac index may change with different atrioventricular delay settings in these pacing modes. Optimization of the cardiac index of VDD/DDD patients requires that atrial and ventricular contraction be appropriately timed [6–8, 10, 17]. Although, VVIR pacing in patients with congenital atrioventricular block could adequately respond in their physiological needs [18], the present study documented hemodynamic benefit, proven by Doppler-echo measurements of cardiac index, at the atrioventricular sequential pacing mode compared to VVIR pacing at the rest.

Doppler echocardiographic measurement of cardiac index is a simple, satisfactory noninvasive method for the evaluation of hemodynamic changes when assessing the optimal atrioventricular delay in patients with atrioventricular sequential pacing. Though a controversial issue, the effects of various atrioventricular sequential pacing on cardiac hemodynamics are supported by some reports showing that a reduction in atrioventricular delay can be used in the treatment of dilated cardiomyopathy in advanced functional class [9, 19, 20]. In our study, atrioven-
tricular delay value is not important since there was no statistical difference between the different atrioventricular delay adjustments at rest during atrioventricular sequential pacing. There is no data comparing cardiac index during rest and exercise Doppler derived atrioventricular delay. The optimal atrioventricular delay, determined by Doppler echocardiographic measurement of cardiac index, changed between 100 and 200 ms and was not predictable for the individual patient. These findings are also shown by the other investigators [6, 7, 21]. Programming of atrioventricular delay should be performed individually in every patient because of personal variability of optimal values of this parameter. Although, we do not know anything optimal atrioventricular delay can be sustained during long-term follow-up. We thought that this especially may be clinically important for children with heart failure and cardiac sequel.

Pacemakers should prevent sudden death and also they are helpful regarding improvement in quality-of-life. This has shown different clinical techniques, e.g., quality of life questionnaire, exercise test, 6-min exercise test, shuttle walking test, measurement of cardiac output with ultrasonography, oxygen uptake, indicator dilution, radionuclide cardiography, and to assess cyclic adenosine monophosphate and atrial natriuretic peptide levels [17]. Most pacemaker recipients were elderly and not particularly active. But exercise is very important in children regarding physical performance. Therefore, we compared total exercise time in both the optimal atrioventricular delay setting and VVIR pacing mode to evaluate the physical performance. Endurance times to treadmill exercise were similar in both of them. The benefits of atrioventricular sequential pacing, proven at rest with echocardiography, were not clear during conventional exercise test. We can say that dual chamber pacing does not improve effort tolerance compared with rate-adaptive ventricular pacing. The ability of VVIR to increase heart rate in response to exertion appears to minimize the benefit of dual chamber over ventricular pacing. These results may be evaluated further with the metabolic parameters during exercise tests, since conventional exercise tests may not reflect true exercise performance. Long-term follow-up would be very useful to detect the beneficial effects of dual chamber pacing, which was not apparent during exercise testing. The optimal atrioventricular sequential pacing might not be the same at rest and during exercise, the optimal atrioventricular delay as programmed at rest may not be necessary to improve exercise tolerance and also the important factor for maximal physical performance is ability to increase the ventricular rate [7].

Conclusion

In conclusion, dual chamber pacing with optimized atrioventricular sequential pacing may be helpful in children regarding cardiac index values. Doppler echocardiography seems indispensable for the noninvasive optimization of the atrioventricular interval. Thus, atrioventricular delay should be programmed separately for each patient. Atrioventricular sequential pacing with VDD/D DD pacemakers with the optimal atrioventricular delay seems superior to VVIR pacing with respect to cardiac index at rest. The benefits of atrioventricular sequential pacing were not occur during conventional exercise test. However, long-term randomized studies are required to determine the long-term effects of the optimal atrioventricular sequential pacing on growth and development at rest and exercise.

References


