The tissue velocity imaging and strain rate imaging in the assessment of interatrial electromechanical conduction in patients with sick sinus syndrome before and after pacemaker implantation

Xiaozhi Zheng¹, Ping Ji¹, Hongwei Mao¹, Jianqun Hu²*

¹ Department of Ultrasound, The Fourth Affiliated Hospital of Nantong University (The First People’s Hospital of Yancheng), Yancheng 224006, Jiangsu Province, P. R. China. ² Department of Ultrasonic Diagnosis, The First Affiliated Hospital with Nanjing Medical University (Jiangsu Province Hospital), Nanjing 210029, Jiangsu Province, P. R. China

ABSTRACT

Tissue velocity imaging (TVI) and strain rate imaging (SRI) were recently introduced to quantify myocardial mechanical activity in patients receiving cardiac resynchronization therapy. To clear whether atrial-demand-based (AAI) (R) atrial pacing can fully simulate the electromechanical conduction of physiological state and to clarify which one is more appropriate for the assessment of electromechanical activity of the heart between TVI and SRI, 63 normal subjects and 64 patients with sick sinus syndrome (SSS) before and after AAI(R) pacemaker implantation (PI) were investigated in this study. The results showed that the time intervals (ms), P-SRa assessed by SRI (not P-Va assessed by TVI) prolonged step by step from the lateral wall of the right atrium (RA), the interatrial septum (IAS) and the left atrium (LA) in normal subjects (5.120±0.62, 17.05±1.54 and 15.09±2.12, p<0.01). P-Va and P-SRa did not differ at the RA, IAS and LA in patients with SSS before PI (p>0.05), and they were significant longer than those of normal subjects (p<0.01). However, they shortened to normal levels in patients with SSS after PI and P-SRa showed again the trend of gradually prolonging from the RA, IAS to LA. At the same time, the peak velocities and the peak strain rates during atrial contraction also returned to normal values from lower levels. These data suggested that AAI(R) atrial pacing can successfully reverse the abnormal interatrial electromechanical conduction in patients with SSS, and SRI is more appropriate for the assessment of the electromechanical activity of atrial wall than TVI.

KEY WORDS: sick sinus syndrome, atrial pacing, electromechanical conduction, tissue velocity imaging, strain rate imaging

INTRODUCTION

To maintain sinus rhythm and to synchronize the cardiac contraction and relaxation is an essential condition for a normal pump function. When myocardial damage exists, such as degeneration, fibrosis, inflammation, ischemia and infarction, some electrical or/and mechanical dyssynchrony may occur, which often results in an irregular heart rhythm, an unstable hydrodynamics and an abnormal blood circulation. Sick sinus syndrome (SSS) is a syndrome of a variety of arrhythmias and multiple symptoms, which is due to the original organic diseases of sinus node or its surrounding tissues that cause the formation of sinus node impulse disorder, or sinus node to the atrial impulse conduction disturbances. To change the situation mentioned above, cardiac pacemakers have been used in clinic since about fifty years ago.

Researchers are making their efforts to gain the best physiological effects from optimizing different pacing modes, including atroventricular synchronous, cardiac chronotropic pacing and ventricular synchronization. Atrial-demand-based (AAI) atrial pacing meets the physiological characteristics of cardiac pumping, which is mainly applied to patients with SSS (who have no atrioventricular block). This is equivalent to an implantation of artificial sinus node for the patients. It has been reported that the incidence of atrial fibrillation, thrombus and heart failure is lower in AAI pacing than ventricular-demand-based (VVI) and DDD pacing mode [1]. Furthermore, the single lead atrial pacing mode, AAI(R) in SSS is mostly safe also in the long term compared to DDD(R) and VVI(R) [2]. In patients with SSS, DDD(R)-pacing, but not AAI(R)-pacing induces significant LV desynchronization and reduction of LVEF [3]. To our knowledge, the normal interatrial electrical impulse originates from the sinus node, transmit to right atrium (RA), interatrial septum (IAS) and left atrium (LA) in order. It is not clear whether AAI (R) atrial pacing can fully simulate the electromechanical conduction of physiological state, because mechanical dyssynchrony does not always
correlate with electrical dyssynchrony [4]. Tissue velocity imaging (TVI) and strain rate imaging (SRI) were recently introduced to quantify mechanical dyssynchrony of the atria and ventricle in patients receiving cardiac resynchronization therapy [5-8]. But which one is more appropriate for the assessment of mechanical activity of the heart has not been clarified. In this study, a comparison of TVI and SRI for the assessment of interatrial electromechanical conduction was done in 30 normal subjects and 31 patients with SSS before and after AAI(R) pacemaker implantation (PI), in order to find a simple, objective and repeatable method to assess the therapeutic effect of AAI(R) cardiac pacemaker.

MATERIALS AND METHODS

Study Population
The study was approved by the local human research ethics committee and free informed consent was obtained from all the subjects. Thirty-one patients (mean age: 51.4 ± 9.2 years, range: 37-66 years) who accepted AAI(R) pacemaker implantation participated in this study during the period from August 2007 to July 2010. They all met the clinical inclusion criteria (syncope, dizzy spells or heart failure) and the electrocardiographic criteria [(sinus arrest >2 s, tachy-brady syndrome with sinus pauses >2 s or sinus bradycardia (>50 beats/min in awake hour) without atrioventricular/bundle branch block and atrial fibrillation. Thirty normal subjects (mean age: 49.8 ± 8.7 years, range: 34-68 years) were enrolled in the study. The inclusion criteria were absence of any history of disease at any of the examined organs, assessed by subject's history, clinical symptoms, electrocardiogram, laboratory data, radiology, echocardiography and computer tomography.

Echocardiographic protocol
Echocardiographic examinations were done within 24 hours before pacemaker implantation and after 7 days using a commercially available ultrasonic system (Vivid 7; General Electric Medical Systems, Milwaukee, WI, USA) with a harmonic 1.7-3.4 MHz variable frequency phased array transducer. This ultrasonic system was equipped with a Q-analyze quantitative analysis software for the TVI and SRI. All the subjects were lying in left lateral decubitus position with the electrocardiography recorded simultaneously. First of all, the standard apical four-chamber view was obtained.

TABLE 1. Time intervals from initiation of the P wave on the electrocardiogram to peak velocity (P-Va) and to peak strain rate (P-SRa) at mid segments of lateral wall of the left atrium (LA) and right atrium (RA) and the interatrial septum (IAS) in the apical four-chamber view in normal subjects (Normal) and the patients with sick sinus syndrome (SSS) before and after pacemaker implantation (PI).

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>SSS before PI</th>
<th>SSS after PI</th>
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<tbody>
<tr>
<td></td>
<td>P-Va (ms)</td>
<td>P-SRa (ms)</td>
<td>P-Va (ms)</td>
</tr>
<tr>
<td>RA</td>
<td>40.02 ± 14.14</td>
<td>5.01 ± 0.62</td>
<td>175.29 ± 63.22</td>
</tr>
<tr>
<td>IAS</td>
<td>35.13 ± 7.07</td>
<td>17.05 ± 3.54</td>
<td>178.13 ± 65.39</td>
</tr>
<tr>
<td>LA</td>
<td>55.02 ± 13.04</td>
<td>45.09 ± 12.26</td>
<td>179.02 ± 73.04</td>
</tr>
</tbody>
</table>

*p<0.01 compared to normal, ′p<0.01 compared to SSS before PI, ′p<0.05 compared to the values of RA in the same group, ′′p<0.01 compared to the values of RA in the same group.
Then, the TVI and SRI function were activated and their dynamic images of three cardiac cycles were stored at a frame rate of 100 frames per second for subsequent analysis. In this process, gains were adjusted at the minimal optimal level to minimize noise, and the filter settings were kept low (50 Hz). Finally, a region of interest was placed at mid segments of lateral wall of the right atrium (RA), left atrium (LA) and the interatrial septum (IAS), respectively. The peak velocities (Va) and the peak strain rates (SRa) during atrial contraction were measured with reference to the P wave on the electrocardiogram during ventricular late diastole (atrial contraction). The time interval (P-Va) was measured from the initiation of the P wave on the electrocardiogram to peak velocity during atrial contraction, and the time interval (P-SRa) was measured from the initiation of the P wave on the electrocardiogram to peak strain rate during atrial contraction (Figure 1). All values for each parameter were obtained by averaging measurements from three successive cardiac cycles.

Reproducibility
Intraobserver variability was assessed in 18 subjects by repeating the measurements on two occasions (5 days apart) under the same basal conditions. To test the interobserver variability, the measurements were performed on the same subject by a second observer who was unknown of the first observer’s results. Variability was calculated as the mean percentage error, derived as the difference between the two sets of measurements, divided by the mean observations.

Statistical Analysis
Data were expressed as the mean±SD. Differences between the mean values of the two groups were analyzed by unpaired t-test. Differences were considered significant at \( p<0.05 \). SPSS version 13.0 (SPSS, Chicago, IL, USA) was used for all statistical analysis.

RESULTS
Time intervals are shown in Table 1 and Figure 2. As assessed by TVI, the P-Va intervals were longer at mid segment of lateral wall of the LA than at the RA and the IAS, and no differences were found between the P-Va intervals of RA and IAS in normal subjects. However, as assessed by SRI, the P-SRa interval at mid segment prolonged step by step from the RA, IAS to LA in these healthy individuals. In patients with SSS before PI, no significant differences were found for any time intervals among atrial walls or IAS, no matter assessed by SRI or TVI. All time intervals were significant longer than that of normal subjects. In patients with SSS after PI, both P-Va and P-SRa intervals shortened to normal levels, or were closed to normal levels. The tendency of prolong progressively

| Table 2 | Peak velocities (Va) and peak strain rates (SRa) during atrial contraction at mid segments of lateral wall of the left atrium (LA), right atrium (RA) and the interatrial septum (IAS) in the apical four-chamber view of normal subjects (Normal) and the patients with sick sinus syndrome (SSS) before and after pacemaker implantation (PI) |
|---------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
|         | Normal (PI)                                     | SSS before PI (PI)                              | SSS after PI (PI)                                | Normal (PI)                                     | SSS before PI (PI)                              |
| RA      | Va (cm/s) -5.97±2.87                             | SRa (1/s) -2.96±0.88                            | SRa (1/s) -4.37±1.91                             | Va (cm/s) -4.37±1.64                            | SRa (1/s) -1.57±0.35                            |
|         | -5.97±2.87                                      | -2.96±0.88                                     | -4.37±1.91                                      | -4.37±1.64                                     | -1.57±0.35                                     |
| IAS     | Va (cm/s) -4.55±2.71                             | SRa (1/s) -1.65±0.33                            | SRa (1/s) -3.06±1.64                             | Va (cm/s) -1.21±0.29                             | SRa (1/s) -1.21±0.29                             |
|         | -4.55±2.71                                      | -1.65±0.33                                     | -3.06±1.64                                      | -1.21±0.29                                     | -1.21±0.29                                     |
| LA      | Va (cm/s) -6.11±2.16                             | SRa (1/s) -3.08±1.21                            | SRa (1/s) -4.34±1.72                             | Va (cm/s) -1.73±0.95                             | SRa (1/s) -1.73±0.95                             |
|         | -6.11±2.16                                      | -3.08±1.21                                     | -4.34±1.72                                      | -1.73±0.95                                     | -1.73±0.95                                     |

\( p<0.05 \) compared to normal, \( p<0.05 \) compared to SSS before PI, \( p<0.05 \) compared to the values of RA in the same group.
of P-SRa intervals from RA, IAS to LA showed again. Peak velocities and peak strain rates are shown in Table 2. The peak velocities and peak strain rates of atrial walls or IAS were lower in patients with SSS before PI than in normal subjects. But the patients with SSS after PI and the normal subjects did not differ at these variables. No significant differences among atrial walls or IAS were found for any peak velocities in the normal subjects, patients with SSS before PI and after PI. Of interest, the peak strain rates were all smaller at mid segment of the IAS than at the RA and the LA in the normal subjects and patients with SSS. The inter-and intra-observer measurement repeatability are presented in Table 3. Intraobserver and interobserver variability for P-Va, P-SRa, Va and SRa were all smaller than 9%.

**DISCUSSION**

Our results showed that time intervals were significant longer in patients with SSS before PI than those of normal subjects, and they did not differ at the RA, IAS and LA. However, they shortened to normal levels in patients with SSS after PI and prolonged step by step from the RA, IAS to LA. This is entirely consistent with normal interatrial electromechanical conduction mode. At the same time, the peak velocities and the peak strain rates during atrial contraction also returned to normal values from lower levels. These findings demonstrates that AAI(R) atrial pacing can successfully reverse the abnormal interatrial electromechanical conduction in patients with SSS, by fully simulating the interatrial electromechanical conduction of physiological state. Meanwhile, it can effectively improve the atrial myocardial contraction and deformation in patients with SSS. This can also partly explain the lower incidence of atrial fibrillation, thrombus and heart failure in AAI pacing than VVI and DDD pacing mode. TVI is a developed technique for the quantification of regional myocardial motion by measuring its velocity and direction [9]. But TVI is angle-dependent, and overall heart motion, rotation and contraction of adjacent myocardial segments influence the measurement of regional velocity [10]. SRI has been recently developed for the quantification of regional myocardial deformation by estimating spatial gradients in myocardial velocities. In our study, although no significant difference was found between the ability of TVI and SRI to assess the mechanical function (peak velocity and strain rate) of atrial wall, the process of interatrial electromechanical conduction (the change of time intervals) was only well assessed by SRI (not by TVI). SRI is more sensitive for the assessment of the time intervals of atrial wall than TVI. This is maybe because SRI can overcome the influence of adjacent myocardial segments to objectively reflect the myocardial movement characteristics [10-12]. In our study, the longitudinal motion of the atrial wall and IAS was gained from the apical four-chamber view. On account of the influence of tethering and the motion of ventricular segments, the atrial segments adjacent to the mitral or tricuspid annulus had not been chosen, although these segments always have highest velocities or strain rates [11,13]. In addition, we found an interesting thing, i.e. the peak strain rates during atrial contraction were all smaller at mid segment of the IAS than at the RA and the LA in the normal subjects and patients with SSS. We speculate the special structure of IAS (combination of fibrous and muscular tissue) can partly account for this finding [14].

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**DECLARATION OF INTEREST**

The authors have no conflict of interest to declare.
REFERENCES


