Long-term synchronization of old transvenous dual-chamber pacemaker and newly implanted leadless ventricular pacemaker with atrial sensing capability

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Introduction
Pacemakers were developed as the only practical solution to treat bradyarrhythmias. Initially pacemakers had wires connected to the external machine; a few years later an internal pacemaker with pulse generator and transvenous leads was developed. Later, leadless pacemakers were developed to provide cardiac pacing without the need of transvenous leads, thus preventing complications of subclavian and axillary vein access and those related to the long-term presence of leads, such as tricuspid regurgitation.

Initially leadless pacemakers were designed to be single-chamber (right ventricle) only; however, recent advances enabled upgrade to A-sense V-sense/pace (VDD) mode in the Micra AV using the custom software. Unlike transvenous pacemakers, which sense atrial electrical activity directly through an atrial lead, the Micra AV algorithm identifies mechanical atrial contraction with the use of the 3-axis accelerometer, thus providing for AV synchronous pacing. However, some patients may need atrial pacing owing to the sinus node dysfunction in addition to the need of the ventricular pacing. If pacing with a transvenous ventricular lead becomes impossible, synchronization between transvenous atrial and leadless ventricular pacemaker is of utmost importance. Recently a case of a Micra AV synchronized with an atrial transvenous pacemaker was reported in this journal. However, synchronization problems may arise after the implantation and the initial follow-up. Here we report the case of the implantation of a Micra AV in a patient with a previous transvenous pacemaker pacing the atrium, with the dyssynchrony developing after initial synchronization, and the solution to the long-term synchrony.

KEY TEACHING POINTS

- It is possible to combine transvenous atrial with leadless ventricular pacing.
- After initially synchronous pacing with 2 pacemakers, later dyssynchrony may develop.
- The DDD pacing mode of the previously implanted transvenous pacemaker (albeit without effective ventricular pacing) helps to establish the long-term synchrony of 2 pacemakers.

Case report
A 71-year-old man with a history of coronary artery disease, aortocoronary bypass, and mitral valve replacement with bioprosthesis in 2013 developed sinus node dysfunction and intermittent atrioventricular (AV) block and underwent permanent dual-chamber pacemaker implantation in 2013 with the right cephalic approach. In the following years he had 95% atrial and variable rates of ventricular pacing. Recently, an elevated threshold up to 3.5 V @ 1.0 ms was demonstrated on the right ventricular lead and the device reached elective replacement indication. The decision was made to put an additional right ventricular lead together with generator change.

A venography was performed, which demonstrated complete occlusion of the right subclavian vein (Supplemental Figure 1), without any opacification of superior vena cava and right atrium, so placement of the new transvenous ventricular lead on the same side was not possible. In addition, echocardiogram demonstrated good left ventricular systolic function and bioprosthetic mitral valve with normal function, but also severe tricuspid regurgitation. Instead of implanting the additional ventricular lead through the left subclavian vein, which would require tunneling of the right atrial electrode and might exacerbate already severe tricuspid regurgitation, the decision was to implant the leadless cardiac pacemaker with the atrial sensing capabilities (Micra AV; Medtronic, Minneapolis, MN).

KEYWORDS

Atrioventricular; Bradycardia; Leadless; Pacemaker; Synchrony

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St Paul, MN) while continuing the atrial pacing from the existing transvenous pacemaker.

An implantation of the leadless pacemaker was performed on December 2020 using the usual technique (Supplemental Figure 2A and 2B); the existing transvenous leads did not interfere with the procedure. There was no change in the severity of the tricuspid regurgitation after the implantation. The old transvenous pacemaker was pacing the atrium and the Micra AV pacemaker was able to sense the atrial mechanical activity and sequentially sense and pace the ventricle. The patient was discharged with transvenous pacemaker in AAI mode and Micra AV in VDD mode 50–105 beats per minute (bpm), A3 Window End of 825 ms, and Sensed AV (AM-VP) of 170 ms with achievement of AV synchrony (atrial pacing by the conventional pacemaker, detected atrial mechanic and ventricular sensing by the Micra AV, Figure 1A).

At a follow-up visit 1 week after the implantation, the patient complained of weakness and functional deterioration. Device interrogation demonstrated AV synchrony only 15.9% of the time (Figure 2A). Manual atrial mechanical testing was performed, and different programming changes were attempted in order to ensure that atrial contraction will be constantly outside the A3 window to improve AV synchrony; however, this was not successful. The patient was discharged home with conventional AAI transvenous pacing and a backup Micra AV VVI pacing of 45 bpm. The patient improved clinically; however, the issue of the dyssynchrony remained. After detailed review of all intracardiac electrograms, false detection of atrial contraction by the Micra AV was observed.

Figure 1  A: An electrogram strip from the interrogation of the leadless pacemaker the day after the implantation demonstrates the appropriate atrial mechanical sensing and ventricular sensing by the pacemaker. A pacing artifact produced by the transvenous pacemaker with resulting P wave can be seen on the surface rhythm strip. B: The leadless pacemaker interrogation a week after the implantation (when the transvenous device is in AAI mode) demonstrates false atrial mechanical detection by the Micra AV (Medtronic, St Paul, MN) without any P wave on the surface electrocardiogram. Atrial pacing spike artifact produced by the transvenous pacemaker can be seen after the QRS.
It can be seen that atrial mechanical detection is not accompanied by the surface P wave and is not related to the later-seen atrial pacing artifact (Figure 1B). After unsuccessful attempts to improve synchronization between the 2 pacemakers using the AAI pacing + Micra AV VDD mode, we realized that the synchrony can be improved using the ventricular sensing of the conventional pacemaker to oblige the atrial pacing to follow the previous ventricular contraction at the constant and physiologic interval. Changing the old transvenous pacemaker mode from AAI to DDD (with minimal and subthreshold ventricular output of 0.25 V @ 0.2 ms) resolved this issue. During the programming, we verified the occurrence of the ventricular sensing or pacing event simultaneously in both pacemakers (Figure 3). At a follow-up visit after 15 days, using DDD programmed conventional PM (just for V sensing without V pacing capability) and Micra AV VDD mode 50 bpm, a significant increase of AV synchrony was observed (from 15.9% [Figure 2A] to 82.4% [Figure 2B]). No adverse interaction between the 2 pacemakers was observed (ie, Micra AV ventricular pacing was not inhibited by the subthreshold ventricular stimulation from the transvenous lead).

Figure 2  A: The leadless pacemaker interrogation a week after the implantation demonstrates suboptimal atrioventricular (AV) synchrony when the transvenous pacemaker is in the AAI mode (AM-VS plus AM-VP of 15.9%). B: After changing to the DDD mode, the AV synchrony is much improved (AM-VS plus AM-VP of 82.4%).
It has to be added that termination of the transvenous ventricular pacing with high output prolonged the time to elective replacement indication for an additional 2.5 years.

**Discussion**

This case report describes a patient with 2 pacemakers (1 of them a leadless Micra AV), which developed synchronization problems after initially successful synchronization.

Recently a VDD operating leadless pacemaker (Micra AV) was developed, which relies on its accelerometer to detect atrial mechanical contraction.

The accelerometer detects 4 different mechanical signals according to the stages of the cardiac cycle (similar to the known 4 cardiac sounds): The A1 signal corresponds to AV valves’ closure, the A2 signal corresponds to VA valves’ closure, the A3 signal corresponds to passive ventricular filling (E wave in Doppler echocardiography), and the A4 signal corresponds to atrial contraction (A wave in Doppler echocardiography).

The end of the ventricular mechanical activity is marked as the “VE” annotation by the leadless device. The atrial mechanical activation (A4) is marked as “AM” annotation and occurs after the P wave. In order to be detected, A4 has to happen after VE. In cases when VE comes too late and obscures A4, it cannot be sensed by the device; programming the device with shortening of A3 detection window and thus making VE happen earlier improves A4 detection and provides AV synchrony.

Recently, a similar case with atrial transvenous and ventricular synchronous leadless pacing was published. The patient in this case was paced in the AAI mode transvenously together with synchronous ventricular pacing by Micra AV. The atrial mechanical test was performed and AV synchrony was achieved with sequential atrial and ventricular pacing. However, the follow-up of the patient was not provided and we cannot know the long-term efficacy of the AV synchrony in this mode.

In our case, despite initial success in AV synchrony, later the dyssynchronous pacing was observed. The optimal AV synchrony was achieved after combining transvenous DDD pacing (albeit with ventricular sensing only) together with Micra AV, resulting in synchronous AV pacing with ventricular sensing and a pacing event occurring at the same time in both pacemakers (Figure 3). This enabled the atrial contraction event to be constantly outside the VE zone because of ventricular sensing of the transvenous pacemaker.

Several additional factors may positively influence the amount of successful atrial sensing of the Micra AV, including low sinus rate variability and low E/A ratio. Atrial pacing by definition has 0 heart rate variability, thus enhancing atrial sensing by the Micra AV leadless pacemaker.
pacemaker. Additionally, history of the aortocoronary bypass was demonstrated in this study as a risk factor for low AV synchrony. Our patient underwent coronary bypass surgery and mitral valve replacement, which can explain the initial difficulty to achieve appropriate atrial sensing by Micra AV.

In summary, sequential pacing of the atria with an existing transvenous pacemaker and of the ventricles with the leadless AV pacemaker is feasible. In our case the AAI pacing with Micra AV VDD mode did not achieve optimal AV synchrony. However, changing the old pacemaker to the DDD mode allows good AV synchrony between the 2 pacemakers.

Conclusion
This case demonstrates successful synchronous atrial and ventricular pacing using transvenous DDD pacing (with atrial sensing/pacing and ventricular sensing only) and leadless Micra AV pacemaker atrial sensing and ventricular sensing and pacing.

Appendix
Supplementary data
Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2021.06.005.

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