Synchronization of the new leadless transcatheter pacing system with a transvenous atrial pacemaker: A case report

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Introduction

Permanent cardiac pacing has afforded immense benefit and treatment to millions of patients who have suffered from bradyarrhythmias. Since its inception, cardiac implantable electronic devices (CIED) were limited to subcutaneously implanted generators with 1 or more transvenous leads.[1] Owing to the numerous potential complications inherent to a transvenous device implantation, such as pneumothorax, hemothorax, pocket hematoma, infection, and lead dislodgement,[2] a solution was put forth in 2016 with the introduction of the leadless ventricular pacemaker, known as the Micra (Medtronic, Inc, Minneapolis, MN).[3] While this device showed a 48% reduction in complication rate vs transvenous devices,[4] its 1 drawback was the lack of atrioventricular (AV) synchrony. Fortunately, this issue was resolved with the improvement and implementation of an accelerometer-based algorithm, allowing for atrial mechanical, as opposed to electrical, sensing with appropriate ventricular pacing, with the release of the Micra AV in the beginning of this year.[5]

As the intended indications for the Micra AV implantation include a patient who has complete heart block with either a high risk of infection, transvenous access issues, or both, there has never been a need to combine a transvenous device with the new leadless pacemaker system. We report the first ever case of a Micra AV synchronized with a transvenous atrial pacemaker.

Case report

A 69-year-old woman presents to an outside facility after a syncopal episode. She has a past medical history of sinus node dysfunction (underlying sinus rate of 35 beats/min) and intermittent Mobitz II AV block status post dual-chamber permanent pacemaker (PPM) placed in 2011. Her history is otherwise significant for end-stage renal disease on hemodialysis via left arm arteriovenous fistula placed in 2015. Initial vital signs were within normal range. Upon interrogation, the right ventricular (RV) lead threshold was 5.5 V at a pulse width of 1 ms; however, prior to this, it was known that the patient had a chronically malfunctioning RV lead with a threshold and impedance of 2.5 V at 1 ms and >3000 ohms, respectively. As there was <1% RV pacing at that time, the decision was made to hold off on lead revision and program the output to 5 V at 1 ms. As a result of the increased threshold, there was intermittent noncapture of the RV lead, as shown in Figure 1, leading to her syncopal episode. Therefore, the RV lead output was further increased to the maximum value of 7.5 V at 1 ms and the patient was discharged with close follow-up in clinic.

A detailed discussion was held with the patient regarding potential options, including lead extraction with reimplantation; however, given the ipsilateral left upper-extremity arteriovenous fistula, it was deemed too high of an infection and bleeding risk to reaccess the left axillary vein. Given these risks and the stable transvenous atrial lead with intact parameters (impedance of 388 ohms, threshold of 1.125 V at 0.4 ms, and 1.4 mV p-wave sensing), it was decided that the Micra AV would be the best option to preserve AV synchrony when ventricular pacing was needed. The patient subsequently underwent successful implantation of the Micra AV. Postimplantation chest radiograph and device testing are shown in Figures 2 and 3, respectively. As the patient's transvenous RV lead was not functioning appropriately, that device was programmed to an atrial pacing–atrial sensing–inhibit (AAI) mode so the Micra AV could be synchronized with the atrial contraction from right atrial pacing. Figure 3A shows the intrinsic Micra AV electrograms with associated marker channels demonstrating appropriate atrial sensing, as evidenced by the ventricular end (VE) and atrial mechanical (AM) markers, and ventricular pacing (VP). Figure 3B shows the results of the manual atrial mechanical testing, which correctly marks the A3 and A4 periods, and

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KEY TEACHING POINTS

- The Micra AV (Medtronic, Inc, Minneapolis, MN) is the best current option for patients with intermittent or permanent atrioventricular (AV) block requiring synchronized, single-chamber pacing who are at high risk for infection and bleeding.
- AV synchrony can be maintained in a patient with sinus node dysfunction and AV block despite a malfunctioning right ventricular lead with implantation of the Micra AV.
- Two independently functioning pacemakers can interact in synchrony; however, careful programming must be performed so as not to allow 1 device to inhibit the other inappropriately.

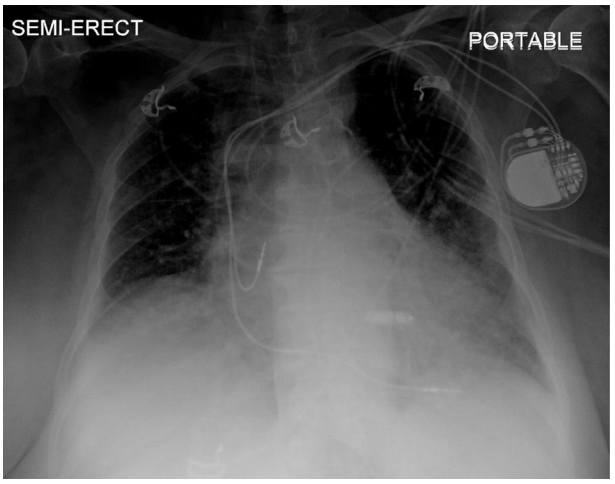

Figure 2 Postimplant chest radiograph demonstrating stable, mid-septal position of Micra AV (Medtronic, Inc, Minneapolis, MN) as well as the previously implanted dual-chamber pacemaker.

Figure 3C shows the separate marker channels from the patient's transvenous device, which was atrially pacing (AP) and ventricular sensing (VS) the paced complexes from the Micra AV. On postoperative day 1 the patient's telemetry demonstrated atrial pacing from the transvenous device programmed to AAI with appropriate ventricular pacing from the Micra AV (Figure 3D). The rest of the patient's postoperative course was uncomplicated, so she was discharged home.

Discussion

In this case report, we present a patient with 2 independently functioning pacemaker systems, a transvenous AAI PPM and the new Micra AV, which were shown to successfully interact together and allow for AV synchronization. While this may not be the most ideal situation, the decision to implant the Micra AV avoided potential complications that would have accompanied extraction of the patient's old RV lead with subsequent placement of a new RV lead or implantation of a completely new transvenous system on the contralateral side. In a registry-based study by Sood and colleagues,[6] it was shown that female sex, creatinine >2, and longer lead implant duration were independent major risk factors for perioperative complications during lead extraction. In addition, there are risks and complications inherent to a transvenous pacemaker ipsilateral to a hemodialysis fistula, such as central venous stenosis,[7,8] all of which lend credence to finding an alternative route for placement of a ventricular pacing system.

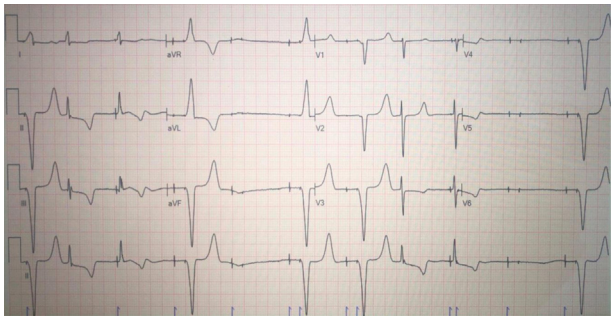

Figure 1 Presenting electrocardiogram demonstrating intermittent ventricular noncapture.

Since the emergence of the Micra and Micra AV leadless pacemaker systems, which have overcome the lead-related limitations of conventional transvenous PPMs, there has been an ongoing interest in being able to have completely leadless devices that function as a dual-chamber, and even tri-chamber, PPM. In a proof-of-concept study by Bereuter and colleagues[9] in 2018, they designed their own leadless pacemaker systems, which were implanted and tested in either ex vivo or in vivo porcine hearts. Separate leadless pacemakers were affixed to the epicardial surface of the right atrium and right ventricle and were shown to successfully communicate wirelessly using an energy-efficient method known as intrabody communication. In a secondary proof-of-concept study, Bereuter and colleagues[10] used the same previously designed leadless pacemakers to assess their utility in cardiac resynchronization therapy using a novel wireless communication method, known as optimized conductive intracardiac communication. In both studies, they demonstrated the ability and effectiveness of 2 or more leadless pacemakers communicating wirelessly and allowing AV synchrony.

In contrast to the wireless communication of 2 separate pacemakers, the Micra AV is unique in that it is the first single-chamber device to use an accelerometer-based algorithm to synchronize ventricular pacing to the sensed mechanical contraction of the right atrium. Each period detected in the manual atrial mechanical test corresponds to a particular part of the cardiac cycle. The accelerometer detects the mechanical vibrations of atrial contraction (period A4) as well as ventricular contraction and relaxation,[11]

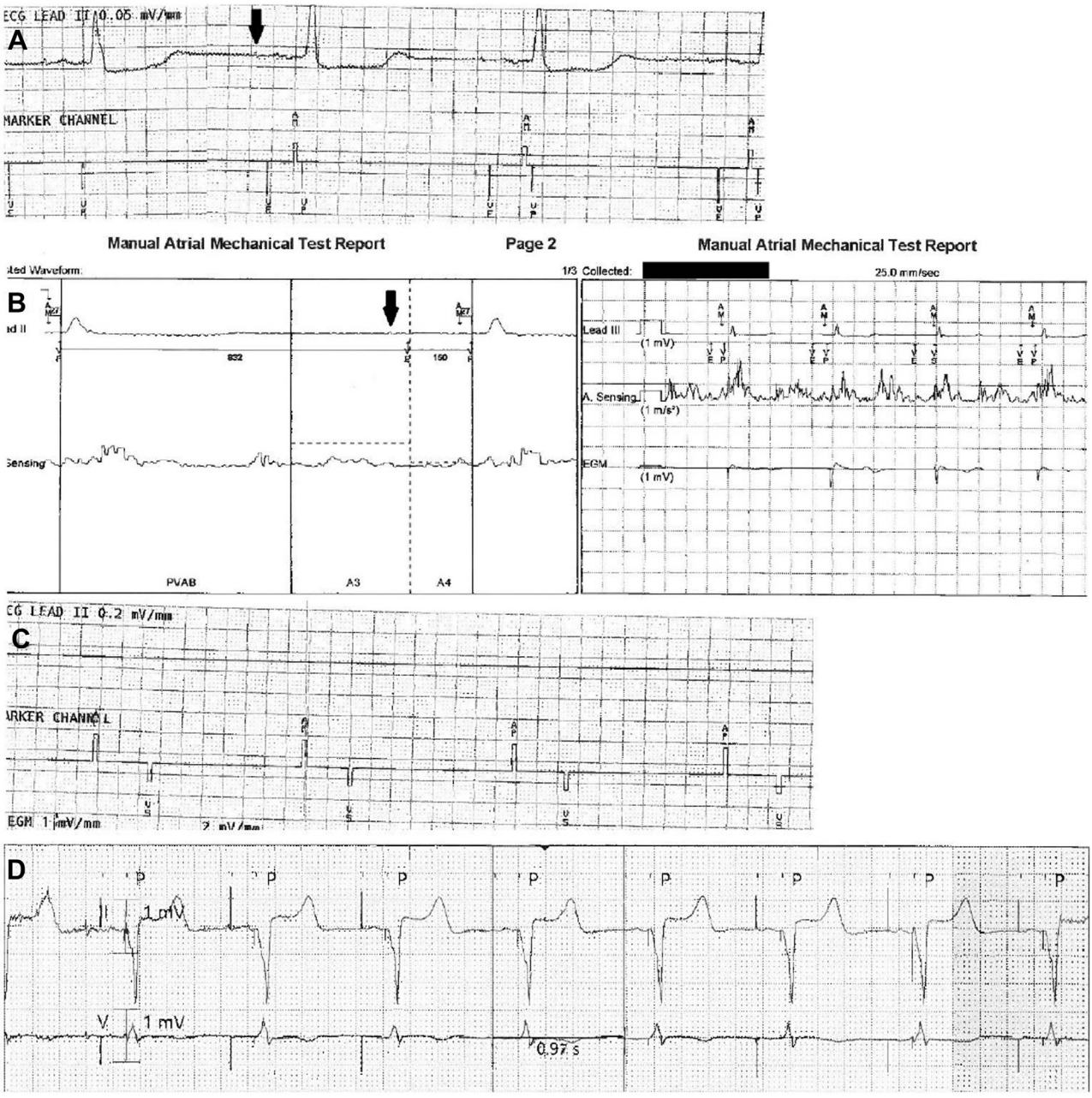

Figure 3 **A:** Intrinsic electrocardiogram with associated marker channel of the Micra AV (Medtronic, Inc, Minneapolis, MN). The marker channel appropriately senses the ventricular end (VE) period, the atrial mechanical (AM) period following the atrial pacing spike (*arrow*) and subsequent P wave, and finally the ventricular pacing (VP). **B:** Manual atrial mechanical test demonstrating that the Micra AV has appropriately sensed A3 and A4 periods to allow for atrial mechanical sensing after atrial pacing (*arrow*) from the transvenous pacemaker with resultant ventricular pacing. PVAB = postventricular atrial blanking. **C:** Marker channel from dual-chamber transvenous pacemaker showing atrial pacing with ventricular sensing of the Micra AV ventricular pacing. **D:** Telemetry strip demonstrating atrial pacing at 60 beats per minute with appropriate atrial sensing and ventricular pacing via the Micra AV.

annotated by the postventricular atrial blanking and A3 periods in Figure 3B. Interestingly in our patient, the pacing spike delivered from the transvenous atrial lead is seen on the Micra AV's intrinsic electrocardiogram (arrow in Figure 3A), followed by appropriate atrial capture and contraction, which is then correctly annotated by the ventricular end (VE) marker, corresponding to the end of A3 (ventricular diastole, timing of E wave on Doppler echocardiography) and the beginning of A4 (atrial systole, timing of A wave on Doppler echocardiography). Owing to the VDD pacing mode, it afforded continued AV synchrony despite a malfunctioning transvenous RV lead.

As we present a very unique situation, one must also think of the potential adverse interactions between 2 separate CIEDs that do not directly communicate with each other. For example, after the introduction of implantable cardioverter-defibrillators (ICD)

in the 1980s, owing to their limited ventricular pacing function, a separate PPM had to be implanted to deliver antibradycardia therapy.[12] As a result, many of these patients unfortunately received inappropriate defibrillator shocks owing to the ICD double-counting atrial and ventricular pacer stimuli.[12,13] In addition, it has been reported that a shock delivered from an ICD led to PPM malfunction in the form of ventricular failure to capture and sense.[13] Along the same lines, it can be proposed that 2 separate PPMs could adversely interact, inhibiting the other from pacing if not programmed appropriately. Therefore, caution and care must be taken when recommending the implantation of a second CIED.

Conclusion

We present the first reported case of a Micra AV implanted in a patient with a dual-chamber transvenous PPM programmed to AAI pacing only owing to a malfunctioning RV lead. Although it would be an extremely rare scenario, AV synchronization of the Micra AV with a transvenous atrial pacemaker is possible, safe, and effective.

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