

Symphony to Leadless Pacing-An Ode to Joy

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Ludwig van Beethoven's 9th Symphony is regarded by many musicologists as one of the finest works in the history of music. It is notable for several reasons, particularly being the first example of a composer using voices, with words sung by a chorus and vocal soloist in the final movement. These words were adapted from the poem "Ode to Joy", written by Friedrich Schiller, and to date symbolize the celebration of music, making all who hear it feel better about life.

Leadless pacing has also made a transformational effect on the lives of patients with bradyarrhythmias. Introduced to overcome the complications and adverse effects associated with conventional transvenous pacemakers, leadless pacing is observed to be safe, with a low risk of both short and long-term adverse events and high rates of successful implantation^{1, 2}. To further the role of leadless pacing, the MARVEL (Micra Atrial TRacking Using a Ventricular AccELerometer) ²³ prospective non-randomized multicenter clinical trial, tested the ability of an enhanced AV synchronous pacing algorithm utilizing the device's three axis accelerometer, to attain mechanical sensing of atrial contractility. The MICRA AV TPS (Medtronic, MN) was released in 2020 with a ventricular pacing and atrial tracking mode (VDD), and achieved mechanical atrial sensing resulting in AV-synchronous pacing of >70% at rest in 95% participants (38 of the 40 with complete heart block) within the trial. Significant benefits to AV synchrony include avoidance of pacemaker syndrome, improvement of quality of life and as seen in these patients, improvement in left ventricle stroke volume and function³⁻⁵.

The study observed that AV synchrony varied with physical activity and posture, with best results achieved at rest. Patient selection is crucial for optimal use of this algorithm as it is difficult to track atrial rates >105 bpm. At higher sinus rates, i.e. during exercise, the A3 and A4 signals fuse, along with encroachment of A4 on PVAB as the sinus rate increases further. Patient characteristics remain crucial and as seen in a subsidiary

analysis of the MARVEL 2, individuals with markers of diastolic dysfunction (higher E/A ratios) and /or atrial myopathy (atrial strain) were found to be at higher risk of reduced mechanical atrial sensing of A4⁶. Moreover, those with weak atrial contractions may not provide adequate A4 signals to the accelerometer. Therefore, performances of the algorithm in a real-world setting may not mirror those seen in the clinical trial arena. Further complicating the issue remains the ideal threshold for AV synchrony, which is assigned to >70% in research studies. In practice however, the AV synchrony cut-off required to achieve meaningful clinical benefit, avoid pacemaker syndrome and improve quality of life remains uncertain, though is certainly not 100%

Recognizing that optimal AV synchrony in routine clinical practice may be challenging, Kowgli et al. in this issue of the Journal of Cardiovascular Electrophysiology, describe their multicenter institutional experience of outpatient programming optimization of the AV-synchronous MICRA leadless pacing system⁷. They included 43 patients with MICRA AV following exclusion of those with persistent atrial fibrillation or reduced follow-up. They describe the frequency of AV synchrony (defined as the ratio of atrial mechanically sensed (AM)-ventricular pacing to total ventricular paced percentage) at device interrogation done at 3 months of follow up. They report an overall mean AV synchronous pacing (AsVP) of 62.9%. In 65% of the patients adequate AV synchrony with AsVP >70% was found. Those with inadequate AsVP (<70%) had a higher body mass index, higher prevalence of congestive heart failure and prior history of cardiac surgery. Authors note that a small A4-wave amplitude, high ventricular pacing burden, and inadequate device reprogramming (over-use of auto A4 threshold, or lack of initiation of VDD mode at initialization) were main considerations for suboptimal AV synchronous pacing.

Most importantly, their data confirms and is in line with recent reports,^{8, 9} that the success in achieving AV synchrony in a real-world setting may be lower than the MARVEL 2 clinical trial. The results also emphasize the importance of active programming changes which can significantly improve AV synchrony following an optimization post implantation. As identified in this report, MICRA AV optimization may require a learning curve, noted by an improvement in AsVP from 55% earlier, to 68% later in the study. Critical programming changes made by performing a manual atrial mechanical (MAM) test while disabling the features that automatically affect these, include adjusting the post ventricular atrial blanking (PVAB), A3/A4 windows and A3/A4 thresholds, and turning off the AV conduction mode (VVI+) in those with complete heart block and escape >40 bpm. The authors and others^{8, 9} have identified helpful examples of troubleshooting these interval timings and thresholds for optimizing AV synchrony, which an implanter must be familiar with in order to successfully manage patients with leadless AV synchronous devices. Critically, while performing a MAM test, a key prerequisite for successful interpretation of device tracings is the inclusion of an optimal ECG tracing. In cases where standard leads do not show a discernable P wave, the Lewis lead method can be helpful¹⁰. Several key steps towards successful optimization of AV synchrony are summarized in **Figure 1**.

Kowgli et al. evaluated AV synchrony at device interrogation 3 months post implant whereas MARVEL 2 limited the analysis duration to about 30 minutes immediately after pacemaker optimization. This is a somewhat artificial setting and would be expected to be different from observations made at 3 months and longer periods of follow-up. Real world settings are also associated with changes in heart rate, patient movement, atrial or ventricular arrhythmias, as well as changes in lifestyle and medications. Therefore, an optimization session both at post-op (prior to discharge) and in the clinic at follow-up, with prior Holter monitoring and exercise testing in younger patients, may help detect AV dysynchrony earlier and allow recognition and correction of atrial mechanical under or oversensing.

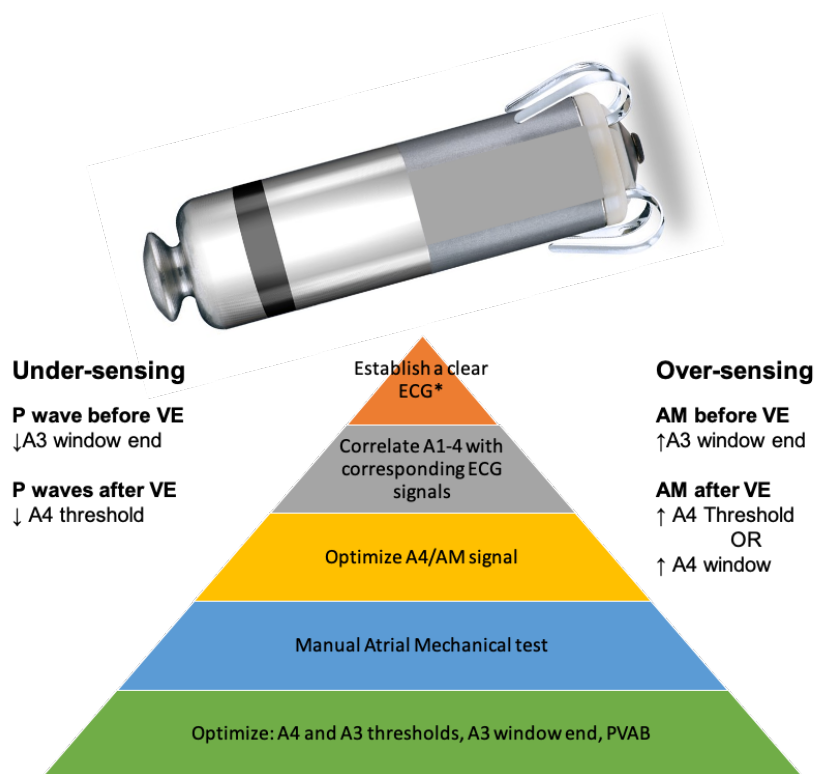
The current study acknowledges the complexity of leadless pacing and the need for optimization at follow-up to achieve higher levels of AV synchrony. It also reflects on patient selection being crucial to reap the full benefits of leadless technology. In patients with fast baseline sinus rates, in younger and physically active patients, or those who may have a greater reliance on AV synchrony at peak heart rates, this device may not be optimal. In addition, P wave amplitude, frequent atrial and ventricular arrhythmias, and sinus bradycardia will adversely affect the ability to achieve AV Synchrony. With appropriate patient selection,

monitoring and best practices of device programming, leadless pacemakers will undoubtedly achieve clinically relevant AV synchrony. The true marvel of leadless technology can be seen as an impressive reduction in complication rates and better patient satisfaction compared to current transvenous devices. Further improvements in design, technology and best practices will deliver symphony to pacing and afford those who use it an experience that is safe and reminiscent of normal cardiovascular physiology.

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Figure 1: Simplified approach to optimize MICRA-AV programming



*use of Lewis lead if needed to clearly see P waves