Lead-generator incompatibility with complete heart block—Double whammy: Device troubleshooting

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Introduction

Differences in the spring contact in device headers across different vendors and lead terminal ring connector surface finish may account for sporadic impedance spikes. High impedance alert may result in polarity switch to unipolar sensing/pacing in hybrid systems (Boston Scientific generator and Medtronic or Abbott leads), which may result in myopotential oversensing and inappropriate inhibition of ventricular pacing. Herein we describe a unique case of lead-generator incompatibility in a patient with complete heart block.

Case report

A 91-year-old man with coronary artery disease, hyperlipidemia, stroke, and severe aortic stenosis underwent dual-chamber pacemaker implantation for complete heart block complicating transcutaneous aortic valve replacement. Medtronic CapSureFix Novus 4076 leads were implanted in the right atrium (RA) and right ventricle (RV) and connected to a Medtronic pacemaker generator. Twenty-four months after implant, routine device surveillance demonstrated 100% RV pacing with stable device impedance, sensing, and pacing parameters. In view of 100% RV pacing and pacing-induced cardiomyopathy (new left ventricular systolic function 30%–35% and global hypokinesis), the patient underwent a pacemaker upgrade to a biventricular system. A Boston Scientific Acuity X4 spiral short lead was positioned in the posterolateral branch of the coronary sinus, and all 3 leads were connected to the Boston Scientific Valitude X4 U128 (Marlborough, MA) pacemaker generator.

The patient declined to enroll in remote monitoring with regular normal in-office device interrogation until the most recent routine device interrogation (23 months post device upgrade) that demonstrated a transiently high impedance of greater than 2000 Ω (in both RA and RV leads) with automatic safety switch to unipolar sensing and pacing (Figures 1 and 2). The patient also denied any associated symptoms. What is the mechanism of transient high impedance and safety switch to unipolar sensing and pacing?

Discussion

The device electrogram in Figure 2 demonstrates biventricular pacemaker with atrial sensing (sinus) and RV/left ventricle pacing, except for high-frequency nonphysiologic noise on both RA and RV channel. Though the initial impression is concerning for potential lead fracture or electromagnetic interference, in-office device evaluation demonstrated normal lead parameters, including bipolar impedance (Figure 1), and denies any associated exposure accounting for electromagnetic interference at the time of event. We illustrate a case of erratic high impedance alerts with a hybrid pacemaker (ie, leads connected to the pulse generator from a different manufacturer). Interestingly, besides the sporadic high impedance alert, the following other observations were not recorded:

KEY TEACHING POINTS

- Differences in the spring contact in device headers across different vendors and lead terminal ring connector surface finish may account for sporadic impedance spikes (often seen with hybrid pacemaker systems).
- High impedance alert may result in polarity switch to unipolar sensing/pacing in hybrid systems (Boston Scientific generator and Medtronic or Abbott leads), which may result in myopotential oversensing and inappropriate inhibition of ventricular pacing.
- All pacemaker-dependent patients with hybrid Boston Scientific–Medtronic or Boston Scientific–Abbott systems be programmed to bipolar sensing/unipolar pacing.

KEYWORDS

Complete heart block; Fretting; Impedance alert; Lead-generator incompatibility; Lead noise

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seen: (1) no significant changes in voltage impedance, sensing, and pacing threshold; (2) nonreproducible lead noise with isometric exercise; (3) no loose set screw or lead structural integrity issues (fracture or insulation breach) identified via fluoroscopy.

The differential diagnosis for sporadic high impedance includes lead fracture or electromagnetic interference or lead-header connector problem. Extremely sudden high impedance (>10,000 Ω) or noise oversensing with normal device impedance trend is suggestive of lead fracture (although rare to happen in both leads simultaneously). Electromagnetic interference (considering simultaneous nonphysiologic high-frequency noise was evident on both RA and RV lead) is possible; however, impedance trends in such a scenario remain within normal limits. Also, patient history at the time of the event on the device interrogation is the key (which was negative in our scenario). The sudden onset of high impedance or noise oversensing (fresh after implant) with the return to baseline is indicative of a lead-connector problem; none of that was noted in our scenario.

Figure 1  A: In-office device interrogation demonstrating baseline device settings. B: Impedance trends since implant with intermittent impedance spikes in right atrium (RA) lead (September 2019) and right ventricle (RV) lead (December 2019). LV = left ventricle.
Leads from different manufacturers have subtle differences in the lead finish design along with the terminal ring connector and micro-rotational movements within the device header. Repeated motion/slipping of the terminal ring connector (axial or radial, especially with non–Boston Scientific leads) creates microscopic particles, which oxidize over time, resulting in intermittent electrical connectivity between the terminal ring connector and spring contact in the device header (also known as fretting). Furthermore, differences in the spring contact design within the pulse generator across different device vendors may cause different degrees of contact force and redundancy. While multibeam contact design is used in Medtronic (resulting in 10 contact points), Boston Scientific and Abbott use canted spring contact design (with 70 contact points). These factors may result in an intermittent increase in impedance, leading to oversensing of the minute ventilation sensor signal (not evident in our case) and/or changes in daily impedance measurements (and safety switch, as noted in our case). As such, Boston Scientific issued an advisory in December 2017, suggesting empiric turning off of the minute ventilation sensor (especially in pacemaker-dependent patients) and a subsequent software upgrade (both of which were performed in our scenario before the occurrence of this event).

The question that arises is why Boston Scientific’s pulse generator is more susceptible to lead-connector and high impedance issues than other vendors. When a device attempts to measure thoracic impedance and pacing impedance (performed every 21 hours, programmable feature [on/off]), subthreshold levels of voltage and current are used and hence prone to be influenced by microparticles and oxides, resulting in high impedance. However, this is not the case when actual pacing is performed, as the latter is typically performed at a

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**Figure 2** Polarity switch to unipolar sensing/pacing, demonstrating noise (myopotential oversensing in right atrium [RA] and right ventricle [RV] lead, resulting in inappropriate mode switch in RA lead and inadequate pacing inhibition in RV lead). AN = atrial noise; ATR ↑ = atrial tachycardia sense – count up; ATR ↓ = atrial tachycardia sense – count down; ATR-FB = atrial fallback started (mode switch); RVP-FB = right ventricular pacing during fallback (mode switch).
higher voltage and current (and is unlikely to be affected by accumulated microparticles and oxides). This explains why lead parameters remained stable during in-office device interrogation in our case. Medtronic pulse generators, on the other hand, owing to their multibeam spring contact design (as compared to canted spring contact design in Boston Scientific/Abbott devices), reduce redundancy with fewer contact points (which means greater force per contact) in the device header. Additionally, they use a pulse of 5 V (in contrast to 0.04 V in Boston Scientific devices) to test pacing impedance.

Owing to sporadic high impedance (as a result of fretting) in our case, there was automatic polarity switch from bipolar sensing/pacing to unipolar sensing and pacing (resulting in pectoral myopotential oversensing with inappropriate mode switch in the RA channel and intermittent pacing inhibition in the RV channel). Based on case series in the literature, safety switch owing to transient high impedances occurs in

![Figure 3](image_url) Device reprogrammed to bipolar sensing/unipolar pacing configuration, thereby eliminating the terminal ring connector from circuitry (with no more noise on right atrium and right ventricle channel).
9% of Boston Scientific pacemakers connected to Medtronic leads, but affects only 1 lead per patient.\(^2,3\) Our case is unique, as this was exhibited in both RA and RV leads (a finding that is rare, occurred regardless of the software update, and has never been described before). We subsequently reprogrammed his device to a bipolar sensing/unipolar pacing configuration, thereby eliminating the ring electrode from the pacing circuit and preventing the safety switch (Figure 3; no more noise on RA and RV channel). The patient was subsequently enrolled in remote monitoring, with no further evidence of intermittent high impedance alert.

Although turning off thoracic impedance and pacing impedance check is a potential solution (thus inhibiting automatic polarity switch), this was not performed in our case, as it would limit the ability to assess the lead impedance trends and lead diagnostics if any problems were to happen to the leads in future (ie, lead fracture or insulation breech). Another potential solution could be turning off the automatic polarity switch (a programmable feature, again not performed in our case). Although rare, there is a possibility of loss of capture (with bipolar pacing configuration) at the time of high impedance alert, which can be life threatening, especially in a pacemaker-dependent patient (like ours). Therefore, both these features were not turned off, and the device was subsequently reprogrammed to bipolar sensing/unipolar pacing (Figure 3). It is worthwhile to highlight that the only way the device could revert back to unipolar sensing/pacing (from current configuration; ie, bipolar sensing/unipolar pacing) is in Safety Core Mode (unprogrammable mode). Safety Core Mode is intended to provide life-sustaining therapy if certain nonrecoverable or repeat fault conditions occur and cause a system reset (thus requiring early replacement).

Table 1 lists the affected Boston Scientific pacemaker models. In the fall of 2019, Boston Scientific implemented an enhanced IS-1 spring contact design to mitigate this behavior on all pacemakers, cardiac resynchronization therapy–pacemaker/defibrillators, and implantable cardioverter-defibrillators. This new design is more resistant to fretting and has approximately 4.5 times greater force per contact point than the original design.

### Conclusion

Differences in the spring contact in device headers across different vendors and lead terminal ring connector surface finish may account for sporadic impedance spikes (often seen with hybrid pacemaker systems). Considering the high possibility of the device switching to unipolar sensing/pacing in hybrid systems (Boston Scientific generator with Medtronic or Abbott leads), which may result in myopotential oversensing and inappropriate inhibition of ventricular pacing, we suggest that all pacemaker-dependent patients with hybrid systems (ie, Boston Scientific–Medtronic or Boston Scientific–Abbott systems) be programmed to bipolar sensing/unipolar pacing. Furthermore, we also dissuade electrophysiologists on the implantation of hybrid systems, given the possibility of low-level incompatibility in the individual components. Appropriate identification of lead-connector interface problems and differential diagnosis of sporadic lead impedance is crucial to avoid unwarranted lead extraction and or system revision.

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