

# A case series of anomalous high pacing lead impedances in normally functioning leads



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## Introduction

Pacemakers and implantable cardioverter-defibrillator (ICD) cardiac leads are used for delivery of short direct current electrical pulses. Low-energy pulses in pacemakers provoke myocardial stimulation while high-energy pulses in ICDs are delivered for lethal arrhythmia termination.

Pacing impedance measurements offer insight into implanted pacemaker system status; a decrease in impedance values may indicate a short circuit or insulation breach,<sup>1–4</sup> while an increase may indicate a pacing lead fracture.<sup>1,3–5</sup>

Remote interrogation systems that capture automatic device diagnostic data, stored episode electrograms, and the presenting rhythm provide the clinician with information similar to that available at an office visit, allowing assessment of the appropriateness of device therapies and operation.

We report a series of 3 cases of transient high lead impedance (>2500 ohms) on remote checks with no other associated lead abnormalities, and no clinical events or abnormality seen on chest radiograph or office checks. These cases shared a common type of device manufacturer with a different type of lead manufacturer. Although ventricular pacing impedance was sporadically highly abnormal, device function was not impaired, and system revision was not necessary.

## Case reports

The index case at our center was a 45-year-old man with an idiopathic cardiomyopathy, who had a St Jude Medical (SJM) Fortify VR single-chamber defibrillator implanted in March 2011, with a Medtronic 6947 ventricular lead. He

**KEYWORDS** Implantable cardioverter-defibrillator; Defibrillator lead; Lead fracture; Lead abnormality; Lead impedance; Pacing impedance; Remote monitoring; Remote interrogation

**ABBREVIATIONS** ICD = implantable cardioverter-defibrillator; SJM = St Jude Medical (Heart Rhythm Case Reports 2015;1:449–452)

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received a vibratory alert from his defibrillator about 5 weeks after implantation. Interrogation showed a single value of pacing impedance greater than 3000 ohms. The device was interrogated, and impedance was normal, as were all other functions of the device. A chest radiograph was obtained and appeared normal. Lead pins were fully seated in the header. No noise had been recorded on the ventricular lead. SJM technical services felt it was a sporadic event. Over the next 3 months, however, sporadic high pacing impedances continued to occur. Values between 2000 and 3000 ohms were seen periodically. High-voltage impedances were always normal. Interrogation in the office showed ventricular pacing impedance values ranging from about 500 ohms to 600 ohms. This finding continued to happen over the next 7 months. The abnormality was isolated to high pacing impedance values (2000–>3000 ohms) recorded through remote monitoring, but never at the time of in-office interrogation, and never high-voltage impedance abnormalities, pacing or sensing abnormalities, or noise on the lead (Figure 1A). We felt that the clinical picture did not suggest a true lead abnormality, but rather an abnormality within the generator. All downloads from the device were sent to SJM technical services. Eventually, technical services hypothesized that there could be a buildup of oxidation owing to the dissimilarity of metals between the Medtronic lead stainless steel pin and the titanium set screw of the SJM header block, causing sporadic high pacing impedances. This would explain why the same abnormality was not seen with SJM defibrillation leads, which have pins made of MP35N. The buildup of oxidation was hypothesized to occur in the absence of any pacing, which would dissipate it.

The second case noted was a 72-year-old man, implanted in April 2012 for primary prevention in the setting of cardiomyopathy due to prior infarcts, with an SJM Fortify DR dual-chamber defibrillator and a Medtronic model 6947 lead. Initially, he was programmed in a DDIR mode at 60 beats per minute, for sinus node dysfunction. Subsequently, he began to have symptomatic episodes of repetitive non-reentrant ventricular-atrial synchrony. When attempts to program around this were unsuccessful, he was reprogrammed to an AAIR pacing mode 2 months after implant.

## KEY TEACHING POINTS

- Sporadic, high pacing impedance values (> 2500 ohms), not associated with any other lead abnormalities, can be observed upon automatic testing, with the combination of the currently available Medtronic implantable cardioverter-defibrillator leads and St Jude Medical implanted defibrillators.
- Careful assessment of all aspects of implanted defibrillator lead performance, and the time course and nature of abnormalities, is advised to identify anomalous or spurious abnormalities.
- Lead extraction and system revision, with the attendant risks of these procedures, should be avoided in cases like these in which there is no clinically significant abnormality of lead function or connection.

About 3 months later, an alert occurred for a single high pacing impedance value of 2725 ohms (Figure 1B). Subsequently, he was programmed back to DDI pacing, and high pacing impedance values were not seen, consistent with the hypothesis that the buildup of oxidation between the lead pin and the header block occurred in the absence of any ventricular pacing.

The third patient had an SJM Fortify VR implanted in August 2011. His ventricular lead was a Medtronic model 6935 lead. Twenty-seven months after implant (November 2013), he had an alert for a pacing impedance greater than 2000 ohms (Figure 1C). He was programmed VVI 40 with AutoCapture off at that time, with a 0% pacing burden. No abnormalities of the lead were found. This patient recently had a defibrillator generator replacement in December 2014. At the time of replacement, the lead was confirmed to be fully seated in the header and the set screws were tight. (The generator replacement was for early sudden battery depletion, which was not felt to be connected to the issue of sporadic high impedances. Testing of the explanted generator is currently pending).

## Discussion

There are 3 desirable properties for conductors in ICD leads: resistance to fatigue with repetitive stress, resistance to corrosion, and low electrical resistivity. Manufacturers attend to the compatibility of their own leads and generators but not to the compatibility of mixed systems with other manufacturers' products. Concern about late penetration<sup>6</sup> and insulation abrasion<sup>7</sup> of the SJM leads has led some operators (including the operator who performed these implants) to use leads from other manufacturers with SJM generators. This results in a contact interface between lead conductors and set screws that may be of different materials not tested for compatibility—in this series of cases, the

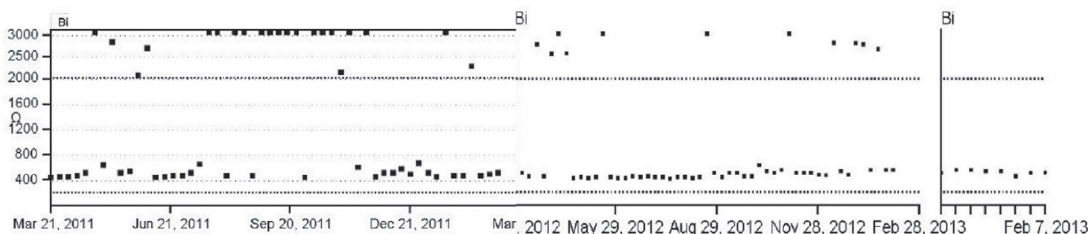
titanium of the set screw in SJM generators and the 316L stainless steel of the Medtronic lead tip conductors. In contrast, recent SJM lead pins (Riata and Durata) are made of MP35N, a multiphase alloy comprising nickel, cobalt, chromium, and molybdenum that has corrosion (oxidation) resistance superior to that of stainless steel.

In the current generation of SJM defibrillator generators (Unify, Fortify, Assura), the electrical contact to the tip lead connector pin is made via the titanium set screw alone. The set screw threads then make the electrical contact through this connector block to complete the remainder of the circuit back through device feed-through wires into the device can (internal communication – SJM engineers). It is hypothesized that a small degree of oxidation may occur at this interface between the titanium lead set screw and the 316L stainless steel lead pin in the absence of any pacing to dissipate it (internal communication – SJM engineers). The current generation of SJM defibrillators (Unify, Fortify, Assura) perform daily lead impedance monitoring using a train of subthreshold, 200  $\mu$ A current pulses. In certain circumstances, it may be that a layer of oxidation may create sufficient electrical resistance to this very small current to register a high pacing impedance. A single pacing stimulus of typical amplitude may be sufficient to dissipate the oxidation, and thus abnormalities are not seen when ventricular pacing has been occurring. The required elements for the occurrence of this sporadic high pacing impedance phenomenon, then, might be the combination of a titanium set screw and a 316L stainless steel lead pin, along with the absence of pacing.

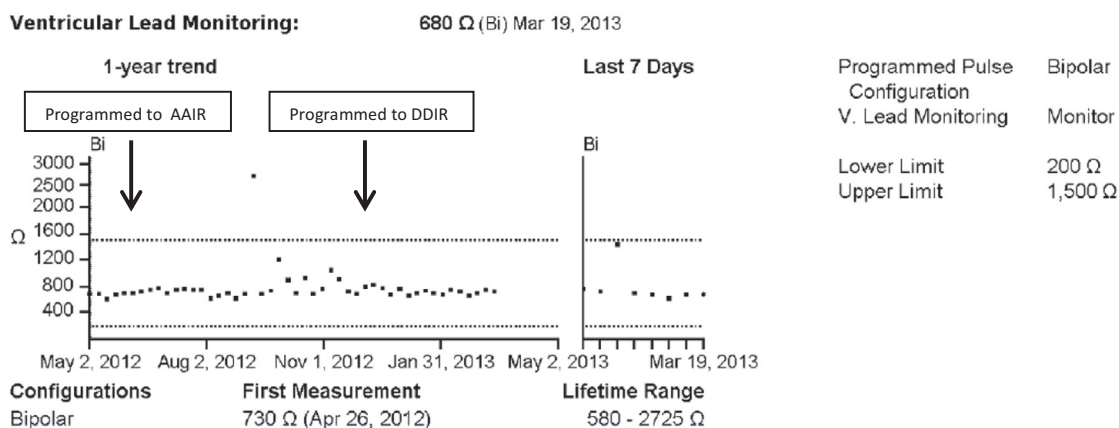
Clinically, the differential diagnosis of sudden high impedance readings includes lead fracture and connection problems. The early onset of high impedance readings within 5 weeks of implant in the index patient along with the normal chest radiograph and the absence of other lead abnormalities or noise on the lead suggested to us that this was not a lead fracture and probably not a set screw problem, although it could not be completely excluded. Thus, we requested an analysis of the situation from SJM. The hypothesis of charge buildup owing to dissimilar metals seemed to fit the situation, so we chose a course of observation. This has turned out to be the correct strategy, with so far just over 7 patient-years of observation with no other lead abnormalities in these patients other than the sporadic high impedances on remote monitoring.

Swerdlow et al<sup>8</sup> proposed an algorithm for differentiating lead fracture from connection problems; they stated that either extremely high maximum impedance or noise oversensing with a normal impedance trend indicated a fracture. A short interval from surgery to impedance rise, or prolonged stable impedance after an abrupt rise, indicated a connection problem. A gradual impedance increase or stable, high impedance indicated a functioning lead. The application of this algorithm to our patients gives a prediction that agrees fairly well with our hypothesis. The branch point of high impedances within 200 days of implant does not give accurate predictions in our patients. The connection

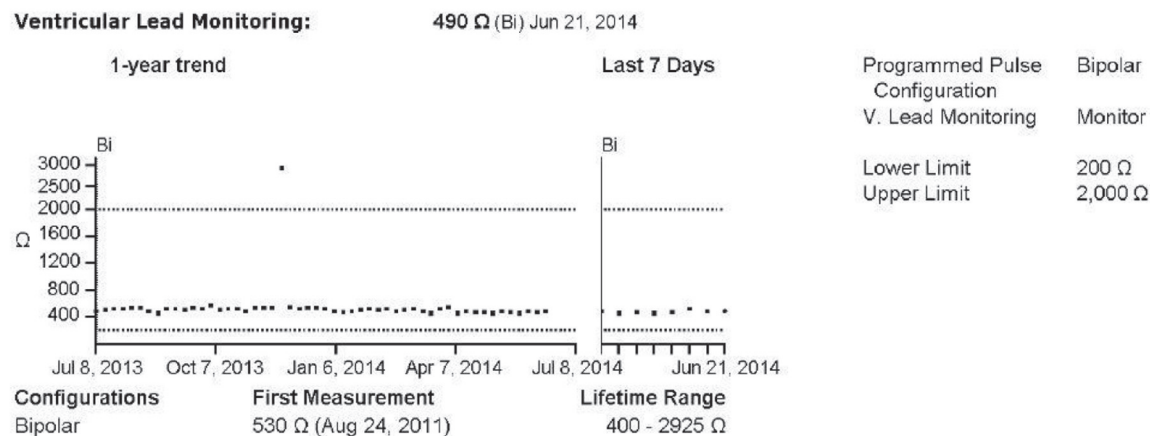
A



B



C



**Figure 1** Impedance trends from St Jude Medical Merlin remote monitoring for the 3 patients show variation in the pattern of sporadic high impedances. **A:** Composite impedance trend over the first 2 years for patient 1. Multiple high impedances are seen. **B:** A single high impedance value was seen in patient 2, a few months after he had been programmed to a mode that avoided ventricular pacing. A few moderately high impedances were also seen in this patient. **C:** Patient 3 had a single high impedance value occurring 27 months after implant.

problems in the group of patients on whom the algorithm is based occurred at the time of implantation, whereas in our patients the hypothetical charge buildup seems to have

occurred sporadically, with very different patterns among the 3 patients. The time to first impedance rise ranged from 5 weeks to 27 months. Even occasional pacing is felt to

dissipate the charge buildup. Changes in medications, sleep habits, or programming (such as the patient changed from DDIR to AAIR and back again) could mean the difference between rare pacing and no pacing at all. Thus, a long latency from implant to first impedance rise would not be expected to be a good discriminator in this situation.

## Conclusion

To our knowledge, this is the first report of a syndrome of benign, intermittent, high pacing impedance values (>2500 ohms), occurring upon automatic testing, not associated with any other lead abnormalities. The hypothesis—that this is due to the formation of a layer of oxidation at the junction of dissimilar metals of the lead pin and set screw, creating high resistance to microampere test pulses, in the absence of functional pacing—seems to fit the clinical picture of the patients presented.

The clinical importance of this observation is that lead extraction and system revision, with the attendant risks of these procedures, should be avoided in cases like these in

which there is no clinically significant abnormality of lead function or connection.

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