**Leads and longevity: how long will your pacemaker last?**

Richard K. Shepard* and Kenneth A. Ellenbogen

Cardiac Electrophysiology Laboratory, Division of Cardiology, Department of Medicine, Medical College of Virginia Hospital, Virginia Commonwealth University, PO Box 980053, Richmond, VA 23298, USA

Received 25 November 2008; accepted after revision 25 November 2008; online publish-ahead-of-print 24 December 2008

This editorial refers to 'Long-term results of high vs. normal impedance ventricular leads on actual (Real-Life) pacemaker generator longevity' by K. Etsadashvili et al., on page 200

Prolonging pacemaker system longevity and time between pulse generator changes remains an important goal of device therapy for several reasons. There is a small but finite risk of infection and other complications each time a generator change is performed. If patients have one less generator change during their lifetime, the relative risk of complications is reduced. A 10% increase in generator longevity will result in large savings for healthcare costs each year. Therefore, interest in maximizing pacemaker longevity continues.

Modern pacemakers use current not only for pacing but also for other functions such as obtaining measurements of diagnostic data, measurements made by rate response sensors, and implementation of algorithms, such as for mode switching. Pacemaker battery life therefore depends on a variety of variables, including baseline battery self-discharge, current drain for device housekeeping functions, current used to pace the heart, and current to sense the underlying heart rhythm. An average pacemaker battery has about 0.5–2Ah of battery life.

Factors controlling current drain with a pacing stimulus include pacing rate, per cent pacing, programmed voltage, pulse width (PW), and lead impedance. Energy use is proportional to PW and to the square of the voltage. By Ohm's law, \( I = \frac{V}{R} \), where \( R \) is the impedance, current is inversely proportional to impedance. For a given voltage (V) and PW, current will be less for a high-impedance lead. For an electrical circuit, a voltage drop occurs and energy is dissipated across a load or impedance. The area of high impedance in a lead should therefore be at the lead tissue interface and not in the lead body itself where energy is wasted. Cardiac tissue capture depends on local current density (current/cm²) so a small lead can capture with less current.

High-impedance leads are designed with a very small diameter electrode to maximize this current density. The electrode is also made porous with a large surface area to volume ratio to minimize repolarization currents (Hemholtz current) and to maximize lead tissue interface. If \( V \) and \( PW \) are constant, then a lead with twice the impedance will only use half as much current. The high impedance electrode is only effective if it has the same or lower pacing threshold than a ‘standard’ pacing lead.1

Other factors may be even more important than maximizing lead impedance. These include minimizing the pacing voltage with design features such as autocapture,2 which perform better using leads with low repolarization. Repolarization is post-pacing capacitive discharge caused by tissue ion and cation movement in response to a voltage gradient. A high repolarization lead can interfere with detection by autocapture algorithms.

Even pacing with a low voltage does not save as much energy as not pacing at all. Algorithms that minimize ventricular pacing such as MVPTm (Medtronic, Minneapolis, MN, USA) not only help preserve left ventricular function,3 but also save battery life. A 95% reduction in pacing will save much more energy than doubling lead impedance.

Several studies have reported predicted pacemaker battery life extension with high-impedance leads.4–6 The studies have consistently shown a reduction in current drain in the first year and an estimated increase in battery longevity. However, no study has yet followed patients to generator replacement to see if actual time to generator replacement in long-term follow-up is prolonged with high-impedance leads.

Etsadashvili et al.7 report on long-term follow-up of two groups of patients, one with normal impedance leads and other with high-impedance leads. They first reported on these patients in 2003.6 Forty patients with sick sinus syndrome (34 patients) or AV block (6 patients) were entered into the study. All patients received a Medtronic KappaTm KDR 401 pacemaker and an identical active fixation atrial lead (Medtronic model 5068). Twenty patients were randomly assigned each to...
either a standard impedance (model 1452T, St Jude Medical) or a high-impedance ventricular lead (Capture Z, model 5034, Medtronic Inc.).

All patients were programmed with a three-fold safety stimulation margin. Over the course of the study, both groups of patients had more than 95% ventricular pacing. All patients who remained in the protocol were followed regularly with interrogation of pacing parameters, estimated time to replacement, and current drain measured at each follow-up. Only 16 of the original 40 patients remained in the protocol for final evaluation. Removal from the protocol occurred for reasons such as rise in pacing thresholds, death, and patients moving.

At every visit, the patients with high-impedance leads showed significantly higher lead impedance and significantly less ventricular lead current drain. However, the overall battery current drain was only marginally different in the two groups at all follow-ups except for 39 months. The battery current averaged about 20 μA. The pacing current during each stimulus was about 50% less with the high impedance versus the standard leads: about 2 μA for high-impedance leads and about 4 μA for normal impedance leads.

For the first 6 years, there was a significant increase in pacemaker estimated longevity in the high-impedance group; however, this did not lead to longer device longevity with only a trend for longer generator life in the high-impedance group (91.2 ± 10.3 vs. 86.7 ± 6.8 months, \( P = \text{n.s.} \)). The results may be skewed by the small number of patients and high dropout rate. Statistical significance may have been reached with a larger study.

From this study, two things seem clear. Patients with high impedance leads have consistently less current drain from pacing by almost a factor of two. However, this was a minority of the device’s overall current drain. More energy was drained from the pulse generator in this study from ‘running’ or performing housekeeping functions by the pacemaker itself. Even so there was a trend for increased longevity with high-impedance leads.

According to the manufacturer, the Kappa\(^\text{TM} \) 400 device used for this study has a reported static current drain of 17.6 μA. Medtronic’s current dual chamber pacemaker, the Adapta\(^\text{TM} \), has a static current drain of 12.4 μA. It is possible that high-impedance leads would have made more of an impact on longevity in a device with a lower static current drain since a larger percentage of battery drain would be from pacing.

High-impedance leads may play an important role in prolonging battery life in certain patients. Patients with a high percentage of paced beats and with a high pacing threshold will have more of the battery drain relative to pacing and high-impedance leads may play more of a role in prolonging battery life. This may also be more important in younger patients who require many generator changes during their life and possibly older patients who may be able to avoid a generator change altogether by getting a little longer battery life.

Equally or more important for generator life is minimizing pacing and minimizing pacing output with autocapture algorithms, and good lead implant technique to minimize thresholds. This study shows that much battery drain is not related to pacing at all, but from static current drain and housekeeping functions. This paper also importantly illustrates how theoretically predicted generator longevity may be different from the actual longevity. High-impedance leads over many years consistently reduce current drain and remain a potentially useful tool for prolonging battery longevity.

Conflict of interest: K.E. is a recipient of research grants from Boston Scientific, Medtronic and St Jude Medical. He has received honoraria from and is a consultant for Medtronic, Boston Scientific, St Jude Medical, Biotronik and Sorin Biomedical. R.K.S. declares no conflict of interest.

References