Battery longevity should be the primary reason for device selection at implant

Antagonist
Ian Wright
Imperial Healthcare NHS Trust
First Implanted Pacemaker
Elmqvist/Senning, Sweden, 1958

Fixed rate NiCad battery
• Dual chamber pacing late 1970s
• Rate responsive pacing mid-1980s
• Electrogram storage 1990s
• Histograms, trend data
• Thoracic impedance monitoring
• Remote monitoring
• .....
Fig. 2.7. Schematic of the first implanted pacemaker [13]
Fig. 2.9. Schematic of the pulse generator of the first demand pacemaker [15]
Fig. 2.10. Schematic of the dual-chamber demand pacemaker [16]
Fig. 2.12. Block diagram of a typical modern pulse generator [4]
Probability of long-term mortality by percent of right ventricular pacing in patients without LBBB in the MADIT II trial with extended follow up.
Implant-based multiparameter telemonitoring of patients with heart failure (IN-TIME): a randomised controlled trial. Lancet 2014

All cause mortality
Sensors for monitoring heart failure.

- **Hemodynamic parameters**
  - Right ventricle:
    - Pressure (Chronicle IHM™)
    - dP/dt max (ePDA)
  - Pulmonary artery:
    - Pressure (Champion™)
  - Left atrium:
    - Pressure (HeartPOD™)
  - Cardiac contractility:
    - Cardiac output: Doppler
    - Heart sound (Peak endocardial acceleration)

- **Biochemical parameters**
  - Oxygen saturation:
    - MV O₂
  - Chemical:
    - PO₂, PCO₂, pH
    - Electrolytes, glucose
    - Cytokines, hormones

- **Electrical and other parameters**
  - Arrhythmias:
    - AF, VT
  - Heart rate derivative:
    - Mean and nocturnal heart rate
    - HRV
  - Pacing parameters:
    - % BVP
    - Paced QRS
    - ST segment
  - Accelerometers:
    - Physical activity level
  - Impedance:
    - Intra-thoracic vector: RV-Can
      (OptiVol™); LV-Can -- Intra-cardiac vector: LV-RV; LV-RA

Lau et al. (Circ 2014) illustrated a medical device setup. The diagram shows a wireless neurostimulator connected to a subcutaneous defibrillation lead and a leadless pacemaker. A wireless PA pressure sensor is also present, along with a drug infusion pump and a master device with ICD can.
• **What is a pacemaker for?**
  – Prevent symptoms and in some cases death from bradycardia
  – Provide diagnostic information to aid detection and treatment of arrhythmias (AF)
  – Provide diagnostic information to aid detection and treatment of heart failure

• **What is an ICD for?**
  – Prevention of sudden cardiac death
  – Treatment for symptomatic ventricular tachycardia
  – Prevent symptoms and in some cases death from bradycardia
  – Provide diagnostic information to aid detection and treatment of arrhythmias (AF)
  – Provide diagnostic information to aid detection and treatment of heart failure

• **What is CRT for?**
  – Prevent symptoms and death from heart failure
  – Prevention of sudden cardiac death
  – Treatment for symptomatic ventricular tachycardia
  – Prevent symptoms and in some cases death from bradycardia
  – Provide diagnostic information to aid detection and treatment of arrhythmias (AF)
  – Provide diagnostic information to aid detection and treatment of heart failure
ENDURALIFE powered CRT-D devices for treating heart failure

Medical technologies guidance
Published: 17 March 2017
nice.org.uk/guidance/mtg33
• Extended battery life is of clinical and patient benefit and associated with fewer replacement procedures
• The average reported device infection rates
  – 1.6% for prospective studies
  – 1.0% for case-control studies and
  – 1.2% for retrospective cohort studies

Polyzos et al. (2015)

• Mortality
  – 0.4% (95% CI 0.1% to 1.1%).

• The rate of reoperation/pocket revision
  – 2.7% (95% CI 0.8% to 5.1%).

Zeitler et al. (2015)
ICD risks likely reducing

• Low rate of sub-pectoral generator placement
• No DFT testing
• Battery longevity in isolation provides limited patient benefits

• Features that promote effective delivery of treatment by their nature can consume battery

• Focussing on battery longevity above all other considerations will stifle innovation

• The discussion should be broader than the battery alone
With my first pacer at 19 years old I used to worry about battery life – why can’t they make one that lasts forever?

Now I am an engineer and understand a few things
• My first pacemaker was huge compared to my current one

• More importantly I like having a newer, better, smaller pacer every 7-10 years

• What if the next TV you buy is the last you will ever own, or your computer – no upgrades... or you mobile, or your car

• Over time there are no more over-the-air TV signals for that TV, or wifi becomes obsolete, unlinking that old PC of yours from the world
• Pacemaker programmers for your model die off and become few and far between

• The software and engineers that designed and were familiar with your pacemaker are no longer with the company

• and the tribal knowledge about how to interrogate your device is lost and the next programmer doesn’t properly include your pacemaker – nobody can afford to maintain interrogation equipment if the devices last 20 or 30 years
• If your hospital changes to use a single company do you want to be the only patient with a different brand?

• You want the world to have more than a monopoly but less than a handful otherwise costs go up
• If they introduced a 30 year pacemaker today, I would beg my doctor for the 7-10 year model for the next 3 or 4 I plan to need for the rest of my life