A batteryless cardiac pacemaker powered by cardiac motion

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Introduction: The battery is one of the most limiting factors of modern pacemaker designs. Battery replacements require repeated surgical interventions with associated morbidities and costs. Alternative power sources not relying on stored energy become essential to improve a patient's quality of life.

Harvesting cardiac energy might provide a continuous autonomous energy source for modern pacemakers. A device, which is able to convert cardiac motion into electrical energy, would allow powering pacemakers without the use of primary batteries.

Motion induced energy generators are found in automatic wristwatches: the movement of a person's wrist accelerates an eccentric mass in the clock housing. An integrated generator converts the rotation into electrical energy. The gained energy therefore directly depends on the externally applied motion.

Methods: A harvesting device was derived from the clockwork of an automatic wristwatch (ETA 204, ETA SA, Grenchen, Switzerland). The clockwork was freed from all time indicating parts. Its custom-made housing (total mass 16.7g, figure 1) allowed it to be anchored on the heart. For an in-vivo study with a 60 kg domestic pic, a sternotomy was performed to suture the prototype onto the anteroapical part of the left ventricle. Subsequently, the harvesting device was connected to a custom-built single-chamber pacemaker. A 47 µF capacitor was integrated to overcome the energy shortage between consecutive generator signals. Finally, an epicardial bipolar pacing wire (TME 66T, Osypka, Germany) was used to deliver the pacemaker stimulus.

Results: The heart successfully accelerated the energy harvesting device. It supplied the pacemaker with enough energy to performed continuous VVI pacing (pacing threshold 1.0 V / 0.5 ms, sensing 9.8 mV, impedance 1279 Ω) at 130 bpm (pacing output 1.6 V / 0.8 ms, arrows in figure 2 indicate pacing stimuli). Simultaneously, the harvesting device generated a mean output power of 52 µW over an additional load resistor of 1kΩ.

Conclusion: We demonstrated the feasibility of pacing the heart using its own mechanical activity. The harvested energy exceeded the power requirement of a modern pacemaker (~10 µW). Furthermore, we expect to increase the performance by optimising this first-generation prototype. However, the presented results were obtained from a single scenario. Further investigations have to be done to show for instance the influence of the additional weight on the heart or the optimal implantation site.

source: https://doi.org/10.7892/boris.70933 | downloaded: 27.4.2024

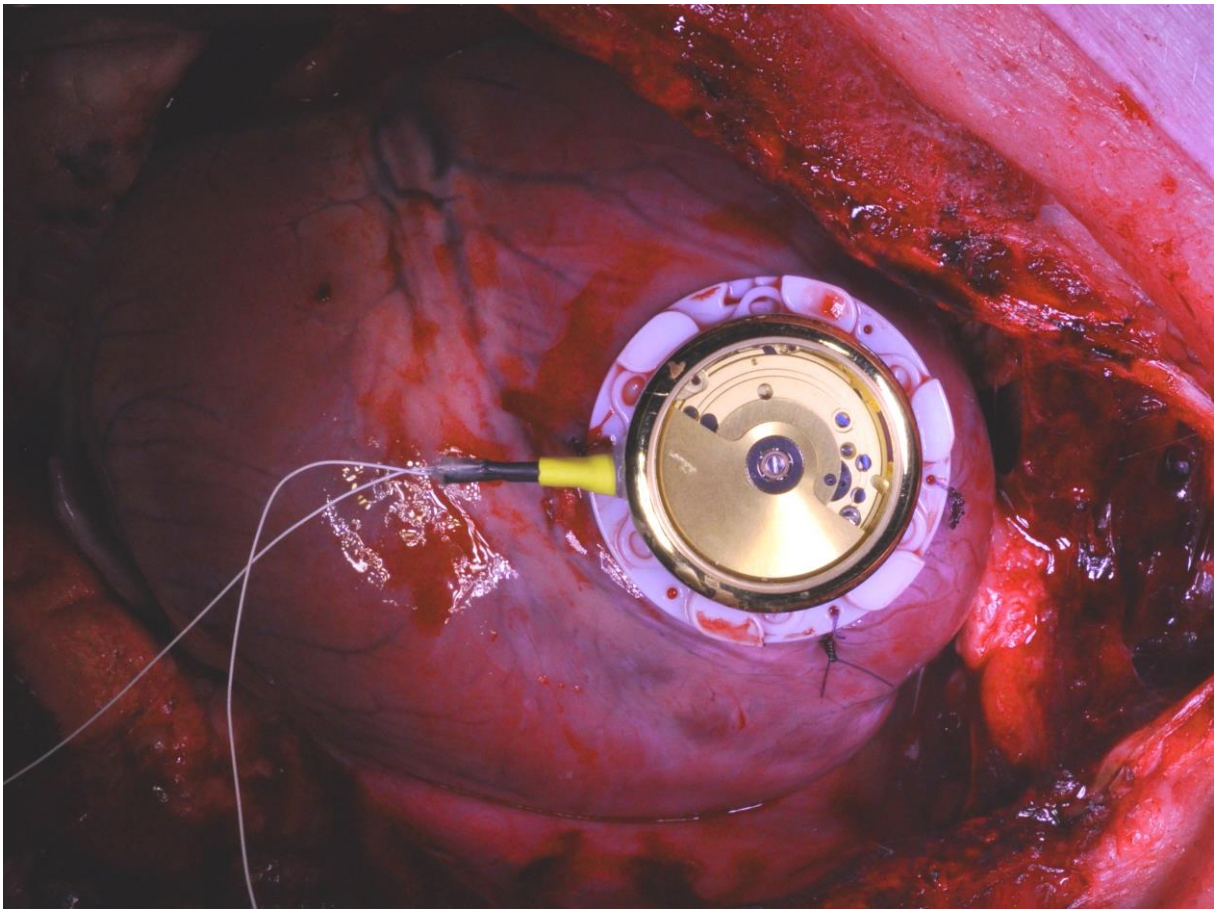

Figure 1

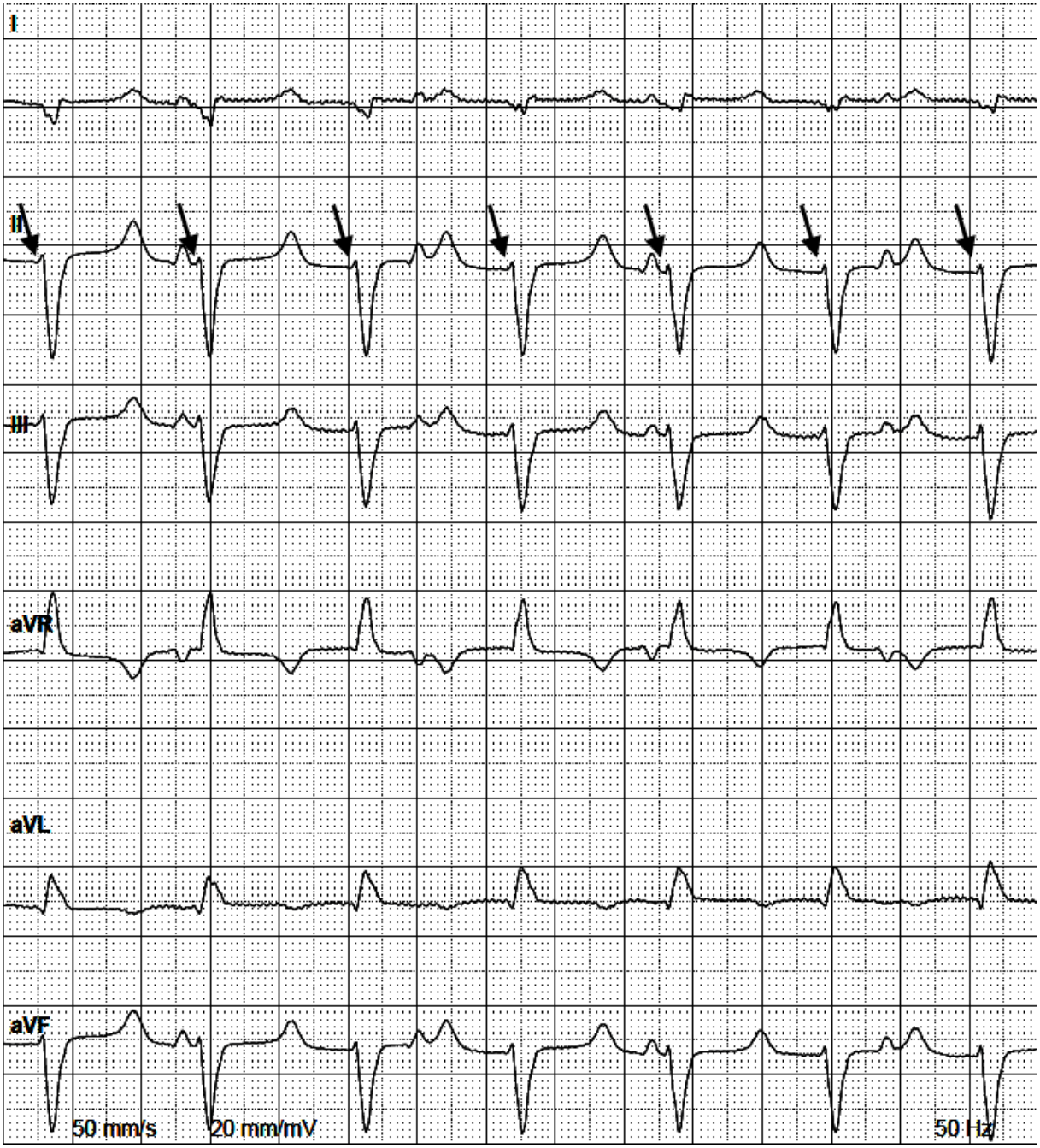

Figure 2