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News & Views

Will the symbiotic pacemaker, a self-powered cardiac implanted electronic device, be the next evolution in pacemaker technology?

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The first permanent implanted pacemaker was successfully used in clinical practice in 1958. In the past 60 years, the development of pacemakers has been witnessed in clinical application [1]. Early pacemakers were large and cumbersome, and had a short battery life, providing only a single-chamber asynchronous pacing (VOO) pacing mode. In 1967, on-demand pacemakers with synchronous pacing (VVI) mode just came out. The emergence of the first dual chamber pacemaker in 1977 symbolized the entry into the physiologic pacing era. In 1982, pacemakers began to provide rate adaptive functions. In this age of accelerating development in scientific technologies and clinical researches, pacemakers have evolved into implantable cardioverter-defibrillators for the treatment of sudden cardiac death and cardiac resynchronization therapy for chronic heart failure, instead of simply being an electronic device that treats bradycardia by pulsing the heart (Fig. 1) [2,3].

Although transvenous pacemakers have become the first-line treatment for patients with symptomatic bradycardia, pacing technology also exists some obvious limitations at present, especially related problems caused by pacing leads, such as lead failure or dislodgment, infection, tricuspid valve insufficiency, infective endocarditis, etc. [4]. Given the nerve-wracking complications, leadless pacemakers' technology ensues. LEADLESS Trial and Micra TPS Trial have demonstrated the safety and efficacy of leadless pacemakers in clinical practice [5,6]. LEADLESS Trial was a prospective, nonrandomized, single-arm multicenter study, which enrolled 33 patients for leadless pacemaker implantation. The implant success rate was 97% and the overall complication-free rate was 94%. Besides, the pacing parameters remained stable after 3 months follow-up. The Micra TPS Trial was a global, multicenter prospective study, which enrolled 725 patients who met guidelines for right ventricular pacing. The electronic device was successfully implanted in 719/725 (99.2%), with a mean procedure duration of (23.0 ± 15.3) min. Device-related serious adverse events occurred in 25 (3.4%) patients and included cardiac perforation 1.5%, vascular complications in 0.7%, venous thromboembolism in 0.3%, and increasing pacing thresholds in 0.3% of patients. No device dislodgment or embolization was observed. In addition, SELECT-LV study has proved the feasibility and safety of wireless technology in left ventricular endocardial pacing [7].

The appearance of leadless pacemakers' technology is quite engrossing and enchanting. However, the battery life seems to be a main bottleneck, restricting its further development [2]. Currently, advanced lithium-based battery technologies can provide long-term stability of pacing output, pacemaker generators need replacing every 8–10 years, which depends on the utilization of pacemakers [8]. Changing generator will inevitably intensify the patients' medical expenses, as well as the risk of procedure-related complications [2].

In order to overcome the limitations of today's pacemaker battery technologies, recently, one breathtaking breakthrough is made by Ouyang et al. (Fig. 2) [9]. They presented an implanted symbiotic pacemaker (SPM) based on an implantable triboelectric nanogenerator (iTENG), reaching the realization of cardiac pacing and sinus arrhythmia correction on a large animal model. The iTENG, with light weight, good flexibility and bio-compatible property, was placed between the heart and the pericardium of a pig. With each heart-beats, the mechanical energy can be transformed into the electrical energy, and the electrical energy can be stored in the SPM, which can in turn pace heart via sinus arrhythmia. Besides, the researchers have demonstrated the energy gained from each cardiac motion cycle is 0.495 μJ, which is adequate for the required endocardial pacing threshold energy (0.377 μJ).

This promising and encouraging study has some remarkable advantages. Firstly, it provides more possibilities for the recycling of pacemaker electrical energy. Perhaps, SPM can reduce the times of generator replacement, or even get rid of it, especially for the young patients with a low proportion of pacing. Secondly, millions of patients worldwide currently rely on a variety of implantable pacemakers for their lives and health. This SPM can significantly economize medical resources, and meanwhile reduce the pain and procedure-related complications of patients due to re-operation. Despite the brilliant prospects for clinical application, the research work is still in the animal experiment stage, and the long-term stability and safety of SPM-related materials and devices need to be continuously observed. Further improvements are required to cater for future clinical use. All in all, today's SPM technology is the most promising solution to the problem of limited battery life in leadless pacemaker technology. We are looking forward to this device being applied to clinical practice as soon as possible.

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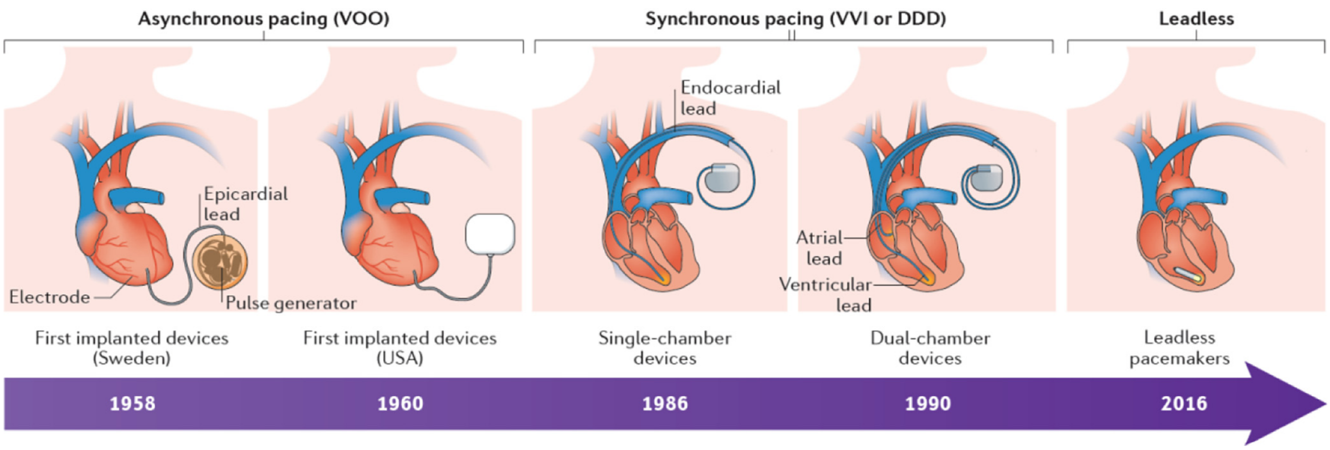

Fig. 1. Timeline of the evolution of pacemaker technology [2]. Copyright © 2018, Springer Nature.

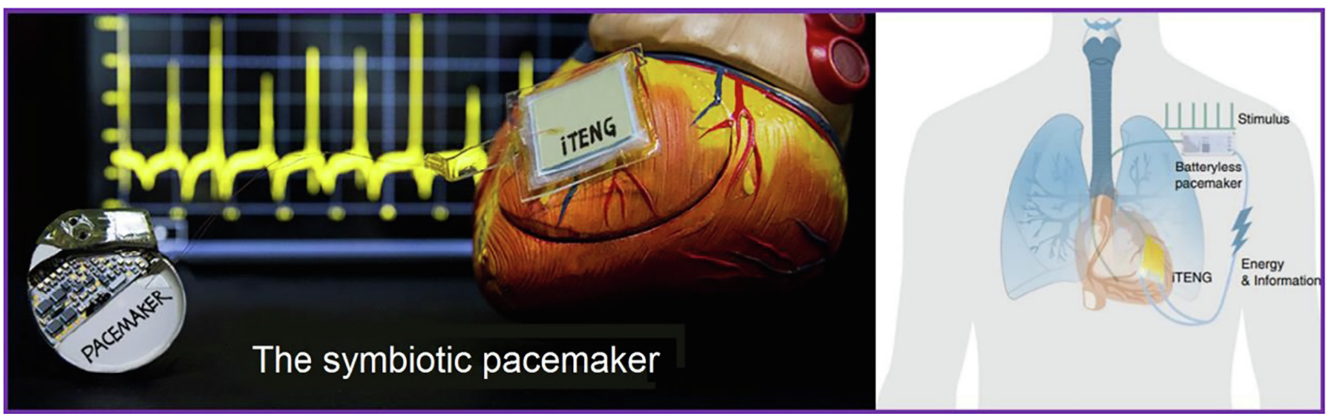

Fig. 2. The symbiotic pacemaker [9]. Copyright © 2019, Springer Nature.

Conflict of interest

The authors declare that they have no conflict of interest.

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