

DESIGN AND OPTIMIZATION OF LOW-POWER IMPLANTABLE PACEMAKER SYSTEM USING ADVANCED MICROELECTRONIC TECHNOLOGIES

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This work reviews the advancements in pacemaker technology, emphasizing their role in regulating heart rhythms in patients with bradycardia and arrhythmia. It covers various designs, including leadless and energy-harvesting pacemakers, and highlights recent innovations such as the world's smallest pacemaker and its potential applications.

Keywords: pacemaker, heart rhythm, energy harvesting, leadless technology, cardiac care.

РАЗРАБОТКА И ОПТИМИЗАЦИЯ МАЛОМОЩНОЙ ИМПЛАНТИРУЕМОЙ СИСТЕМЫ КАРДИОСТИМУЛЯТОРА С ИСПОЛЬЗОВАНИЕМ ПЕРЕДОВЫХ МИКРОЭЛЕКТРОННЫХ ТЕХНОЛОГИЙ

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Рассмотрены достижения в области технологий кардиостимуляторов, подчеркивая их роль в регуляции сердечного ритма у пациентов с брадикардией и аритмиями. Представлены различные конструкции, включая безэлектродные и энергоаккумулирующие кардиостимуляторы, а также освещены последние инновации, такие как самый маленький в мире кардиостимулятор и его потенциальные области применения.

Ключевые слова: кардиостимулятор, сердечный ритм, сбор энергии, беспроводная технология, кардиологическая помощь.

A pacemaker is a compact medical device implanted subcutaneously to regulate heart rhythm, particularly in patients with conditions such as bradycardia or arrhythmias. It functions by delivering electrical impulses to the heart, ensuring normal contractions. This article reviews the significance of pacemakers, their operational mechanisms, indications for use, and recent advancements in the field.

A pacemaker comprises two main components: an electrical generator, which contains a battery and electronic circuitry to generate impulses, and electrodes, which are thin wires that connect the device to the heart, transmitting these signals. The primary role of the pacemaker is to stimulate the heart to beat at a regular rate when natural rhythms are insufficient.

Pacemaker implantation is indicated for various conditions, including:

Bradycardia. Characterized by a heart rate below normal levels, resulting in inadequate blood circulation.

Heart Block. Occurs when electrical signals between the atria and ventricles are disrupted.

Frequent Fainting. Often caused by abrupt drops in heart rate.

Sick Sinus Syndrome. Arises from dysfunction in the sinus node, the heart's natural pacemaker.

Post-Surgical Complications. Certain heart surgeries may lead to rhythm disturbances necessitating pacemaker support.

Different pacemaker designs are available, including:

Traditional Pacemaker. Utilizes implanted electrodes to deliver impulses.

Leadless Pacemaker. A compact device implanted directly in the heart without external leads, allowing for easier implantation.

Dual-Chamber Pacemaker. Synchronizes electrical signals between the atria and ventricles.

Three-Chamber Pacemaker. Enhances cardiac output in heart failure patients by optimizing pumping efficiency.

Recent research has explored methods to extend the battery life of leadless pacemakers through energy harvesting. By converting mechanical energy from the heart's contractions into electrical energy, this innovation has the potential to prolong device functionality. Traditional pacemakers typically have a battery life of 6 to 15 years, and replacing batteries can be complex, especially for leadless models fully implanted within the heart.

Studies have demonstrated the feasibility of harvesting mechanical energy to power implantable devices, allowing the heart's natural movements to generate the required electrical voltage. Prototypes designed to capture energy from heart contractions have shown promising results, with one device harvesting approximately 10 % of the energy needed for each heartbeat. Optimization of materials and manufacturing processes may further enhance energy harvesting efficiency.

Future research includes long-term in vivo trials to validate these findings and ensure the safety and durability of this technology. Collaborations with leading pacemaker manufacturers are anticipated to integrate energy-harvesting designs into existing leadless pacemakers, potentially benefiting younger patients who may need multiple devices throughout their lives.

Moreover, American researchers have developed the world's smallest pacemaker, which can be injected into the heart through the skin without the need for surgery. This innovative device contains no electrodes or wires and dissolves into biocompatible fragments, which are excreted from the body. Future applications may involve injecting multiple miniature pacemakers into various heart regions, providing a comprehensive assessment of electrical activity and enabling targeted interventions.

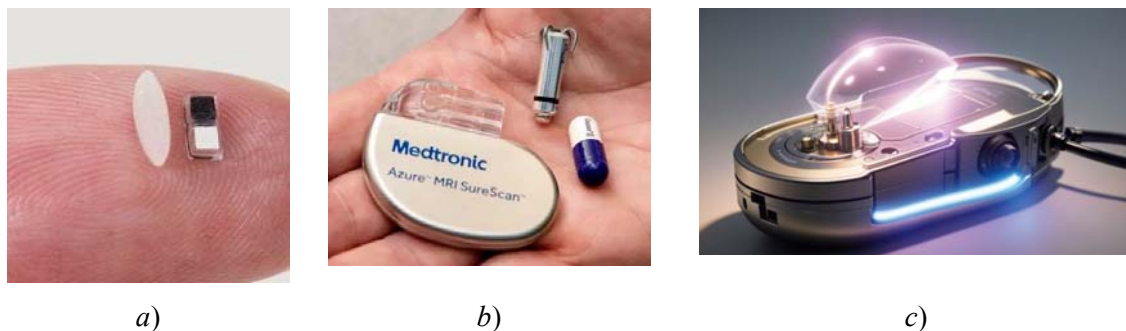


Fig. 1. Images of pacemakers:
a – the smallest pacemaker; b – a pacemaker; c – a light-activated pacemaker

The advancements in pacemaker technology, particularly in energy harvesting and miniaturization, represent significant progress in cardiac care. These innovations aim to enhance the longevity and efficacy of pacemakers, ultimately improving patient outcomes and quality of life for individuals with heart conditions. Continued research and development are essential for realizing the full potential of these life-saving devices.

Reference

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WIRELESS CAPSULE ENDOSCOPY: A TECHNOLOGICAL LEAP TOWARD REPLACING TRADITIONAL ENDOSCOPIC METHODS**W. H. Amhaz¹, M. F. S. H. Al-Kamali²**¹ *Gomel State Medical University, Republic of Belarus*² *Sukhoi State Technical University of Gomel, Republic of Belarus*

Wireless capsule endoscopy has transformed gastrointestinal diagnostics by offering a non-invasive method for imaging the small intestine. Utilizing intelligent algorithms, capsule robots can detect lesions and initiate therapeutic interventions, enhancing clinical outcomes.

Keywords: wireless capsule endoscopy, gastrointestinal diagnostics, intelligent algorithms, lesion detection, therapeutic interventions.

**БЕСПРОВОДНАЯ КАПСУЛЬНАЯ ЭНДОСКОПИЯ:
ТЕХНОЛОГИЧЕСКИЙ СКАЧОК К ЗАМЕНЕ ТРАДИЦИОННЫХ
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Беспроводная капсульная эндоскопия преобразила диагностику заболеваний желудочно-кишечного тракта, предложив неинвазивный метод визуализации тонкого кишечника. Используя интеллектуальные алгоритмы, капсульные роботы могут обнаруживать поражения и инициировать терапевтические вмешательства, улучшая клинические результаты.

Ключевые слова: беспроводная капсульная эндоскопия, диагностика заболеваний желудочно-кишечного тракта, интеллектуальные алгоритмы, обнаружение поражений, терапевтические вмешательства.

Wireless capsule endoscopy (WCE) has revolutionized gastrointestinal imaging by employing high-resolution cameras that capture thousands of images as the capsule traverses the digestive tract. Once ingested, the capsule is propelled by peristalsis, wirelessly transmitting images to an external recording device for analysis. This procedure typically lasts several hours, allowing patients to resume normal activities, thus minimizing discomfort and disruption.

WCE offers several advantages over conventional endoscopy. It is minimally invasive, eliminating the need for anesthesia and surgical instruments, which significantly reduces patient risk and discomfort. The panoramic view provided by WCE enhances visualization of the small intestine – a region often difficult to assess using traditional methods. Its capacity to capture images from multiple angles facilitates detailed evaluation of mucosal lesions, polyps, and bleeding sites, promoting higher patient compliance.