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Top Stories

Intersection of bioengineering and arrhythmia therapy

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Improvements in the treatment of arrhythmias could likely be facilitated by new power management and delivery developments that implement advancements in chemical, optical, electronic, ultrasound, and robotic techniques.

Miniaturized and optically controlled bioresorbable system for pacing

Temporary cardiac pacing is necessary in conditions such as growth of the heart and body in prenatal patients, recovery after surgery, correction of metabolic or electrolyte abnormalities, and ischemia. In a recent study, Zhang et al[1] report on a millimeter-scale cardiac pacing system that is built with bioresorbable optoelectronic components, including onboard self-powered electrodes and a wireless optical control mechanism, with generalized capabilities in electrotherapy and specific applications in temporary cardiac pacing. The extremely small size of these devices enables minimally invasive implantation via percutaneous injection and endovascular delivery. Experiments demonstrated effective pacing in mouse, rat, porcine, canine, and human cardiac models at both single- and multisite locations. Pairing with a skin-interfaced wireless device allows autonomous, closed-loop operation upon detection of arrhythmias. Remaining challenges include bioabsorbable material safety and miniaturization, which could facilitate migration, reduce insulation from interference, and difficulty of removal in case of complications.

Ultrasound and electroactive biomaterial for rate control

Wireless remote control of electrical activation independent of a power supply was also demonstrated by Han et al.[2] Investigators used glycol chitosan–coated barium titanate nanoparticles (BTNPs), which exhibit a high piezoelectric effect, can generate electromagnetic fields under ultrasound stimulation, and show potential as a wireless neuromodulation tool with widespread applications. BTNPs were injected into the inferior right ganglionated plexus in beagles and irradiated with ultrasound energy. Animals injected with BTNPs maintained biosafety and had reduced ventricular rates in proportion to the concentration of the injected material and the ultrasound power: up to ∼25% during sinus rhythm and ∼20% during tachypacing-induced atrial fibrillation. Further studies are needed to establish long-term bioactivity and biosafety for clinical applications. This study highlights the potential use of wearable devices with recently developed energy-efficient ultrasound transducers to control internal powerless actuators.

Injectable hydrogel conductors for inaccessible veins

Direct electrical access into the mid-myocardium could be used to treat ventricular arrhythmias; however, there are no electrodes small enough to navigate the coronary veins therein. Rodriguez-Rivera et al[3] developed an injectable ionically conductive hydrogel electrode that can fill the epicardial coronary veins and transform them into flexible electrodes. A new hydrogel chemistry based on a polyether urethane diacrylamide macromer was developed to match myocardial stiffness, resist hydrolysis, and provide conductivity 2–3 times that of the native myocardium. Ionic hydrogel electrodes provided stable electrical stimuli over many cycles and across a substantial length of cardiac veins. In vivo deployment and pacing in a porcine model demonstrated that the ionic hydrogel electrode filled the anterior interventricular vein and extended to depths far more distal than current systems. Despite concerns regarding cardiac engorgement and potential long-term adverse effects on function and substrate modification, the study demonstrates the potential of injectable ionic hydrogel electrode for pacing previously inaccessible mid-myocardial tissue and also paves a pathway for painless defibrillation.

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How short can a pulse for pulmonary vein isolation be?

Pulsed-field ablation (PFA) is a rapidly evolving and widely adopted technology for atrial fibrillation ablation. Currently, PFA procedures using microsecond-scale duration pulses (μsPFA) require either general anesthesia or deep sedation to control muscle contractions (MCs) and prevent pain. Reducing MCs is clinically important. Xie et al[4] compared, in a swine model, the peak acceleration of diaphragmatic motion and efficacy of pulmonary vein isolation as a function of amplitude, duration, and number of pulses. The study found that PFA using nanosecond-scale duration pulses (nsPFA) and μsPFA achieved comparable transmural and circumferential lesion creation without damaging adjacent structures, such as the esophagus, or causing phrenic nerve paralysis; however, nsPFA induced significantly lower MCs than did μsPFA. These findings suggest that nsPFA may offer an equally effective alternative to μsPFA, with a significant reduction in MCs.

Magnetic ball chain robots for cardiac arrhythmia treatment

In mapping and ablation procedures, robotics has the potential to enable more precise mapping and lesion creation, reduce operator fatigue, extend catheter reach, and reduce the use of fluoroscopy. Pittiglio et al[5] report on a novel magnetic navigation system with 2 key elements: an ablation catheter consisting of a chain of spherical permanent magnets at its distal tip and an actuation system comprising 2 cart-mounted permanent magnets undergoing pure rotation. The catheter design enables a high magnetic content, leading to a minimized footprint of the actuation system and easier integration with clinical workflow. The study demonstrates that the ball chain catheter can ablate heart tissue and generate lesions comparable to current clinical ablation catheters. A prototype validation predicts that using 2 permanent magnets as small as 119 mm in diameter and 6.6 kg in mass could potentially improve the accuracy of lesion creation.

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