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Optogenetic Modulation of Cardiac Autonomic Ganglia: A Closed-Loop Intervention for Refractory Ventricular Arrhythmias

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Abstract

Pharmacological management of refractory ventricular tachycardia (VT) remains inadequate. We present a translational study employing optogenetic stimulation of intrinsic cardiac ganglia via channelrhodopsin-2 (ChR2) expression delivered through cardiotropic AAV6 vectors. In a porcine ischemic cardiomyopathy model, light-emitting diode (LED) arrays integrated into a bioabsorbable epicardial patch enabled real-time, closed-loop vagomimetic stimulation triggered by arrhythmia detection algorithms. Optogenetic neuromodulation reduced VT inducibility by 82% and prevented sudden cardiac death in 90% of treated animals versus 30% in controls. Histological analysis confirmed selective ChR2 expression in cholinergic neurons without off-target myocardial effects. This neuromodulatory strategy circumvents systemic autonomic side effects of conventional therapies.

Keywords: optogenetics, cardiac ganglia, ventricular arrhythmia, closed-loop stimulation, channelrhodopsin-2, bioelectronic medicine