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Progress in Biophysics and Molecular Biology 90 (2006) 444–468
Progress in Biophysics & Molecular Biology
www.elsevier.com/locate/pbiomolbio

Review

Soft tissue impact characterisation kit (STICK) for ex situ investigation of heart rhythm responses to acute mechanical stimulation

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Available online 9 August 2005

Abstract

Both mechanical induction and mechanical termination of arrhythmias have been reported in man. Examples include pre-cordial impacts by sports implements (baseballs, pucks) that can trigger arrhythmias, including ventricular fibrillation, or via the so-called pre-cordial thump, used as an emergency resuscitation measure to convert arrhythmias to normal sinus node rhythm. These interventions have been partially reproduced in experimental studies on whole animals. Relating observations at the system's level to underlying mechanisms has been difficult, however, largely because of: (i) a deficit in efficient and affordable pharmacological agents to selectively target (sub-)cellular responses in whole animal studies, and (ii) the lack of suitable experimental models to study the above responses at intermediate levels of functional and structural integration, such as the isolated heart or cardiac tissue. This paper presents a soft tissue impact characterisation kit (STICK), suitable for quantitative investigations into the effects of acute mechanical stimulation on cardiac electro-mechanical function in rodent isolated heart or tissue preparations. The STICK offers independent control over a range of

Abbreviations: APD, action potential duration; CK, creatine kinase; ECG, electrocardiogram; PVC, premature ventricular contraction; SAC, stretch-activated channel; STICK, soft tissue impact characterisation kit; VF, ventricular fibrillation; VT, ventricular tachycardia

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0079-6107/$ - see front matter
doi:10.1016/j.pbiomolbio.2005.07.004

relevant biophysical parameters, such as impact location and energy, pre-impact projectile speed and contact area, as well as over the timing of a mechanical stimulus relative to the cardiac cycle (monitored via electrocardiogram, ECG, here recorded directly from the cardiac surface). Projectile deceleration upon interaction with the tissue is monitored, contact-free, with a resolution of 175 μm, providing information on tissue deformation dynamics, force, pressure and work of the mechanical intervention. In order to study functional effects of cardiac mechanical stimulation in the absence of tissue damage, impacts must be limited (for juvenile Guinea pig heart) to 2–2.5 mJ in the slack left ventricle (diastolic impact) and 5–10 mJ in contracture (systolic impact), as confirmed by enzyme assay and histological investigation. Impacts, timed to coincide with the early T-wave of the ECG, are capable of triggering short runs of ventricular fibrillation. Thus, the STICK is a suitable tool for the study of acute cardiac mechano-electric feedback effects, caused by short impulse-like mechanical stimulation, at the level of the isolated organ or tissue.

Keywords: Mechano-electric feedback; Stretch activated channels; *Commotio cordis*; Pre-cordial thump; Langendorff heart; Fibrillation; Creatine kinase assay

Contents

1. Introduction: effects of acute mechanical stimulation on heart rhythm

Unsurprisingly, there are few controlled data on the induction of arrhythmias by acute mechanical stimulation in man. Consequently, mechanisms and determinants of the response remain ill-understood (Kohl et al., 2005). Nonetheless, many case reports highlight