An Improved Understanding of Gastrointestinal Electrical Activity Through Experimental Recording and Mathematical Modelling

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Gastrointestinal (GI) Electrophysiology

Motions (motility) of the gut play a critical role in maintaining a healthy digestive system. An electrophysiological event, termed **slow wave**, co-regulates motility by influencing the contractility of smooth muscle cells in the GI tract.

Slow waves are autonomously generated by a type of pacemaker cells called the **interstitial cells of Cajal (ICC)** (Fig. 1).

Slow waves occur at different frequencies along the GI tract (~3 cycles-per-minute (cpm) in the stomach; ~10 cpm in the intestines).

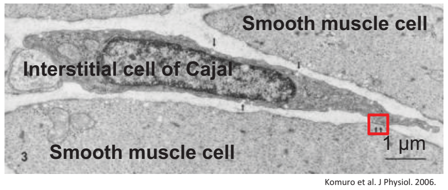

Fig 1. An electron-microscopic image of the coupling (red box: gap junction) between an interstitial cell of Cajal and two neighbouring smooth muscle cells.

Current Challenges in Clinical Practice

GI disorders are common in the modern day world. However, modern GI physiology and clinical practices still rely on relatively rudimentary measurements of gut functions.

Can a better understanding of slow wave electrophysiology lead to more accurate diagnosis and effective treatments of GI disorders?

High-Resolution (HR) Electrical Mapping

Flexible printed circuit (FPC) electrodes were designed to record slow waves from the serosal surface under intra-operative conditions. Up to 256 electrodes, with 4.0-7.6 mm inter-electrode distances, were used at a time (Fig. 2).

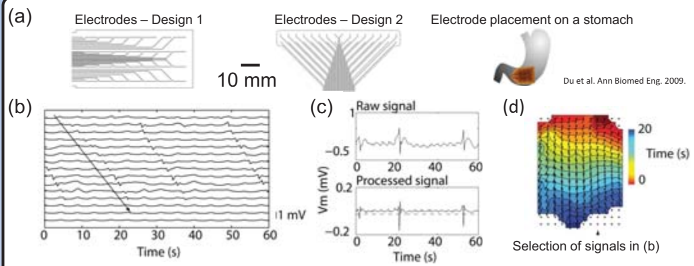

Fig 2. (a) FPC electrode; (b) recordings; (c) AT identification; (d) AT map.

A series of signal processing techniques were applied to the recordings and the activation sequences of slow wave propagation were reconstructed in **activation times (AT) maps**.

HR mapping of gastroparesis (a digestive disorder that occurs in ~20% of diabetes) has demonstrated slow wave dysrhythmias, when compared to baseline activity (Fig.3).

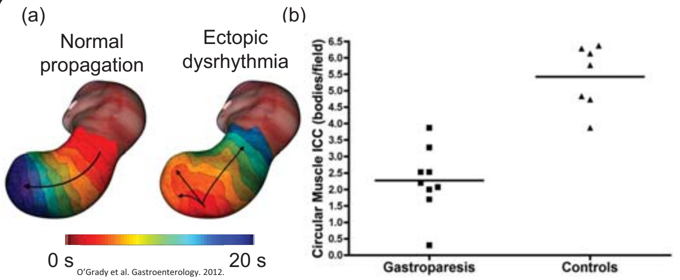

Fig 3. (a) HR AT maps of gastric slow waves in control and gastroparesis; (b) Diminished ICC bodies count in gastroparesis compared to control.

Multi-scale Mathematical Modelling

Mathematical modelling has become a valuable *in-silico* research tool, as there is an ever-increasing need to gain an integrative and quantitative understanding of how slow waves achieve coordinated functions across multiple biophysical scales (Fig. 4).

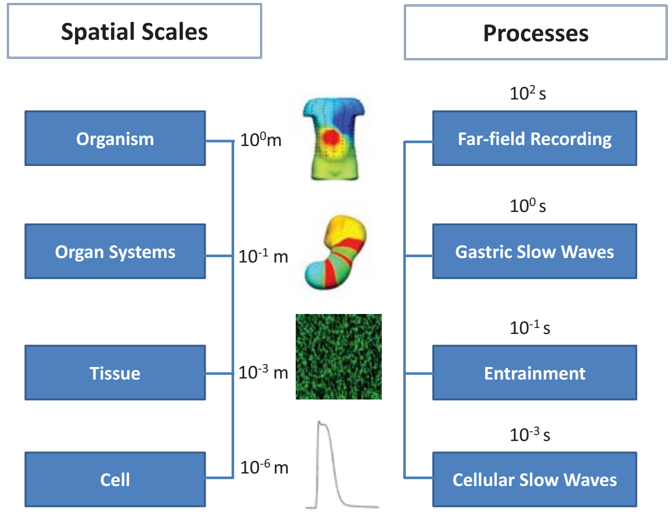

Fig 4. Spatiotemporal organisation of GI multi-scale mathematical models.
Du et al. Wiley Interdiscip Rev Syst Biol Med. 2013.

Simulation of Ectopic Activation

A bi-directionally coupled ICC networks model was developed to simulation the ectopic activation of gastric slow waves. Ectopic activation demonstrated velocity anisotropy due to the differential preferential conduction in each ICC network from different depths of the GI wall (Fig 5).

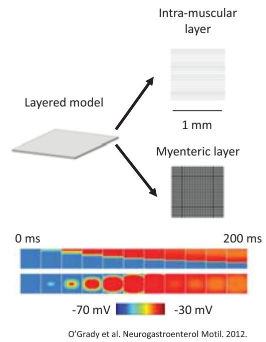

Fig 5. A layered model showing normal propagation and ectopic activation.

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