Title of the project: Optimising implanted cardioverter defibrillator devices through patient-specific device configuration, implant strategies and therapy delivery

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Aim of the project

We aim to develop a series of personalised models of anatomically-accurate, biophysically-realistic electrotherapy devices embedded within detailed whole-torso computational models to enable novel development and patient-specific optimisation of device design, configuration, and therapeutic protocol delivery. Realistic electrogram sensing will also be modelled and used to further guide, and personalise, signal interpretation and device decision-making based-on signals sensed by the recording electrodes, to further optimise configurations. The project will also investigate updating of personalisation strategies based-on continuously-recorded patient data from the device.
Outcomes of the project will be:

1. An efficient modelling workflow for constructing patient-specific torso models of implanted devices and strategies for predicting optimal (personalised) implant configurations and programming of existing device technologies.
2. A platform for investigating, and further optimising, state-of-the-art novel electrotherapy designs and protocols, to facilitate clinical transition of these novel devices.
3. Generic guidance on optimal device strategies based-on patient anatomy, specific disease-type and stage.

Project description

Sudden cardiac death (SCD) due to ventricular arrhythmias remains one of the most important causes of mortality in Western Society. Implanted cardioverter defibrillators (ICDs) can automatically detect and treat ventricular arrhythmias by applying appropriate electrotherapy, effectively preventing SCD. Despite saving countless lives every day from otherwise lethal cardiac episodes, these devices remain far from an optimal therapy. The very high-strength electrical shocks drain ICD batteries, whilst inappropriate shocks due to mis-sensing of cardiac rhythms causes significant pain and associated psychological issues in device recipients. Furthermore, the applied shock therapy often fails, and multiple therapies are required, frequently making the arrhythmia worse and leading to ultimate shock-failure and death.

ICD device design is evolving rapidly, from the traditional (and still most frequently used) transvenous devices (TV-ICDs), with electrodes implanted directly within the cardiac chambers and veins, to the increasingly common sub-cutaneous devices (S-ICDs), which utilise electrodes entirely outside the heart. Despite reducing complications, S-ICDs require higher energies to ensure defibrillation and, not having electrodes physically in contact with the heart, are currently not able to pace the heart directly, which can be useful for applying anti-tachycardia pacing (ATP) therapies – a painless first line of defence for TV-ICDs which often circumvents the need for strong defibrillation backup shocks. Most recently, sub-sternal (extra-vascular) devices (EV-ICDs) are also coming to market, which act as an intermediary between the TV- and S-ICD devices.

The algorithms used for detection and decision making within an ICD from the continuously-sensed electrogram signals are relatively crude, lacking patient-specific information, and can be particularly problematic for S-ICDs and EV-ICDs. Moreover, the electrotherapy itself is delivered from standard electrode configurations without attempts to personalise such delivery based on a priori patient information and data. A strong need therefore exists to personalise the functioning of ICD devices in order to optimise electrotherapy, improving recipient quality-of-life and ultimate survival.

Here, we plan to build-upon recent developments in computational cardiac digital twin technology to construct robust pipelines for the construction of personalised whole-torso computational models, including realistic representation of device electrodes and leads, to optimise, through personalisation, delivered electrotherapy. The latest cardiac imaging data will be used to construct anatomically-realistic patient-specific models, incorporating biophysically-realistic representations of common ICD electrode/lead configurations from TV-, S- and EV-ICDs. Simulated electrotherapy protocols (biphasic shock, ATP and the latest novel shock vectors and sequences) will be simulated using the state-of-the-art cardiac simulation software (through NumeriCor). Specific metrics related to the effect of the field on the cardiac tissue and which relate most closely to defibrillation threshold will be investigated. Patient-specific adjustments to device configurations, specific implant locations, applied shock vector and electrotherapy sequences will be investigated to understand how such adjustments may be used to optimise electrotherapy efficacy, and well as initial arrhythmia detection and decision making. Finally, investigation of how models may be updated in time due to structural and functional remodelling due to disease progression will also be conducted.

Suitable for a candidate with a strong background in physical sciences, with a keen interest in clinical application.