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MODELLING ELECTRICAL ACTIVITY FROM CELL TO BODY SURFACE

M. L. Buist, A. J. Pullan, P.J. Hunter
Department of Engineering Science, The University of Auckland,
Private Bag 92019, Auckland, New Zealand.
email: m.buist@auckland.ac.nz

Abstract — We present here a modelling framework in which the interaction of the passive external tissue with the extracellular potentials of the myocardium can be studied. The procedure involves iterating between solutions of the bidomain equations, valid in the myocardium, and Laplace's equation, valid in the passive tissue, until continuity of potential and current flow has been achieved across the heart's surfaces. Initial simulations on a two-dimensional cross section of a human torso shows that the iterative process readily converges.

Keywords — body surface potential, cardiac activation, integrative modelling.

I INTRODUCTION

The aim of this current work is to present a modelling framework in which the interaction of the passive external tissue with the extracellular potentials of the myocardium can be studied. If one is interested in accurate detailed modelling of the heart and torso, it is a prohibitively large computational job to solve for the extracellular potential field everywhere simultaneously due to the size and complexity of the myocardial and torso problems. An alternative approach is to divide the problem into two parts. This first involves the computation of the activation sequence, assuming the heart is isolated and insulated. Traditionally one then superimposes dipoles of various number, strength and orientation on the computed activation sequence to generate body surface potentials [1]. Such an approach allows no effect of the surrounding tissue to be included. We present a new approach to the problem in which there are two subproblems and an iterative approach is added to ensure continuity of current and potential across the heart's surfaces. This new approach allows one to use the most efficient method to solve the two subproblems, which by their nature have different solution requirements.

II METHODS

We use the bidomain equations to model the myocardial activation process and the resulting potential field inside the heart. Continuity of extracellular potential connects the bidomain equations to the equation governing current flow in the surrounding tissue. The potential in this passive tissue is governed by the generalised Laplace equation. The torso is insulated by air which means there can be no normal current flow across the torso surface. A finite element derived finite difference grid is generated at constant material space intervals over the myocardium to solve the bidomain equations. An anatomically accurate myocardial fibre field which was generated from data measured by LeGrice *et al.* [2] was incorporated. A coupled finite element/boundary element approach is used to solve the generalised Laplace equation through to the body surface [3].

Consistent with previous approaches [1], equivalent dipole sources are calculated from the transmembrane potential gradient and these dipoles are used in the passive torso problem to generate body surface potentials. However this does not ensure continuity of current or potential across the heart's surfaces between the extracellular bidomain and the dipole source solution. The approach adopted here uses the equivalent dipole solution as an initial guess in an iterative process to satisfy the continuity conditions. The boundary conditions on the extracellular domain in the myocardial region are updated using solutions from the surrounding torso. A new extracellular bidomain solution is then obtained. The torso boundary conditions on the epicardial and endocardial surfaces are then updated from the new extracellular solution and the torso problem is resolved where the initial dipole sources have been removed. This process is continued until both continuity of current and potential across the myocardial surfaces has been achieved.

III RESULTS

This new approach has been applied to a two-dimensional transverse slice through the torso at the mid sternum level. Simulations have shown the iteration process readily converges. This modelling framework has the capability of incorporating a variety of cellular models and mechanical deformation.

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