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Computational analysis of hemodynamics in a human ventricular model

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Key Words: Human ventricular model(), Ventricular hemodynamics (), Cellular excitation contraction (-)

Abstract

A 3D human ventricular model is proposed to simulate an integrative analysis of heart physiology and blood hemodynamics. This consists of the models of electrophysiology of human cells, electric wave propagation of tissue, heart solid mechanics, and 3D blood hemodynamics. The 3D geometry of human heart is discretized to a finite element mesh for the simulation of electric wave propagation and mechanics of heart. In cellular level, excitations by action potential are simulated using the existing human model. Then the contraction mechanics of a whole cell is incorporated to the excitation model. The excitation propagation to ventricular cells are transiently computed in the 3D cardiac tissue using a mono-domain method of electric wave propagation in cardiac tissue. Blood hemodynamics in heart is also considered and incorporated with muscle contraction. We use a PISO type finite element method to simulate the blood hemodynamics in the human ventricular model.

1. (excitation) (SA node) (gap junction)

(contraction) (Cardiac muscle) 가 (AV node) (Purkinje fiber) (His bundle)

† , ‘+’가 (Depolarization) 가 , 가 L-type

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* 가
 **

(CICR, Calcium induced calcium release).
가

NL

(1).

Cross

bridge

(tropomyosin)

(troponin)

cross bridge가

2.

2.1

()

cross

bridge

2

T

→TCa, TCa→TCa*

NL

가 가 cross bridge
(half sarcomere length)가

NL

[2].

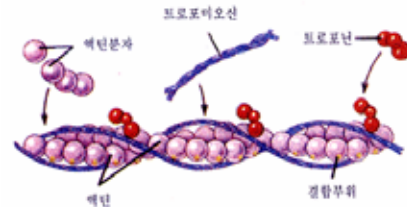
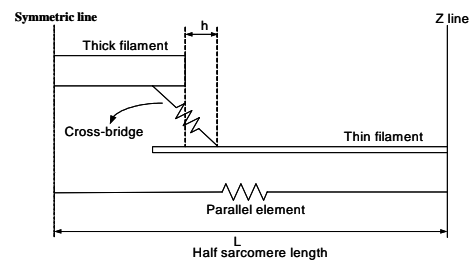
가

reticulum)

(SR, sarcoplasmic
가

SR

가



TN

[1].

Fig. 1 Muscle unit structure used in NL model.

2.2 NL (cross bridge)

ATP가 가

가

cross bridge

NL

() (가

)

cross bridge ATP

(Z)

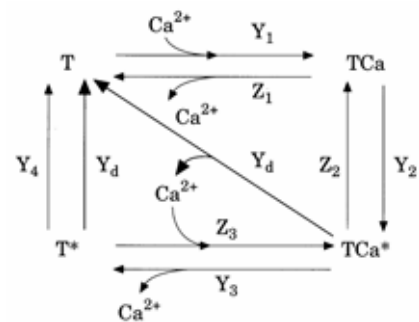


Fig. 2 Diagram of calcium and cross-bridge dynamics.

bridge

(parallel elastic resistive force)

cross

2.3

Hemodynamics

monodomain [3]
 reaction-diffusion

가

Navier-Stoke

PISO

3

가

가

4

2004

Ten

[4].

Tusscher [1]

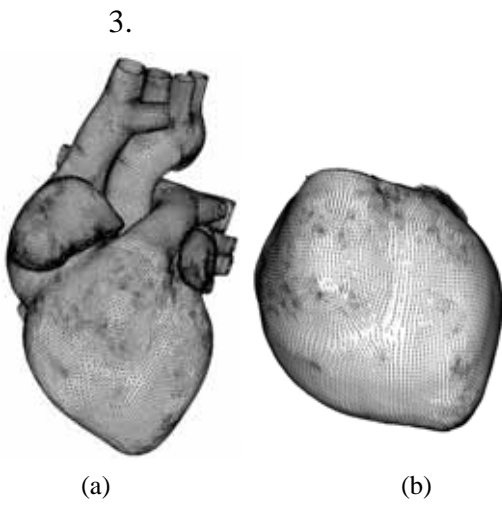


Fig. 3. 3D model of virtual heart. (a) Computational model, (b) Ventricular model with fiber orientation

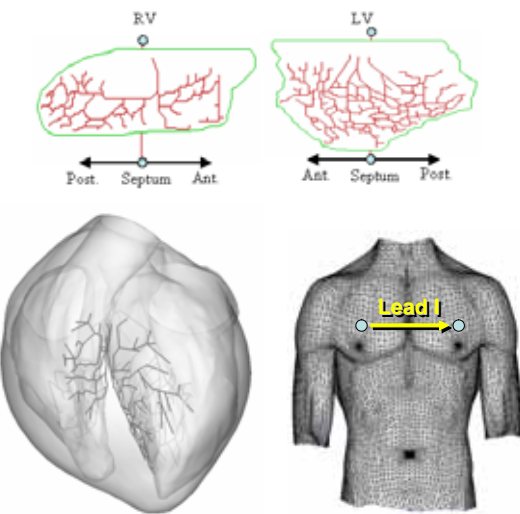
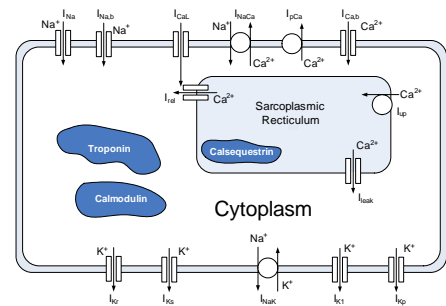
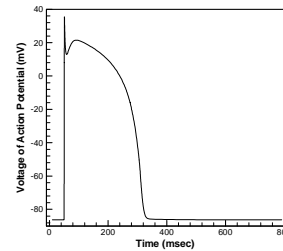


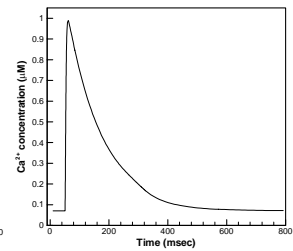
Fig. 4 for the 3D virtual heart



(a) Schematic of the ventricular cell model



(b) Action potential



(c) Free calcium

Fig. 5 Electrophysiological results of ventricular cell.

(SA node) - (AV node)-Purkinje fiber

5(a)

5(b)

Purkinje fiber
 Purkinje fiber

fiber

Purkinje

(5(c)).

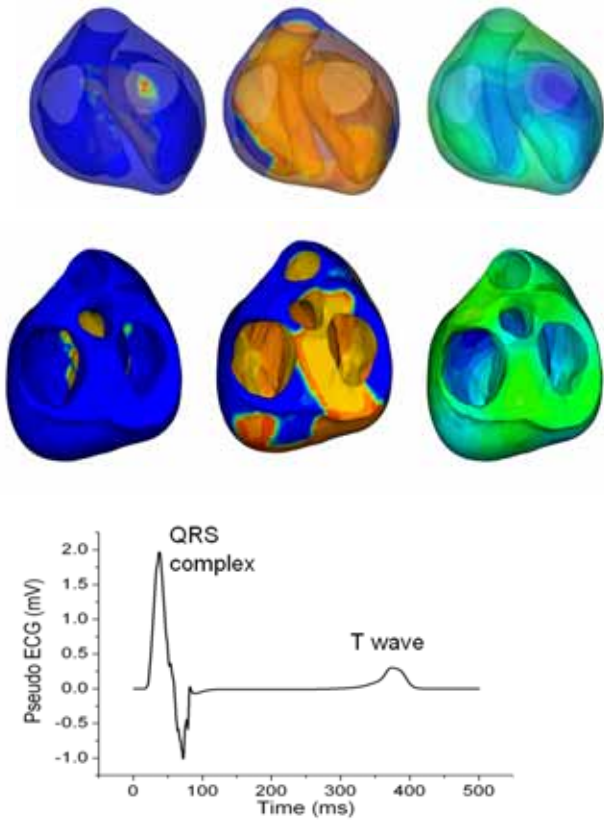


Fig. 6. Electric conduction systems.

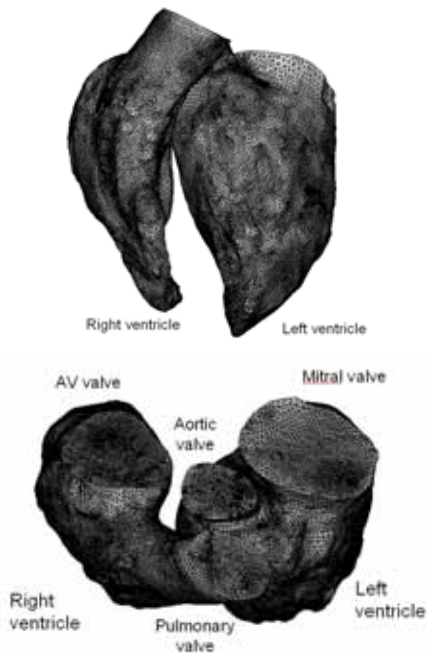


Fig. 7. Schematic of the 3D ventricular model.

6 (depolarization)

6

pseudo-ECG() . 7

7

Mitral valve,
AV(atrio-ventricular) valve,
Aortic valve,
Pulmonary valve

4.

3

가

monodomain

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