A three-dimensional model of the human atria with heterogeneous thickness and fibre transmurality. A realistic platform for the study of atrial fibrillation

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Aims: Multiscale cardiac modelling has been increasingly used since it provides a promising framework to improve our understanding of atrial fibrillation (AF) physiopathology. Atrial wall thickness and fibre transmurality have been suggested to have a significant role in arrhythmogenic dynamics. Thus, in this study, we have developed a highly detailed 3D model of the human atria including those features.

Methods: We improved our previous atrial model by adding an anatomical description of the wall thickness (from 0,5 to 7 mm; mean value of 3 mm) and transmural fibre orientation. The electrical activity was described by a heterogeneous and chronic AF remodelled version of the Courtemanche model. First, propagation in sinus rhythm was validated against experimental local activation times. Then, reentrant activity was simulated by pacing the coronary sinus with a high-frequency ectopic focus.

Results: The presented 3D model has a spatial resolution of 300 µm and is comprised of 1.945.101 hexahedral elements and 2.174.034 nodes. Its fibrillatory activity was compared with two models with the same electrophysiological properties but less anatomically detailed and different propagation patterns were observed. The new model showed a single non-stable rotor moving from the Bachmann's bundle towards the left superior pulmonary vein. On the other hand, a model with homogeneous thickness reproduced a single rotor moving around the superior vena cava while a model with only the wall thickness definition generated three alternant rotors moving around the anterior wall and the pulmonary veins.

Conclusion: Our results suggest that geometrical definition of the model affects atrial activation, especially in arrhythmias, highlighting the importance of using realistic models for AF studies. The new highly detailed model is an excellent tool for gaining insight into AF, allowing to consider new variables of study, like effects of transmurality in fibrosis or ablation.