Left Atrial Appendage Electrical Isolation Reduces Atrial Fibrillation Recurrences

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Left atrial appendage electrical isolation reduces atrial fibrillation recurrences: a simulation study

Gharaviri: Atrial fibrillation recurrences after catheter ablation

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Non-standard Abbreviations and Acronyms:

PV = Pulmonary vein

PVI = Pulmonary vein isolation

AF = atrial fibrillation

(persAF) = persistent atrial fibrillation patients

LAA = left atrial appendage

LAAI = left atrial appendage isolation

CA = catheter ablation

Pulmonary vein (PV) isolation (PVI) improves freedom from atrial tachyarrhythmia recurrences in patients with paroxysmal and persistent atrial fibrillation (AF).[1] However, PVI has a limited success rate in persistent AF patients (persAF) and ablation techniques adjunctive to PVI isolating non-PV triggers remains an area of debate in these patients.[1] Recently, there has been a growing interest in the electrical and anatomical role of the left atrial appendage (LAA) in triggering and sustaining AF, particularly in persAF or after repeated AF ablation procedures.[2] Whether isolation of triggers originating from the LAA or substrate modification caused by LAA isolation (LAAI) is the underlying mechanism for AF recurrence prevention is still unknown.

We investigated the effect of LAAI in a structurally detailed model of the human atria, extensively described previously[3] (supplemental material). The model entails wall thickness heterogeneities, endocardial trabeculated network, and a subepicardial layer with realistic fiber orientations. The material properties for the atria were set to produce an approximately normal P-wave during sinus rhythm (Table S1).

In total, 20 different pacing locations were selected in both atria based on reported possible sources of extra-PV ectopic focal activity in AF patients[4] (Figure).

In each simulation, AF was initiated by applying incremental pacing with the duration of 2 seconds at a selected pacing site. The pacing cycle length started with 280ms and gradually reduced to 124ms. AF initiation likelihood was compared between control (no ablation) and catheter ablation (CA) simulations with different degrees of fibrosis. CA simulations included four groups: PV isolation (PVI), PVI plus linear lesions encircling the left atrial posterior wall (BOX), PVI plus LAA circumferential isolation (PVI + LAAI), and BOX + LAAI. Virtual ablation lesions consisted of tissue volumes modeled by non-conductive elements. The outcome of the stimulation protocol was analyzed in terms of the type of self-sustained rhythm after 2 seconds of stimulations. If no activity was observed, the initiation was considered unsuccessful. Otherwise, a distinction between AF and atrial flutter (AFL) was made (supplemental material), with the latter being considered unsuccessful.

The spatial distribution of fibrosis was uneven, with patches or islands presenting higher degree of fibrosis (Figure S1).[3] Simulations were performed without fibrosis, with moderate fibrosis, and severe fibrosis, in which 0%, 50%, and 70% of elements were fibrotic. [3]

In total, 300 simulations were performed. Each simulation group entails 60 simulations (20 simulations for each fibrosis degree).

In control simulations, an increase in the fibrosis degree led to a significant increase in AF initiation likelihood. In simulations without fibrosis or with moderate fibrosis (which may represent paroxysmal AF patients), PVI and BOX caused a significant reduction in AF initiation likelihood, either by preventing initiation of fibrillation or by converting AF into AFL (Figure). In contrast, in PVI and BOX simulations with severe fibrosis (which may represent persAF) we observed no significant reduction in AF initiation likelihood. In simulations with LAAI on top of PVI or BOX, we observed a comparable reduction in AF

initiation likelihood as in PVI only or BOX simulations in the absence of fibrosis or in the presence of moderate fibrosis. In severe fibrosis, adding LAAI to PVI or BOX further reduced AF initiation likelihood by at least one third.

An increase in fibrosis degree in control simulations led to a significant increase fibrillation wave generation rate and therefore a significant increase in AF conduction pattern complexity, quantified as number of waves per cycle (Figure). In simulations without fibrosis or with moderate fibrosis, CAs caused a significant reduction in fibrillation wave generation rate and AF conduction pattern complexity. In contrast, in severe fibrosis simulations, a significant reduction in wave generation rate and AF pattern complexity was only observed in simulations with LAAI plus PVI or BOX.

In our control group, the averaged AF cycle length (AFCL) was 149ms, value previously reported in AF patients. In simulations without fibrosis or with moderate fibrosis, CAs caused a significant AFCL prolongation (Table S2). In severe fibrosis simulations only the presence of LAAI concomitant with CAs could significantly increase AFCL.

The simulations were performed on a single atrial geometry and inter-subject variability could have effects on simulations results. However, the in-depth study of the atrial anatomy effect on AF initiation is beyond the scope of this study.

We modelled LAAI and investigated its effect on AF recurrences in the presence of different degrees of fibrosis. As presented, adding LAAI to either PVI or BOX significantly lowered AF recurrence rate in severe fibrosis simulations, which is consistent with clinical studies mentioning the significant effect of LAAI in lowering AF recurrence rates in persAF.[2]

Finally, we could demonstrate that the mechanisms underlying AF initiation prevention in the presence of LAAI is not due to isolating triggers in LAA, but rather related to the reduction of AF conduction pattern complexity as a result of substrate modification due to LAAI.

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Figure 1. A) Catheter ablation patterns and pacing points (pacing locations located outside of ablated area were indicated by black stars and the pacing location within the ablated area was indicated by yellow). B) AF and AFL initiation likelihood in control and catheter ablation simulations with different degrees of fibrosis. C) Number of waves per cycle. Wave life span and wave generation rate (the slope of fitted line) in D) control E) PVI F) PVI + LAAI simulations with sever fibrosis.

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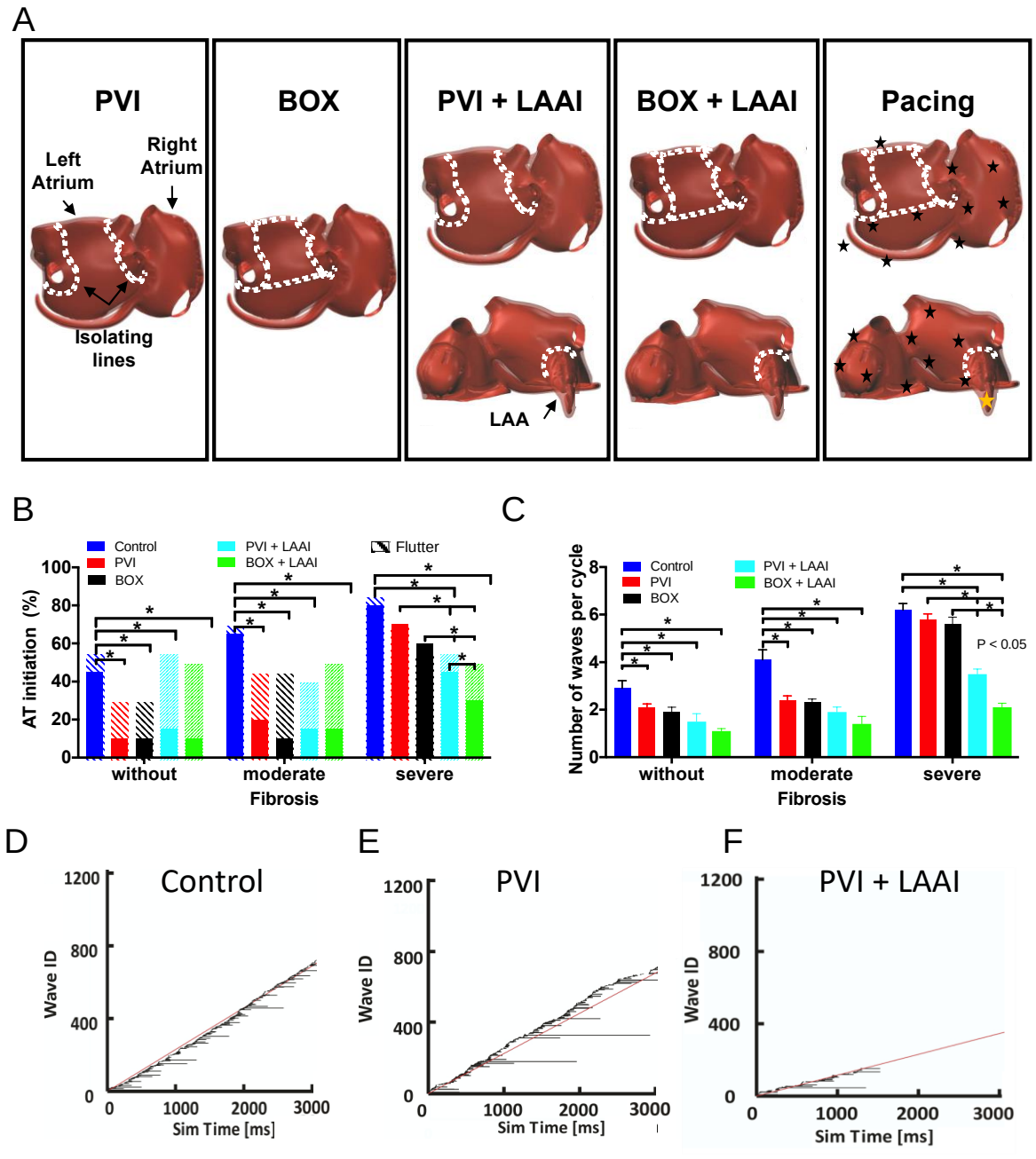

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