Electromechanical Wave Imaging for mitral valve disease characterization in the clinic

Background, Motivation and Objective

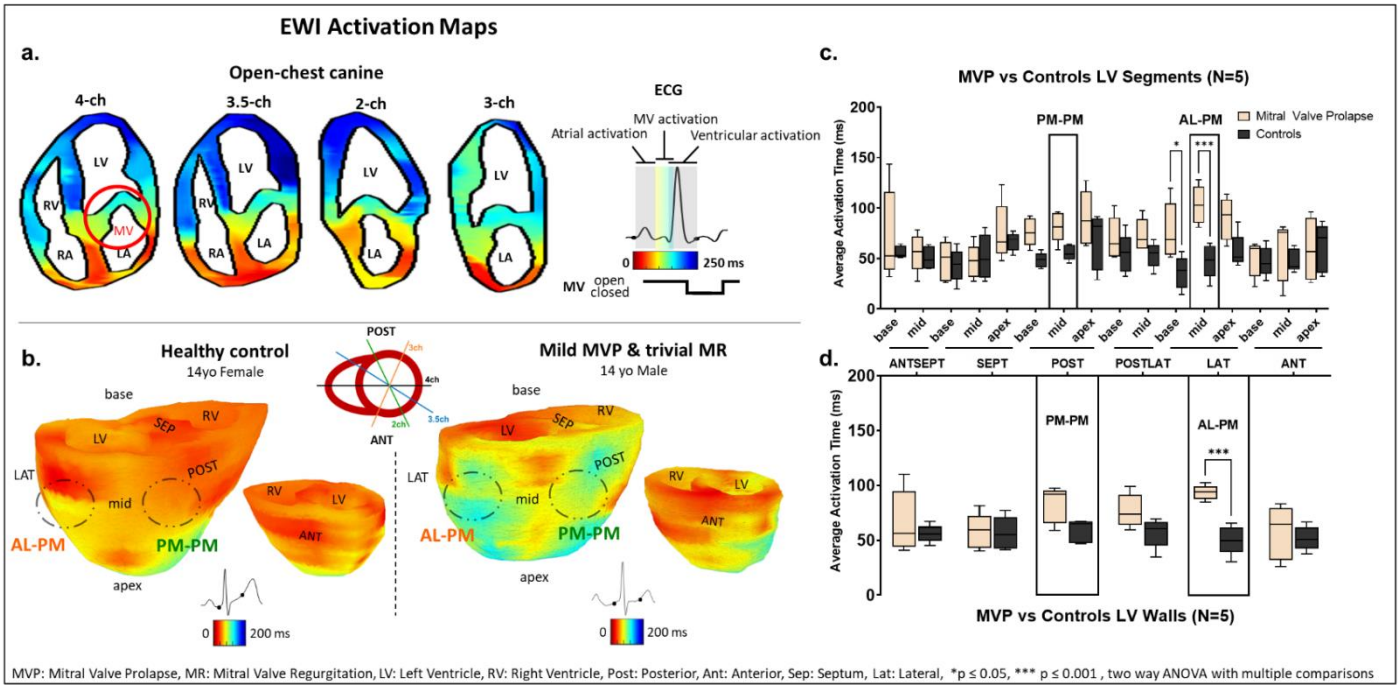
Current clinical echocardiography for Mitral Valve (MV) prolapse diagnosis is operator-dependent, qualitative and unobservant of present electromechanical issues. Literature shows that a timely electrical activation of the MV, following atrial and preceding ventricular activation, the left ventricular (LV) papillary muscles (PMs) and adjacent tissue prevents MV prolapse (MVP) and undesired regurgitation (MR). Electromechanical Wave Imaging (EWI) is a high frame rate ultrasound modality that noninvasively maps the electromechanical (EM) activation in all cardiac chambers. This study assesses the activation of the MV region using EWI.

Statement of Contribution/Methods

One open-chest healthy mongrel canine (31kg) was imaged with 2D EWI (2000 Hz single diverging wave at 14cm) in apical views (4-,3.5-,2-,3-chamber) on a Vantage 256 with a 2.5 MHz P4-2 phased array and 3-lead ECG recording. In the clinic, five MVP pediatric subjects of varying MR and five age-matched controls (13±4.8 yo, 4 male) were imaged with the same sequence. Axial displacements were estimated using 1D RF crosscorrelation, EM interframe strains were derived with a 5 mm least squares kernel, generating 2D 4-chambered and 3D rendered EWI ventricular activation isochrones for the canine and the human study, respectively. Mean EM activation times are calculated for the canine MV and pediatric LV walls (ANTSEPT, SEPT, POST, POSTLAT, LAT, ANT), for mid, basal, and apical segments. Mid-LAT/mid-POST walls concur with the anterolateral (AL)/ posteromedial (PM) LV PMs and full LAT and POST walls form the surrounding tissue.

Results/Discussion

EWI successfully imaged the MV EM activation across all views in both studies. A mean MV EM activation delay of 83.57 ms (82 ms electrical value, .02% error) was found interjected between atrial and ventricular activation (Fig 1a). In the clinic, MVP subjects exhibited later LAT and POST wall EM activation, against controls (Fig. 1b, d). Mean MVP EM activation was higher in AL-PM and PM-PM LV mid areas across all subjects (Fig 1c, AL-PM: 103±19 vs 48±17 ms, p=.0006, PM-PM: 82±15 vs 56±8 ms p =.4). We introduced a first-of-its-kind, novel approach for MV EM activation imaging and MVP detection in vivo, illustrating the electrical and valvular cardiac system' interconnectivity, providing a more holistic and objective diagnosis of heart valve disease with echocardiography.



MVP: Mitral Valve Prolapse, MR: Mitral Valve Regurgitation, LV: Left Ventricle, RV: Right Ventricle, Post: Posterior, Ant: Anterior, Sep: Septum, Lat: Lateral, *p ≤ 0.05, *** p ≤ 0.001 , two way ANOVA with multiple comparisons