

Quantification of 3-directional Motion of Papillary Muscle Using Tissue Velocity Mapping in Patients with Mitral Valve Prolapse

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INTRODUCTION:

Mitral valve prolapse (MVP) is a common disorder affecting 2-3% of the general population. MVP is defined by mitral valve leaflet systolic excursion of more than 2 mm into the left atrium (1). Classic MVP is characterized by thickened and elongated (sometimes flail) leaflets, and thickened chordae tendinae. We have previously shown that some MVP patients have fibrosis/scar in the tip of the papillary muscles identified by late Gadolinium enhancement MRI, presumably due to chronic excess tension generated by the mitral leaflets (1). The 3D motion of papillary muscle has not been previously studied in humans and may advance our understanding of the mechanical stress imposed on the papillary muscles, an important variable in mitral regurgitation progression and/or fibrosis generation. In this study, we sought to investigate the feasibility of high spatial and temporal resolution MR tissue velocity mapping to study the 3D motion of papillary muscle and its velocity in MVP patient as well as healthy adult subjects.

METHODS:

Subjects: Six MVP subjects (age 50 ± 12 years, 4 males, BSA 1.8 ± 0.2 m²) with different degrees of mitral regurgitation (Mreg) (median: moderate Mreg) and four healthy adult subjects (age 20 ± 1 years, 2 males, BSA 1.8 ± 0.2 m²) were studied. All images were acquired on a 1.5T Philips Achieva (Philips, Best, the Netherlands) using 5-element phased array coil. The study were approved by our institutional IRB.

Imaging Techniques: Left ventricular (LV) function and aortic flow was evaluated in each subject by acquiring short axis cine SSFP slices along the LV and a phase contrast velocity map in ascending aorta. A single 2D slice were chosen from the breath-hold cine SSFP LVOT view stack as previously described (1), which captures the anterolateral papillary muscle in the entire cardiac cycle. A free-breathing cine SSFP image with three averages were acquired at this slice level to determine the visibility of the papillary muscle with free breathing. Subsequently, a free-breathing 2D tissue velocity imaging sequence were acquired with sensitivity to motion in all three directions. The imaging parameters for phase contrast were as follows: TR/TE/α=4.5/6.8/15°, FOV= 330x309 mm², slice thickness of 8 mm, waster-fat shift of 0.57, voxel size of 1.8x1.8x8 mm³, temporal resolution of 27.1ms, velocity encoding of 30 cm/s with three repetitions. **Analysis:** All images were transferred to the MR cardiac analysis software ViewForum (Philips Medical Systems, Netherlands) workstation for analysis. Analysis of LV function and volumes are as described (1). Region of interest on the tip of papillary muscle were drawn on the magnitude images and its location were copied into all the velocity maps. Only systolic motion was analyzed because prolapse occurs in systole where the stretch on the papillary muscle occur. The magnitude of mean maximum systolic velocity (PapVel) was calculated by taking the magnitude of the vector velocity in three directions. Univariate analysis are performed on the following variables with PapVel as the outcome variable: age, gender, body surface area, LV end_diastolic dimension index (LVEDDI), LV end_systolic dimension, LV end_diastolic volume (LVEDV) index, LV mass index, Mreg volume, Mreg fraction, and Mreg category. Eff_EF is calculated by aortic total flow volume/LVEDV, Mreg fraction is calculated by Mreg volume/LV stroke volume. Mreg category was determined from Mreg fraction into none, mild, moderate, moderate to severe, and severe groups (2).

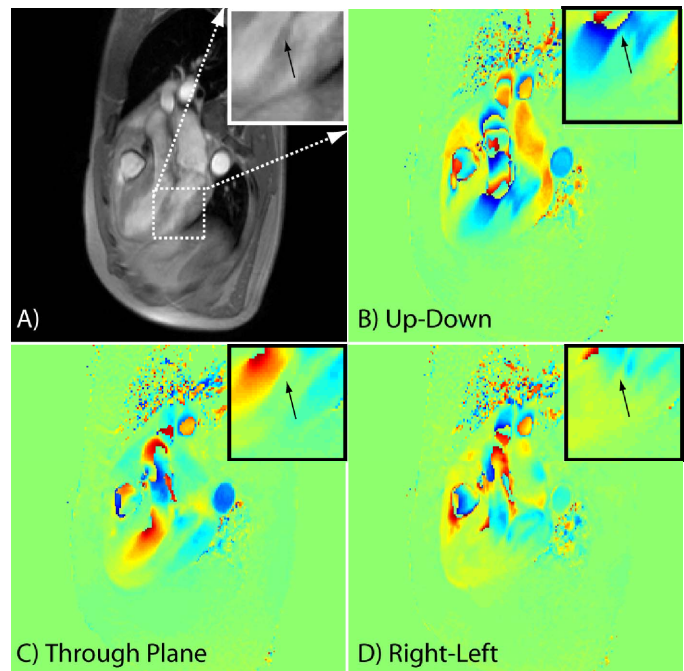


Figure 1: Phase contrast magnitude image of a MVP patient, shown in systole, with corresponding velocity images in three directions. Arrows point to the region of interest where 3 dimensional motion of the antero-lateral papillary muscle can be visualized and quantified.

RESULTS:

Figure 1 shows the magnitude (A) and tissue velocity maps (C-D) of the antero-lateral papillary muscle acquired in a MVP patient in systole. Three direction of motion can be measured in the antero-lateral papillary muscle with predominant motion in up-down orientation in the imaging slice orientation. The statistical analysis in this cohort of MVP patients demonstrates an increased maximum mean velocity of the tip of the papillary muscle in MVP patients (15.1 ± 5.8 cm/s versus 6.5 ± 1.5 cm/s, $p = 0.014$) during systole. Univariate linear regression showed that PapVel is correlated to MVP status ($p=0.022$), eff_EF ($p=0.024$), Mreg fraction ($p=0.04$), and Mreg category ($p=0.028$).

CONCLUSIONS:

We demonstrated the feasibility of high spatial and temporal resolution tissue velocity mapping to quantify motion of the papillary muscle in all three directions (anterior-posterior, foot-head, and right-left). Our preliminary data show that MVP patients have increased tip papillary muscle velocity during ventricular systole. A larger population of patients is required to further evaluate this technique and determine if this measure is correlated with progression of mitral regurgitation and/or papillary muscle fibrosis.

REFERENCES:

[1] Han, Y., et al. JACC Img 2008, 1(3); 294-303 [2] Gelfand EV, et al. J Cardiovasc Magn Reson 2006;8:503-7.