Tissue phase mapping analysis of myocarial function after heart transplantation

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Introduction: The outcome of heart transplantation (HTX) depends on an early diagnosis of transplant rejections. However, myocardial biopsies, the gold standard for the diagnosis of rejection, are invasive and suffer from a high sample error especially in the beginning of disease. Therefore, there is need for non-invasive diagnostic tools for an early detection of HTX rejection before global cardiac function is irreparably damaged. In recent years, the LV rotation after HTX has gained increased interest. It has been shown that the twist (basal minus apical rotation) strongly correlates with myocardial contractility [1] and that diastolic untwist is closely linked to active relaxation as it produces an intraventricular pressure gradient creating the suction that is essential for optimal chamber filling [2]. In addition, it seems that HTX rejections go along with a reduction in LV twist [3,4]. However, even without rejection this motion component might be altered after HTX at rest and exercise [5] due to fibrosis or denervation. Recently, we demonstrated differences in radial and long-axis myocardial motion in HTX recipients (n=9) using Tissue Phase Mapping (TPM) [6]. The aim of our study now was to analyze in addition rotation and twist in HTX patients (n=14) without signs of rejection. We compared the results with an age-matched cohort of healthy volunteers (n=20).

Methods: 3 short-axis slices (base, mid, apex) of 14 patients after HTX (age=50±12, years between HTX and measurement 3.2 ± 2.5) and 18 age-matched volunteers (age=51±4) were acquired at a 1.5T Sonata and a 3T Trio system (Siemens). A black-blood prepared gradient echo sequence was used (temporal resolution 13.8 – 24.0 ms; spatial resolution 1.3×2.6 - 2.4×2.9 mm; slice thickness=8mm; *venc*[in-plane]=15cm/s, *venc*[through-plane] =25cm/s) with prospective ECG gating and navigator respiration control [7] or during breathhold [8].
Data post-processing (Matlab) included manual segmentation of the LV contours and a transformation of the measured velocities (v_x,v_y,v_z) into radial (v_r), rotational (v_φ) and long-axis (v_z) velocities adapted to the LV anatomy. For v_r and v_z, global (averaged over the entire slice) and segmental (according to AHA 16-segment model) systolic and diastolic peak velocities were derived. The LV rotation angle φ was calculated over time for each slice according to $\varphi(t) = \sum_t v_\varphi(t)/r(t)$, where r is the mean LV radius at the time frame t. The twist angle is then $\varphi_{Twist} = \varphi_{Base} - \varphi_{Apex}$. The maximum rotation angle was determined for the basal and the apical slice as well as the early systolic peak rotation angle (see arrows in Fig.3) All results were compared to the healthy volunteers using un-paired t-tests (*p<0.05;**p<0.01).

Results: Systolic and diastolic long-axis peak velocities of HTX patients are reduced in most segments compared to volunteers (see Fig.1). Especially in infero-lateral and inferior regions, the differences are significant in basal, midventricular and apical slices. The mean values of peak velocities confirm this result (see Fig. 2) and show significant divergences in base and middle. The rotation angle of the apex is slightly higher in volunteers compared to HTX patients (Fig. 3); however, all differences are statistically non-significant. There is almost no difference of the twist. A significant deviation could be observed at early systole at the base with a higher peak of counterclockwise rotation in volunteers compared to patients after HTX (see Fig 4 and arrows in Fig. 3).

Discussion: Using TPM, we could find slightly reduced apical (non-significant) and significantly altered early systolic rotation in the basal slice location at rest in patients after HTX. No difference could be observed for the twist which is in concordance with earlier literature [5]. The segmental analysis revealed a significant decrease of the long-axis velocities particularly in the inferior and infero-lateral segments (Fig.1) corroborating the importance of a segmental analysis provided by TPM data.
One study limitation is given by the fact that the control group was age-matched to the recipients group – a comparison to the donator-matched group as well is of importance since it is known that rotation and twist depends on age [9] as well as radial and long-axis velocities [10]. However, a systematic description of rotation and twist in the transplanted adult heart as well as a comparison between MRI methods (e.g. TPM) and Echocardiography (e.g. Speckle Tracking) is still lacking but is an essential base for further studies of HTX rejection. As fibrosis, denervation, immunosuppressive agents are factors which might affect myocardial function over time after HTX, follow-up studies including the time after HTX are necessary to evaluate the value of rotation in these patients. TPM therefore might help to improve the follow-up of patients after HTX in future.

References: [1] Hansen et al. *Circ Res* 1998;62:941–52. [2] Notomi et al. *Circulation* 2006;113:2524-33. [3] Hansen et al. *Circulation* 1987, 76:998-1008. [4] Sato et al. *Heart Lung Transplant* 2011;30:536-43. [5] Esch et al. *J Physiol* 2009;587:2375–86. [6] Foell et al. *ISMRM* 2011;p2366. [7] Jung et al. *MRM* 2006;55:937-42. [8] Jung et al. *MRM* 2008; 60:1169-77. [9] Notomi et al. *Circulation* 2006;113:2534-41. [10] Foell et al. *Circ Cardiovasc Imaging* 2010;3:54-64.

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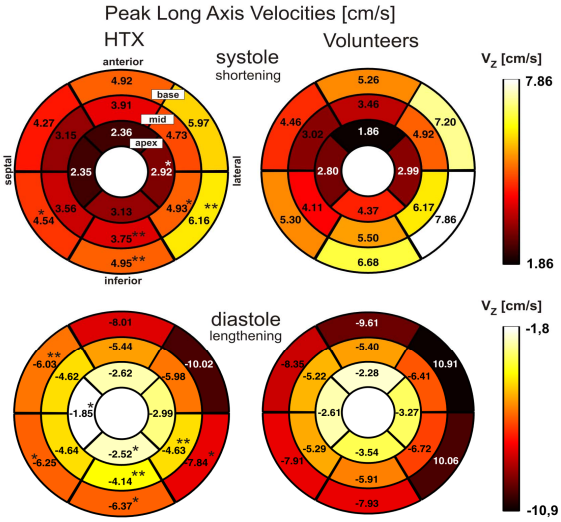

Fig. 1: Comparison of segmental long-axis peak velocities of the LV in systole (upper plots) and diastole (lower plots). The data represent the mean values over all volunteers and HTX patients.

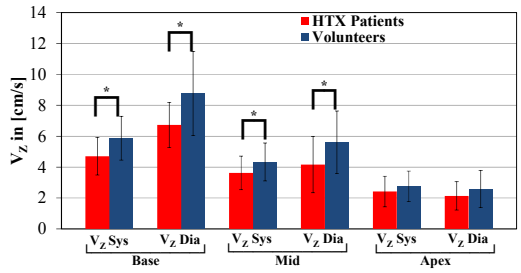

Fig.2: Comparison of mean peak long-axis velocities for each slice over all HTX patients and volunteers.

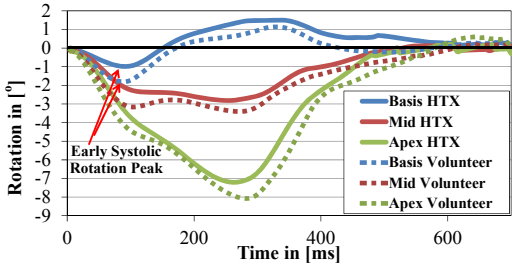

Fig. 3: Mean rotation over time of HTX patients and volunteers. Red arrows indicate the early systolic rotation peak in the base of the left ventricle.

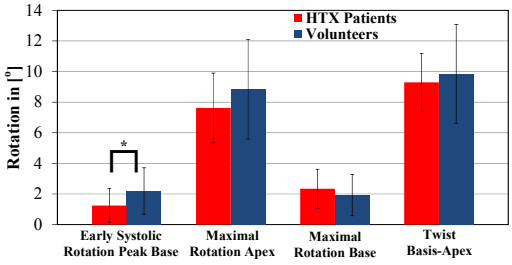

Fig. 4: Comparison of mean peak rotation for base and apex over all HTX patients and Volunteers. The twist is the difference between the base and apex