New approach for assessment of human cardiac shunts using rapid 1H MR T1 mapping in combination with inhaled pure oxygen

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Introduction: Quantification of human cardiac shunts is usually performed using noninvasive echocardiography or invasive catheterization by measuring oxygen content in heart chambers and great vessels. Moreover, phase-contrast MRI techniques have been recently established for clinical use. As an alternative, we report a new, noninvasive approach using a rapid oxygen-enhanced ^{1}H MR T_1-mapping technique (1).

Methods: Three healthy volunteers and three patients with cardiac shunts, one with the right-to-left ventricular septal defect (VSD) and persistent ductus botalli, and the others with the left-to-right atrial septal defect (ASD), were examined on 1.5-T VISION, Siemens. T_1 maps based on an IR snapshot FLASH technique (1) were acquired in the heart in combination with breathhold on end-expiration while the subjects breathed 21% oxygen (room air) and 100% oxygen (pure oxygen) respectively. ROIs including 30 pixels were drawn in all heart chambers and great vessels to measure blood T_1. The measured blood $1/T_1$ (mean ± SD) was plotted as a function of inhaled oxygen concentrations and the slope, oxygen transfer function (OTF), was calculated (2). Molecular oxygen physically dissolved in blood is weakly paramagnetic and acts as a T_1-shortening contrast agent. Thus, it is possible to obtain information about oxygen content in blood using molecular oxygen as a tracer substance.

Results: As a representative example, Figure 1(a) and 2(a) depict a T_1 map in a 4-chamber view and a transversal T_1 map in the 39-year-old female patient with right-to-left VSD and persistent ductus botalli while breathing room air. Figure 1(b) and 2(b) show the plots of blood $1/T_1$ vs. oxygen concentration in all heart chambers and aorta. The blood in the right atrium and right ventricle show OTF of approximately 0 s^{-1} also observed in the healthy volunteers. However, compared to OTF of 0.14 s^{-1} in the left atrium also observed in the healthy volunteers and 0.04 s^{-1} in the ascending aorta, the blood in the left ventricle and descending aorta show abnormally decreased OTF of 0.06 s^{-1} and 0 s^{-1} respectively. This is consistent with the results from the catheterization in this patient. In summary, the blood in the left ventricle was "less arterial" than the blood in the left atrium and therefore is mixed with the venous blood from the right ventricle via the right-to-left VSD. The blood in the descending aorta was "less arterial" than the blood in the ascending aorta and therefore is mixed with the venous blood from the pulmonary artery via persistent ductus botalli.

Discussion: New, noninvasive assessment of human cardiac shunts was successfully demonstrated using a rapid oxygen-enhanced ^{1}H MR T_1-mapping technique. This method directly depicts shunt effects via oxygen physically dissolved in blood as a contrast agent and is sensitive enough to detect all kinds of cardiac shunts. It has the potential to provide qualitative information before and after occlusion of the defect without the need of catheter. Future work will concentrate on quantitative determination of shunt volume.

References:

1. Deichmann R, et al. J Magn Reson 1992;96:608-612.
2. Jakob PM, et al. Magn Reson Med, submitted.

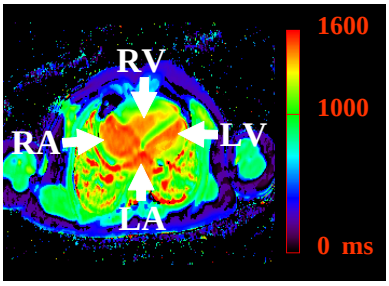

Figure 1(a)

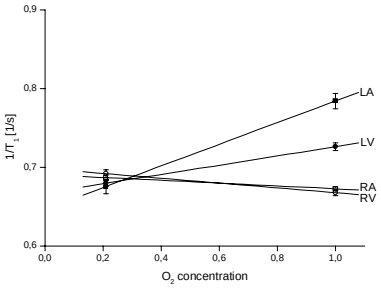

Figure 1(b)

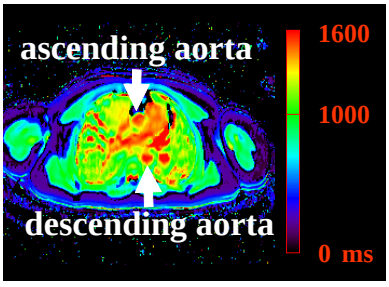

Figure 2(a)

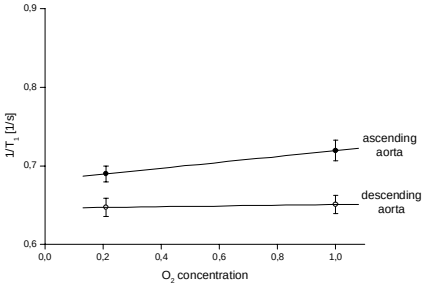

Figure 2(b)

Figure 1. (a) T_1 map scaled from 0 to 1600 ms in a 4-chamber view in a 39-year-old female patient with right-to-left VSD and persistent ductus botalli while breathing room air. RA and RV stand for right atrium and ventricle, LA and LV for left atrium and ventricle. (b) Plot of blood $1/T_1$ vs. oxygen concentration in all cardiac chambers from Figure 1(a). OTF of 0.14, 0.06, -0.02, and -0.03 s^{-1} were measured in LA, LV, RA, and RV, respectively.
Figure 2. (a) Transversal T_1 map scaled from 0 to 1600 ms in the same patient while breathing room air. (b) Plot of blood $1/T_1$ vs. oxygen concentration in the ascending and descending aorta from Figure 2(a). OTF of 0.04 and 0 s^{-1} were measured in the ascending and descending aorta respectively.