Assessment of Myocardial Perfusion Reserve with Blood Oxygen Level-Dependent Cardiovascular Magnetic Resonance Imaging

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Background: New Blood Oxygen Level-Dependent Cardiovascular Magnetic Resonance Imaging (BOLD-CMR) sequences show a high sensitivity and consistent image quality that allows for assessing tissue oxygenation. We hypothesized that BOLD-CMR can quantitatively assess myocardial blood flow changes using myocardial oxygenation as a biomarker.

Objective: To test whether a BOLD-CMR sequence accurately estimates myocardial perfusion changes.

Methods: Six anesthetized mongrel dogs were instrumented with a coronary infusion catheter in the circumflex coronary artery (LCX), an MR-compatible epivascular flow probe around the LCX and a catheter in the coronary sinus. Using a clinical 1.5 T MRI system (MAGNETOM Avanto, Siemens Healthcare, Germany), SSFP BOLD-CMR was performed during graded intracoronary infusion of adenosine in the LCX. Typical scan parameters were: Field-of view (FOV) 190x280 mm; matrix size 106x192; slice thickness 10 mm; T_R/T_E 5.8/2.9 ms; flip angle 90º; typical breath-hold duration 14s. Images were analyzed using clinically validated software (cmr[42], Circle Cardiovascular Imaging Inc., Calgary, Canada) and the BOLD signal intensity (SI) for each was calculated. Correlations of coronary flow, oxygen saturation in the coronary sinus and myocardial BOLD-CMR signal intensity (BOLD-SI) changes were calculated by regression analysis. The same CMR imaging protocol was used in 11 healthy volunteers (6 male, 5 female) before, during and after intravenous adenosine infusion (140 ⌠g/kg). Myocardial perfusion reserve in the human volunteers was calculated from flow measurement in the coronary sinus using velocity-encoded CMR.

Results: In dogs, adenosine-induced blood flow changes in the LCX agreed very well with changes in coronary venous saturation (logarithmic scale, r^2=0.94, p<0.001). Furthermore, coronary venous saturation showed a strong yet linear correlation with BOLD-SI changes (r^2=0.80, p<0.001). Consequently, as shown in Figure 1, blood flow changes correlated very well with the BOLD-SI (r^2=0.84, p<0.001). The exponential correlation is described by the equation (y) = $98.3+25.4*(1-e^{-0.0017x})$ (x=flow, y=BOLD-SI). In the volunteers, adenosine infusion resulted in a significant myocardial perfusion increase (416±69% of baseline, p<0.001). BOLD SI increased significantly by 20.1±9.5% (p<0.001 as compared to baseline). The reproducibility of the BOLD-SI in the two baseline measurements before and after adenosine infusion was excellent (mean difference 0.1±2.6%, p=0.97).

Conclusion: State-of-the-art BOLD-sensitive MRI sequences detect changes of myocardial perfusion in an experimental animal model and in humans in vivo. This technique may allow for an accurate, non-invasive assessment of myocardial perfusion reserve in humans.

Figure 1: Blood flow changes and BOLD-SI in canine model under adenosine infusion.