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Effects of myoglobin oxygenation on oxygenation-sensitive cardiovascular magnetic resonance images: an in-vitro study

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Background: Haemoglobin (Hb) is an O2-binding transport protein with variable magnetic properties depending on its oxygenation status. Oxygenation-sensitive (OS-)CMR sequences (T2-, T2*-mapping and bSSFP sequences) can discriminate the oxygenation status of Hb, thus Hb can be used as an intrinsic contrast agent (blood oxygen level-dependent (BOLD) effect). Myoglobin (Mb) also binds and transports O2 in skeletal and heart muscle fibres and shares structural and functional similarities with Hb. The impact of Mb oxygenation on OS-sequences is yet unknown.

Purpose: The aim was to determine if Mb oxygenation of in-vitro samples has an impact on OS-images in clinically used CMR sequences.

Methods: Equine metMb powder was dissolved in water (14.4 mg/mL) and reduced to deoxygenated Mb (dMb) using excess sodium dithionite (Na2S2O4). With a desalting column the dithionite was separated from dMb, which then spontaneously oxygenated to MbO2 at room air. Light-spectroscopy was used to confirm the presence of MbO2. Oxygen concentration from ambient air (20%) was reduced down to 0.4% to assure the patency of Mb. Ten samples were scanned in a 3T clinical MRI system (Siemens Magnetom PRISMA), all within a single imaging plane. A T2 map (FLASH), a T2* map and an OS-bSSFP sequence were modified to obtain a spatial resolution <0.5mm. 50 mL gaseous O2 and N2 were bubbled through the samples in the MRI and lastly dissolved dithionite was added to irreversibly deoxygenate to dMb. CMR images were acquired for each state.

Results: Light spectroscopy yielded the characteristic double peaked optical density (OD) maxima for MbO2 (545nm and 580nm) with room air, which transformed into a single-peaked OD maxima curve for dMb (550nm) with decreasing oxygen concentration. As seen in the Figure, T2 and T2* were significantly shortened in the dMb samples compared to MbO2 samples (MbO2: T2 180 ± 41ms, T2* 101 ± 39ms) following deoxygenation with N2 (dMb: T2 135 ± 23ms, T2* 58 ± 18ms) and dithionite (dMb: T2 117 ± 14ms, T2* 57 ± 10ms, *p < 0.01). The bSSFP OS-CMR sequence showed no significant SI changes between Mb oxygenation states. Although T2* maps were generally more artefact prone, they showed greater relative changes between the oxygenation states of Mb than T2 maps. Conclusion: Using an in-vitro model, altering oxygenation states of Mb resulted in measurable changes in both, light spectrometry and oxygenation-sensitive CMR images, specifically T2 and T2* mapping. Our study indicates that the Mb molecule has a BOLD-like effect. It is now warranted to study its potential confounding or augmenting role in diagnostic OS imaging.

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