Title: Differentiation of blood clot hematocrit and age in vitro using $R_2^*$ and quantitative susceptibility mapping at 3T

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Structured Abstract:

Introduction: Knowledge of thrombus composition and age may aid treatment of ischemic conditions such as stroke, heart attack and pulmonary embolism by predicting the efficacy of common recanalization therapies. Current MR-based thrombus characterization methods rely on a "susceptibility vessel sign" obtained from late-echo gradient echo (GRE) images, a qualitative metric sensitive to deoxygenated red blood cells (RBCs), but unable to distinguish between the effects of RBC concentration (hematocrit) and deoxygenation (associated with thrombus aging). This work evaluates the ability of $R_2^*$ and quantitative susceptibility (QS) maps to quantitatively distinguish between clots of varied hematocrit and age in vitro.

Methods: Phantom- Arterial porcine blood was used to create blood samples of 10, 20, 30, 40, 50 and 60% hematocrit. Samples were clotted inside 1cm diameter polystyrene tubes, inserted into an agar-filled container and kept at 37°C except while scanning. The phantom was scanned without repositioning every 15 minutes up to 6 hours post clotting, and then at time points of 22 and 26 hours and 2, 3 and 6 days. Imaging- Scans were performed at 3T with a 32-channel head-coil using a custom dual echo-train 3D GRE sequence ($TE_1/\Delta TE/TE_5 = 3.20/1.46/9.04$ ms, $TE_6/\Delta TE/TE_10 = 45.35/16.75/7.15$ ms, TR: 47.6 ms, resolution: 0.94x0.94x1 mm$^3$, matrix: 192x192x40, BW: 142.86 kHz, flip angle: 10°, scan time = 6 min 10 sec). Image post-processing- Channel-combined complex data were processed using the B0-NICE and MEDI QS algorithms[1,2] to calculate $R_2^*$ and QS maps, respectively. Matlab was used to determine mean clot $R_2^*$ and QS values.

Results: Clot $R_2^*$ values increased slowly (< 0.5 1/s•hr) over the first 6 hours. Between clots, measured $R_2^*$ values were proportional to hematocrit but plateaued at high hematocrit (≥ 40%). QS values were linearly proportional to clot hematocrit and remained constant throughout the 6-hr period. Clot $R_2^*$ increased rapidly (up to 4.0 1/s•hr) over the next 40 hours of aging, and the similarity between high hematocrit clots remained. QS values also increased over the next 40 hours before reaching a plateau, and varied linearly with hematocrit at every time point. When $R_2^*$ is plotted against QS values for all clots from 6 to 144 hours of aging a linear relationship with a unique slope is observed for all clots (decreasing from 336 to 190 1/s•ppm as hematocrit increases from 10 to 60%).

Discussion: Because values remained low and changed little with time, fresh blood clots (< 6 hrs after formation) of up to 60% hematocrit can be differentiated using $R_2^*$ or QS alone. Between 6 and 144 hours clot $R_2^*$ and QS values both increased greatly, hindering the ability of either measure alone to estimate hematocrit in a thrombus of unknown age. However, examining $R_2^*$ and QS simultaneously allowed clots of different hematocrit to be distinguished at any age.