Responsiveness of BOLD MRI to Short-Term Temperature Changes of the Rabbit Knee Joint in Inflammatory Arthritis

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Abstract

The purpose of this study was to test the BOLD (Blood Oxygen Level Dependant) MRI responsiveness of articular knee joint tissue to short-term temperature variations in rabbits. BOLD MRI measurements were obtained for high and low intraarticular temperature and by polarographic probe data (pO_2, representing intraarticular tissue oxygen tension).

Introduction

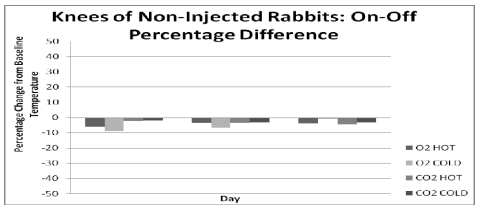
The purpose of this study was to show how tissue oxygenation levels are behaving in relation to temperature changes. Three different types of media were considered in terms or the arthritis effect – nonexistent, minimal and maximal.

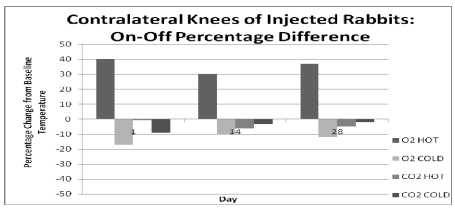
Methods

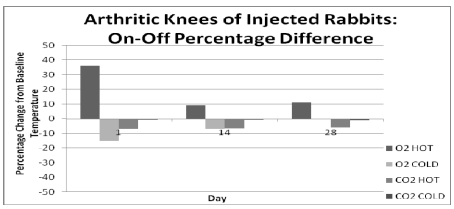
Arthritis was induced by intraarticular administration of carrigennin (0.5cc/kg) to the male juvenile New Zealand rabbits. There were 21 contralateral, 21 arthritic and 9 non-injected knees used in the study – a third of each group per day of euthanasia. Each group was scanned for the high and low temperatures on day 1, 14 and 28 and all were scanned on baseline. The stimulants for BOLD MRI were 100% Oxygen and Carbogen (95% Oxygen, 5% Carbon Dioxide). The BOLD MRI measurements (on-off signal differences and percentages of activated voxels) obtained at baseline, at high (40 + Celsius) and at low temperatures (32 - Celsius). Both stimuli were used in all cases with paradigms of 60 seconds for the carbogen inhalation and 30 seconds for the full oxygen inhalation. The rabbits were placed in the MRI room in supine position. The surface circular coil (3 inch diameter) was placed to enclose both knees. Imaging was performed on a 1.5 Tesla GE Scanner running two sequences with RF pulse (TR/TE/FlipAngle/bandwidth/field of view: 2000ms/40ms/90^o/62.50/10cm – 1 NEX) to acquire 7 T_2*-weighted images. Slice thickness was 3.0 and frequency was 64 with a phase of 256. The image acquisition time was 6 minutes 14 seconds. The rate of spin dephasing R_2* was used as a BOLD parameter. R_2* maps were reconstructed in UNIX environment. Internal and external responsiveness were evaluated. The internal responsiveness was assessed by calculating standardized response mean (SRM) [2]. This is the ratio of the *difference between increased or decreased temperature and the baseline temperature BOLD measurements* and *the standard deviation of this difference*. Values of >0.8 change were considered to represent large changes, <=0.8 and >0.5 moderate changes, and <=0.5 and >0.2 small changes [3]. This ratio was evaluated using paired T-tests. The external response was assessed by measurement of the Pearson coefficients, (r-values) between the BOLD MRI parameter and polarographic probe intraarticular pO_2 at the aforementioned time-points. P-values < 0.005 were considered statistically significant[4].

Results

With regard to internal responsiveness, the change was as expected for contralateral and arthritic knees. With increased temperature the BOLD signal intensity increased (by 30%) with full oxygen as a stimulant, and with decreased temperature it did the opposite (by 20%). This did not happen with carbogen – there was a decrease in signal for both high and low temperatures – compared to the baseline. However in the non-injected rabbits' knees the behaviour of BOLD MRI measurements was as in the reduced temperature in both situations. Using high thresholds and on_off_differences for data analysis, moderate responsiveness (SRM <=0.8 and >0.5) was only demonstrated in contralateral knees using100% O2 and 30 sec of time paradigms as technical sets for data acquisition. With regard to external responsiveness, there was a high negative correlation between intraarticular pO_2 and BOLD measurements for the carbogen stimulant, namely for increased temperature r = -0.97, P = 0.04 and for decreased temperature r = -0.98, P = 0.02.







Conclusion

BOLD MRI has the potential to assess local tissue oxygen levels as dependent on local temperature with most significant responsiveness changes noted in the knee contralateral to the knee where arthritis was induced. Physiologic compensatory mechanisms in the contralateral joint may explain these results. Larger responsiveness changes were noted with full oxygen as a stimulant. Further assessment of responsiveness of BOLD MRI in arthritic joints with higher magnetic field scanners may confirm the current results and enhance potential changes.

References

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