Temperature Distribution Changes in Low Back Muscles during Applied Topical Heat: A Magnetic Resonance Thermometry Study

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Introduction: A common treatment for low back pain is topical heat therapy involving sustained contact of the lower back with a temperature source in the 38 to 40 C range (1). The mechanism of pain relief from topical heat treatment involves presynaptic inhibition of nociception in the dorsal horn of the spinal cord, i.e. "gate control" (2). In addition, the temperature distribution among muscles in the lower back will play an important role in relieving muscle spasms and increasing blood flow to enhance the healing response. Magnetic Resonance Thermometry (MRT), which uses the sensitivity of the water resonant frequency to temperature (3), appears well-suited to non-invasively measure temperature distribution changes among muscles in the lower back during topical heat therapy. As such, MRT may prove useful as a tool for studying mechanisms underlying successfull topical heat therapy. Here we explore the feasibility of monitoring changes in the temperature distribution among the lower back muscles of volunteers subjected to mild topical heating during MRT studies.

Materials and Methods: Nine studies with 6 healthy adult volunteers were performed during the course of this study. Volunteers were placed supine in a 1.5 T scanner (General Electric Medical Systems, Milwaukee, WI) with their lower backs resting on a water flow-through rubber pad. Water temperature was controlled with two heat pumps circulating water through the pad. Two constantan-copper thermocouples were placed under the lower back and used to monitor local pad/skin temperatures at two locations. A gradient echo sequence with FA/TR/TE = 30/100/28 ms, FOV of 38 cm, and slice thickness 10 mm, was used to collect axial images through the lower back at three separate slices in 18 s scan times. Volunteers were instructed to breathe shallowly and, if possible, maintain breatholds during the 18 s acquisitions. The three slice acquisitions were repeated every minute for 30 to 40 minutes as the water temperature was cycled to obtain skin/pad temperatures between approximately 32 C to 40 C and then back down to 32 C. Phase and magnitude images were reconstructed from the data and subtraction of phase images acquired at high temperatures from pre-heating baseline images were used to generate temperature difference images assuming a -0.008 ppm/C water frequency shift (4,5).

Results: Figure 1 shows an axial magnitude image displaying a portion of the gluteus musculature in which three muscle locations are shown at increasing distances from the heated surface. The plot below the image shows the temperature as a function of time from each of these regions as the water pad was cycled in a roughly linear manner from 32 C to 41 C over the first 16 minutes, held for 5 minutes at 42 C, and decreased for the last 10 minutes of the experiment down to 33 C. Two observations are of note. The first is the steady increase in temperature at all 3 locations in a manner consistent with distance from the heated surface. The region closest to the surface experienced the greatest temperature rise of approximately 4 C. The second observation is the resilience of the elevated temperatures to decrease with surface temperatures back to baseline during the last 10 minutes of the experiment. A control study in one volunteer in which no heating was applied showed no systematic temperature variations in the musculature.

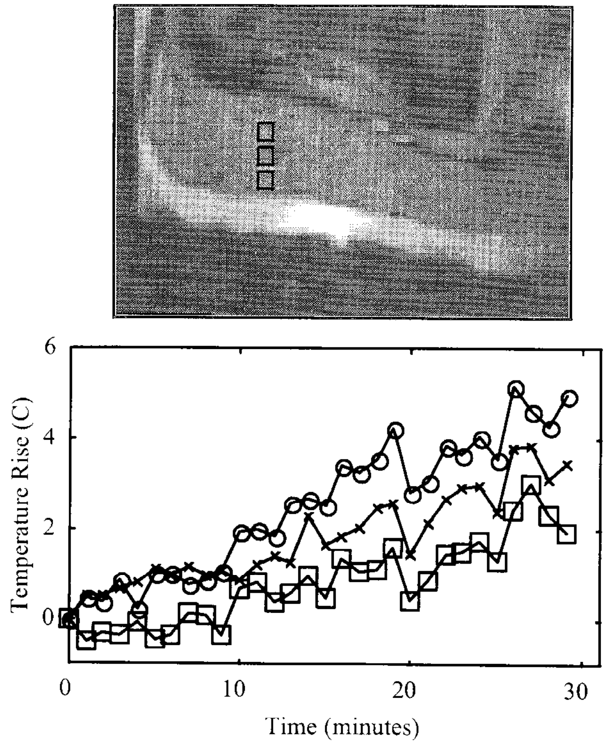

Figure 1: Gluteus muscle showing three regions of interest at varying depths from the heated surface from which the temperature traces in the lower plot were extracted. Boxes represent region 37 mm from the surface, crosses 28 mm from surface and circles 19 mm from surface.

Discussion: Our results show the feasibility of using MRT methods for studying changes in the temperature distribution accompanying topical heat therapy in the lower back. Small changes in position, however, can lead to frequency shifts as large or larger than the shifts associated with temperature changes. Thus interscan motion over the course of relatively long periods can lead to inaccurate temperature maps at later time points due to the use of reference scans acquired in the initial imaging phase. Development of methods and apparatus for overcoming this problem, probably in the form of gentle restraint devices, would be useful. Because of this problem, the interesting finding of a delayed response to cooling of the lower back muscles needs further verification, preferably with the use of longer scan periods with improved interscan motion restraint to insure temperature accuracy.

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