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*BRIEF COMMUNICATION*

# MAGNETIC RESONANCE ASSESSMENT OF EXTRAVASCULAR FLUID VOLUME IN EXERCISED SKELETAL MUSCLE*

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Courtice recently reviewed milestones in the elucidation of lymphatic physiology (1). Each increment in knowledge depended in part upon advances in research technology. For example, the development of catheters and cannulae sharply raised the understanding of lymph flow kinetics. Investigators are currently searching for noninvasive ways to evaluate interstitial fluid flow and lymphatic function. These noninvasive methods may complement well-established physiologic techniques which largely depend upon solute and fluid analysis of the lymphatic effluent.

Radiopaque contrast lymphography has provided reliable clinical visualization of the peripheral lymphatic system. The injection of radioisotopic labeled colloidal particles into the lymphatic system has yielded additional insight into lymphatic physiology, including semiquantitation of lymph node function. Since these techniques are invasive, they may distort the underlying physiologic processes (2). For this reason, we are continuing to search for new methods to investigate functions of interstitial fluid and lymph return of the blood vascular compartment.

Simultaneous multiple isotope dilution studies using external detectors have previously provided noninvasive assessment of the extravascular transport of macromolecules, as well as fluid changes in the extravascular space (3,4). Lymph flow can be quantified in those tissues where macromolecules return to the blood vascular space exclusively by the lymphatic system (5). More recently, whole body lymphangioscintigraphy using interstitial injection of radiolabeled noncolloidal macromolecules has become the clinical procedure of choice for the initial assessment of peripheral lymphatic disorders (6,7). This technique, only minimally invasive, is not thought to distort the physiology of the lymphatic system and thus can be used to evaluate lymphatic structures and flow in experimental counterparts of human disease.

Magnetic resonance (MR) imaging of the lymphatic system along with computer tomography has been primarily used thus far to image lymph nodes. In this brief paper, we describe the use of MR to evaluate shifts in extravascular fluid in exercised skeletal muscles thereby providing indirect insight into tissue fluid-lymph dynamics. MR technology utilizes the principle that tissue magnetized within a strong external magnetic field and excited by radiofrequencies to a higher

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state emits signals which can be converted into images. The terms T1 and T2 relaxation time are exponential time constants unique to MR. These parameters independently represent the different rates at which tissue magnetizes and excited tissue loses magnetization. The rate of magnetization loss governs the intensity of signal emitted from a tissue. The contributions of T1 and/or T2 signals, referred to as image "weighting", are also a function of the machine parameters (pulse sequences) used to obtain the image.

MR images composed predominantly of T2 signal (i.e., T2-weighted) tend to be highly sensitive to alteration in tissue water composition and are therefore preferable for evaluating liquid content and indirectly tissue fluid formation and lymph drainage. MR images composed predominantly of T1 signal (T1-weighted), with a greater signal-to-noise ratio, provide better detail of anatomic structure. Certain physiological, and most pathological processes, promote an increase in extravascular water in the form of interstitial and/or intracellular fluid. Alterations in the tissue extravascular water result in an alteration of the tissue T1 and T2 relaxation times which is reflected in the intensity of the MR image.

*RESULTS AND COMMENT*

Earlier studies at our institution suggested that a significant change occurred in the T2-weighted images of skeletal muscle after exercise. After short bouts of resisted foot dorsiflexion, the T2=signal of the lower leg anterior compartment muscles transiently increases by as much as 23±2.6%, depending on the force generated during the activity (T2=29.6±0.9% x Force, r=.89, n=9) *(Fig. 1)*. The cross-sectional area of the anterior lower leg muscles also increases by approximately 4 to 8% after exercise. This increased signal, which is consistent with increased extravascular fluid, persists for approximately 30 minutes and subsequently decreases at a rate compatible with diminution via lymphatic drainage (Fisher, MJ, RP Meyer, GR Adams, JM

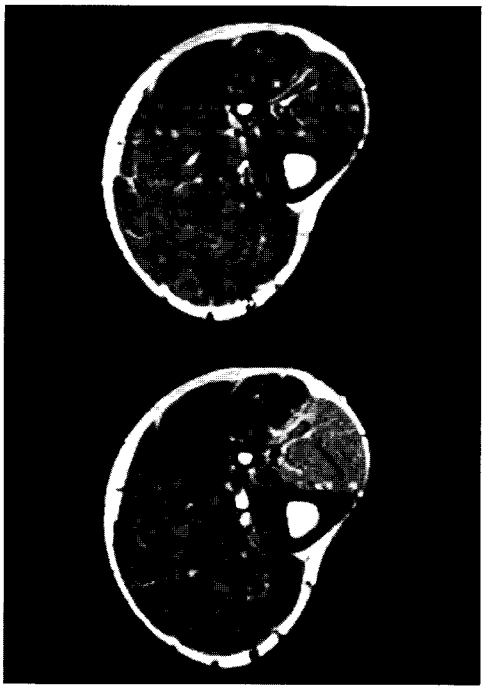

*Fig. 1. Cross section of the human lower leg taken before and after dorsiflexion exercise revealing an increase in the T2 signal of the anterior tibialis muscle after exercise.*

Foley, EJ Bohler: Direct relationship between proton T2 and exercise intensity skeletal muscle MR images. Dept. of Radiology and Physiology, Michigan State University, East Lansing, MI). Peripheral venous obstruction due to exercise also increases muscle cross-sectional area. The increase in cross-sectional area is greater than the proportional increase in muscle T2 signal. The mechanism of signal prolongation and muscle area increased volume following exercise has not as yet been clarified since it is not yet possible to distinguish interstitial from intracellular fluid volume.

These preliminary studies using MR images of skeletal muscle before and after exercise demonstrate an increase in T2-weighted signal proportional to the force of exercise. This signal persists for approximately 30 minutes and the duration is not notably affected by venous obstruction. This transient change in T2-

weighted signal in exercised muscle relates to a short-term increase in the tissue extravascular water (i.e., concentration of mobile proton). Further studies designed to assess whether the signal increase is primarily from an increase in intracellular or interstitial fluid are currently underway.

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