Evidence for muscle pump-generated intravascular pressure as a driving force contributor to bone intersititial fluid flow

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INTRODUCTION Insufficiency of poroelastic bone bending as the sole mechanism driving bone interstitial fluid flow (BIFF) to account for the shear stress required to activate mechanoreceptors on osteocytes and osteoblasts, has stimulated a search for alternative or complementary mechanisms in the quest for a comprehensive bone remodeling model. Some investigators, noting that a substantial amount of interstitial fluid is exchanged with blood and lymphatic capillaries, have suggested that this exchange may play a substantial role in both microtransport through the collagen matrix and lacunar-canalicular transport. In order to accept the vascular system as a significant source of transport driving BIFF it must first be demonstrated that capillary filtration, the process by which fluid is transported from blood vasculature, is sufficiently convective to drive interstitial percolation. We have proposed that while, as shown by Otter et al.[A], resting transmural vascular pressures are sufficient to generate streaming potentials across cortical bone, it is likely that these forces must be complemented by muscle pump contractions during exercise to generate convective percolation flows which will develop the required mechanotransducer shear stress activation threshold.

To determine a minimal baseline for a muscle pump driven BIFF (MPD-BIFF) model, we have investigated the role of repetitive skeletal muscle contractions, uncoupled from gravitational loading, on blood flow and capillary filtration in cortical bone of the rabbit tibia. We tested the hypothesis that these effects increased when the muscle pump was activated.

MATERIALS & METHODS The experimental model combined non-invasive, low magnitude transcutaneous neuromuscular stimulation (TENS) with real-time measurements from intravital microscopy (IVM) of optical bone chamber implants. Sling suspension of rabbits was utilized to eliminate gravitational reaction forces throughout TENS and data collection. TENS-induced muscle contraction forces were measured *in situ*, resultant bone strains were calculated and systemic circulatory parameters were monitored in order to eliminate these factors as contributors to bloodflow changes. Blood flow rates and capillary filtration were measured by video-image analysis of 1 μm fluorescent microspheres and dextran conjugated fluorescein isothiocyanate (FITC) and rhodamine (ITC) injected intravascularly during IVM. Bone formation, angiogenesis and mineral apposition rates (tetracycline labelling) were analyzed from weekly microscopy pictures. Changes in bone mineral content and density were determined with CT scans obtained at implantation and termination.

RESULTS Mechanical loading and baseline systemic circulation did not significantly contribute to the findings. Rhythmic muscle contractions were shown to increase cortical blood flow, rate of capillary filtration, rate of bone apposition and angiogenesis.

CONCLUSIONS & DISCUSSION The hypothesis was supported by the data. However, since no measurements were made on single capillaries, we could not confirm previous reports by this laboratory[B] of convective extravasation.

[A]Otter M, V Palmieri, G Cochran (1990) **J Orthop. Res. 8**: 119-126.
[B]Winet H, JY Bao (1990) in GT Yates (ed) **Engineering Science, Fluid Mechanics, A Symposium in Honor of TY Wu**. N.Y.: World Scientific. pp. 161-169.