Musculoskeletal Functional Imaging: Clinical Applications

Garry E. Gold, M.D.
Stanford University

Traditional MR imaging studies of the lower extremity are performed with the subject supine in a closed-bore MRI scanner. This provides excellent detail of anatomic structures in a static position, but is limited in showing the response of tissues to motion or stress. Kinematic and Real-time MRI are useful in studying the response of the musculoskeletal system to stress and during motion.

Kinematic MRI relies on the subject to perform repeatable motion cycles, akin to cardiac gating, and then an image can be reconstructed at multiple positions along the cycle. This has been used to study knee motion (1), total joint arthroplasty (2) and muscle motion (3).

Cine phase-contrast MRI can be used to determine tissue velocity during a motion cycle (4). This has also been used to measure aponeurosis tendon strain (5). Cine MRI with Displacement encoding can be used to measure muscle tissue strains near the myotendinous junction (6). Real-time MRI is useful in imaging structures while in motion, and does not require repeatable motion cycles (7, 8). As long as the frame rate of the acquisition is higher than the rate of motion, images relatively free of artifact can be produced. Frame rates can be increased by use of view sharing, spiral imaging, or parallel MR imaging. Tissue velocity can be measured with real-time MRI (9).

Open MRI scanners provide greater flexibility in performing biomechanical measurements (10, 11). Kinematic and real-time imaging in these systems is also possible, usually at lower frame rates than closed-bore systems (12). These systems can have the advantage of putting the subject in a more physiologic posture for the pain-generating activity. Combining stress and motion MR imaging with biomechanical finite-element models gives us the potential to estimate stress in joints during use (13).

Clinical situations in which functional MR imaging are important include compartment syndromes, popliteal artery entrapment syndromes, patellofemoral pain syndrome, and any condition in which pain is elicited on motion or under load. Common conditions that could benefit from functional approaches include shoulder instability, impingement syndromes, and nerve entrapment.

References

1. Shellock FG. Functional assessment of the joints using kinematic magnetic resonance imaging. Semin Musculoskelet Radiol 2003; 7:249-276.
2. Lee KY, Slavinsky JP, Ries MD, Blumenkrantz G, Majumdar S. Magnetic resonance imaging of in vivo kinematics after total knee arthroplasty. J Magn Reson Imaging 2005; 21:172-178.
3. Drace JE, Pelc NJ. Elastic deformation in tendons and myotendinous tissue: measurement by phase-contrast MR imaging. Radiology 1994; 191:835-839.
4. Asakawa DS, Blemker SS, Gold GE, Delp SL. In vivo motion of the rectus femoris muscle after tendon transfer surgery. J Biomech 2002; 35:1029-1037.
5. Lee HD, Finni T, Hodgson JA, Lai AM, Edgerton VR, Sinha S. Soleus aponeurosis strain distribution following chronic unloading in humans: an in vivo MR phase-contrast study. J Appl Physiol 2006;

100:2004-2011.

6. Fiorentino NM, Epstein FH, Blemker SS. Activation and aponeurosis morphology affect in vivo muscle tissue strains near the myotendinous junction. J Biomech. 2012 Feb 23;45(4):647-52.

7. Kerr AB, Pauly JM, Hu BS, et al. Real-time interactive MRI on a conventional scanner. Magn Reson Med 1997; 38:355-367.

8. Nayak KS, Pauly JM, Kerr AB, Hu BS, Nishimura DG. Real-time color flow MRI. Magn Reson Med 2000; 43:251-258.

9. Asakawa DS, Nayak KS, Blemker SS, et al. Real-time imaging of skeletal muscle velocity. J Magn Reson Imaging 2003; 18:734-739.

10. Beaulieu CF, Gold GE. Interactive and interventional sports medicine imaging. Top Magn Reson Imaging 2003; 14:115-130.

11. Besier TF, Draper CE, Gold GE, Beaupre GS, Delp SL. Patellofemoral joint contact area increases with knee flexion and weight-bearing. J Orthop Res 2005; 23:345-350.

12. Santos JM, Gold GE, Besier TF, et al. Full-Flexion Patellofemoral Joint Kinematics with Real-Time MRI at 0.5T. In:ISMRM. Miami, Fl., 2005.

13. Besier TF, Gold GE, Beaupre GS, Delp SL. A modeling framework to estimate patellofemoral joint cartilage stress in vivo. Med Sci Sports Exerc 2005; 37:1924-1930.