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PERSPECTIVE

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Dynamic magnetic resonance imaging of muscle function after surgery

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Dynamic magnetic resonance imaging (MRI) techniques have created new opportunities to study muscle function in vivo before and after surgery. This commentary is on the use of cine phase contrast MRI to study the function of the rectus femoris muscle after surgical transfer. Rectus femoris transfer surgery is performed to correct a stiff-knee gait in persons with cerebral palsy. In this procedure, the distal tendon of the rectus femoris is moved posterior to the knee and sutured to one of the hamstring tendons. The surgery is thought to convert the rectus femoris from a knee extensor to a knee flexor; however, the outcomes are inconsistent, and it is not known if the surgery successfully converts the muscle to a knee flexor. Cine phase contrast (cine-PC) MRI allowed us to visualize the motion of the knee flexor and extensor muscles, and to quantify the velocities of the muscles during knee motion.

We characterized the in vivo action of the rectus femoris and vastus intermedius (knee extensors), and the hamstring muscles (knee flexors) by measuring the velocities of muscle tissue during knee motion. We used cine-PC MRI to measure the velocities of these muscles in ten unimpaired control subjects (ten limbs) and six subjects (ten limbs) after rectus femoris transfer surgery. Cine phase contrast MRI requires numerous cycles of repeated motion to acquire multiple time frames of images representing one motion cycle [1]. We analyzed the motion and velocity of the muscles using sagittal plane cine-PC movies with 24 time frames. The cine-PC MR images were acquired with a 36×27 cm field of view, 17 ms repetition time (TR), 30° flip angle, 256×128 matrix, and 1-cm slice thickness. Knee range of motion within the MR scanner was approximately 40 degrees. The superior–inferior tissue velocity is depicted in the grayscale value of each pixel in the velocity images. We encoded velocities in the range of −20 to +20 cm/s. We calculated the velocity of the muscles from the images using custom software developed at Stanford University [2].

The dynamic cine-PC video of the lower limb of control subjects and subjects after surgery can be viewed online (See Electronic supplementary material (ESM)). Descriptions of the findings follow. The sagittal plane cine-PC anatomy images of a control subject show the rectus femoris and vastus intermedius muscles anterior to the femur and the hamstrings muscles posterior to the femur (video 1); the knee flexor and extensor muscles move in opposite directions during knee motion as expected. In the corresponding velocity images of this subject (video 2), the rectus femoris and vastus intermedius muscles have superior velocity (*dark pixels*) during knee extension while the hamstrings simultaneously have inferior velocity (*light pixels*). The velocity is reversed during knee flexion. In all the control subjects, the rectus femoris muscle moved with velocity in the same direction as the vastus intermedius muscle. Velocities of the vastus intermedius during knee extension were similar between control subjects and tendon-transfer subjects. However, in all of the subjects who had undergone rectus femoris transfer, the rectus femoris muscle moved in the same direction as the vastus intermedius, but with less velocity than in the control subjects (e.g. videos 3 and 4). The velocity measurements indicate that the rectus femoris is not converted to a knee flexor after its distal tendon is transferred to the posterior side of the knee, but its capacity for knee extension is diminished by the surgery [3, 4].

Based on the velocity data acquired, we have proposed that the beneficial effects of rectus femoris transfer may derive from reducing the effects of the rectus femoris as a knee extensor, rather than converting the muscle to a knee flexor. We believe connective scar tissue that forms after surgery may restrict muscle motion, and prevent the force generated by the rectus femoris muscle from being transmitted effectively to the tendon [3, 5]. Successful operative techniques for this surgery may depend on providing a freely gliding environment for the transferred muscle and minimizing the risk of scarring [4]. Dynamic imaging is a powerful tool to study skeletal muscle function in vivo. Such images can provide valuable information regarding muscle function after surgery and allow orthopedic surgeons to evaluate post-operative function, refine surgical concepts, and improve surgical design.

References

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