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Magnetic resonance imaging findings after rectus femoris transfer surgery

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Abstract We describe the magnetic resonance (MR) imaging appearance of the knee flexor and extensor tendons after bilateral rectus femoris transfer and hamstring lengthening surgery in five patients (10 limbs) with cerebral palsy. Three-dimensional models of the path of the transferred tendon were constructed in all cases. MR images of the transferred and lengthened tendons were examined and compared with images from ten non-surgical subjects. The models showed that the path of the transferred rectus femoris tendon had a marked angular deviation near the transfer site in all cases. MR imaging demonstrated irregular areas of low signal intensity near the transferred rectus femoris and around the hamstrings in all subjects. Eight of the ten post-surgical limbs showed evidence of fluid near or around the transferred or lengthened tendons. This was not observed in the non-surgical subjects. Thus, MR imaging of patients with cerebral palsy after rectus femoris transfer and hamstring-lengthening surgery shows evidence of signal intensity and contour changes, even several years after surgery.

Keywords Muscle · Magnetic resonance imaging · Rectus femoris · Tendon transfer · Cerebral palsy

Introduction

Orthopedic surgery is performed to improve the mobility of patients with cerebral palsy. For example, surgeons frequently perform hamstring lengthening to decrease excessive hamstring tension. In the hamstring lengthening procedure, the intramuscular aponeuroses or the distal tendons of the semimembranosus, semitendinosus, gracilis, or biceps femoris are lengthened [1]. Surgeons often perform rectus femoris transfers concomitantly with hamstring lengthenings. In rectus femoris transfer, the distal tendon of the rectus femoris is separated from the quadriceps tendon, tunneled through the subcutaneous tissue, and sutured to one of the knee flexor muscles, such as the sartorius or semitendinosus [1, 2, 3, 4]. The goal of the surgery is to convert the rectus femoris to a knee flexor.

Previous studies of the rectus femoris muscle after transfer surgery indicate that this muscle is not generally converted to a knee flexor [5, 6]. Analysis of cine phase-contrast magnetic resonance (MR) images has revealed that the rectus femoris muscle moves in the same direction as the vasti during knee flexion and extension, even after the distal tendon of the rectus femoris is transferred posterior to the knee. We hypothesized that connective or scar tissue may form after surgery, adhering the rectus femoris to the underling muscles, and constraining it to displace with the knee extensors. The first goal of this study was to examine patients after rectus femoris transfer for evidence of scar by using MR imaging. The second goal of this study was to examine the hamstrings after lengthening and to look for evidence of scar tissue.

We used MR imaging to describe the course and appearance of the transferred tendon, the extent of signal changes compared with images from non-surgical subjects, and the presence of fluid around the surgical site. Assessment of MR imaging findings consistent with inflammation and connective tissue formation is important for understanding muscle function after surgery. Connective or scar tissue has been hypothesized to alter the post-operative function after tendon transfer surgeries in the upper limb [7, 8] and lower limb [5]; however, this is the first study to report MR evidence of scar tissue after tendon transfer surgery.

Materials and methods

Subjects

Images were acquired in 10 unimpaired subjects with no history of lower-limb surgery (dominant limb; age: 23–38 years, 5 female, 5 male) and from 10 limbs of 5 subjects (age: 8–17 years, 2 female, 3 male) with cerebral palsy, after bilateral rectus femoris transfer and hamstring lengthening surgery (Table 1). Four different surgeons performed the procedures, and consequently, there was variation in surgical technique and the extent of surgical dissection. No subject had undergone bone surgery. At the time of imaging, subjects varied from 8 months to 9 years after surgery. Each subject was screened for MR imaging risk factors and provided informed consent in accordance with institutional policy.

Imaging

MR imaging was performed on a 1.5-T GE Signa scanner (GE Medical Systems, Milwaukee, Wis.). Each subject was positioned

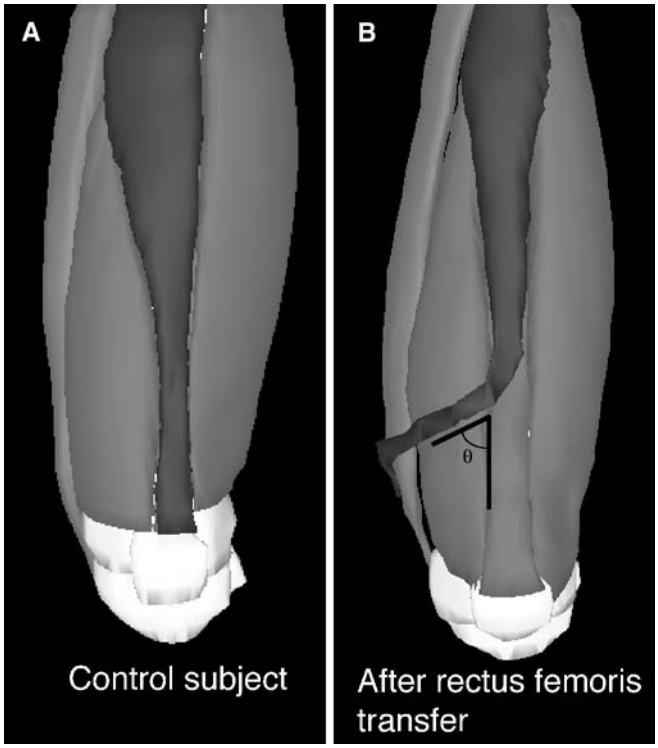

Fig. 1A, B Three-dimensional coronal model reconstruction from the left leg of (**A**) a non-surgical subject and (**B**) a subject with a transferred rectus femoris tendon (*black*). The vasti muscles (*light gray*) are shown, as is the transfer site on the semitendinosis (*dark gray*). The angle of deviation of the transferred tendon in the coronal plane is shown (θ)

Table 1 Magnetic resonance imaging findings

Subject no. (age in years)	Time since RF transfer (years)	Transfer site	Concomitant surgery[a]	Limb	Angle of RF transfer tendon (degrees)	Rectus femoris tissue (0–4)[b]	Hamstring tissue (0–4)[b]	Fluid (0–4)[c]
1 (12.9)	0.8	Sartorius	Medial and lateral HAMS, PS	Left	32	1	2	2
				Right	27	2	1	3
2 (15.6)	1.6	Sartorius	Medial HAMS, PS	Left	20	1	2	0
				Right	39	2	2	1
3 (8.8)	3.0	Semi-tendinosus	Medial and lateral HAMS, PS	Left	40	2	4	0
				Right	50	1	1	0
4 (14.8)	3.2	Semi-tendinosus	Medial and lateral HAMS, PS	Left	40	2	1	2
				Right	38	3	3	3
5 (16.6)	9.0	Sartorius	Medial and lateral HAMS, PS, ADD, TAL	Left	48	1	2	1
				Right	53	2	1	1

[a] Psoas tenotomy (*PS*), adductor myotomy (*ADD*), medial and lateral hamstring lengthening (*HAMS*), gastrocnemius lengthening (*GAS*), tendo-achilles lengthening (*TAL*)

[b] *0* no scar tissue, *1* minimal, *2* mild, *3* moderate, *4* severe

[c] *0* no fluid, *1* minimal, *2* mild, *3* moderate, *4* severe

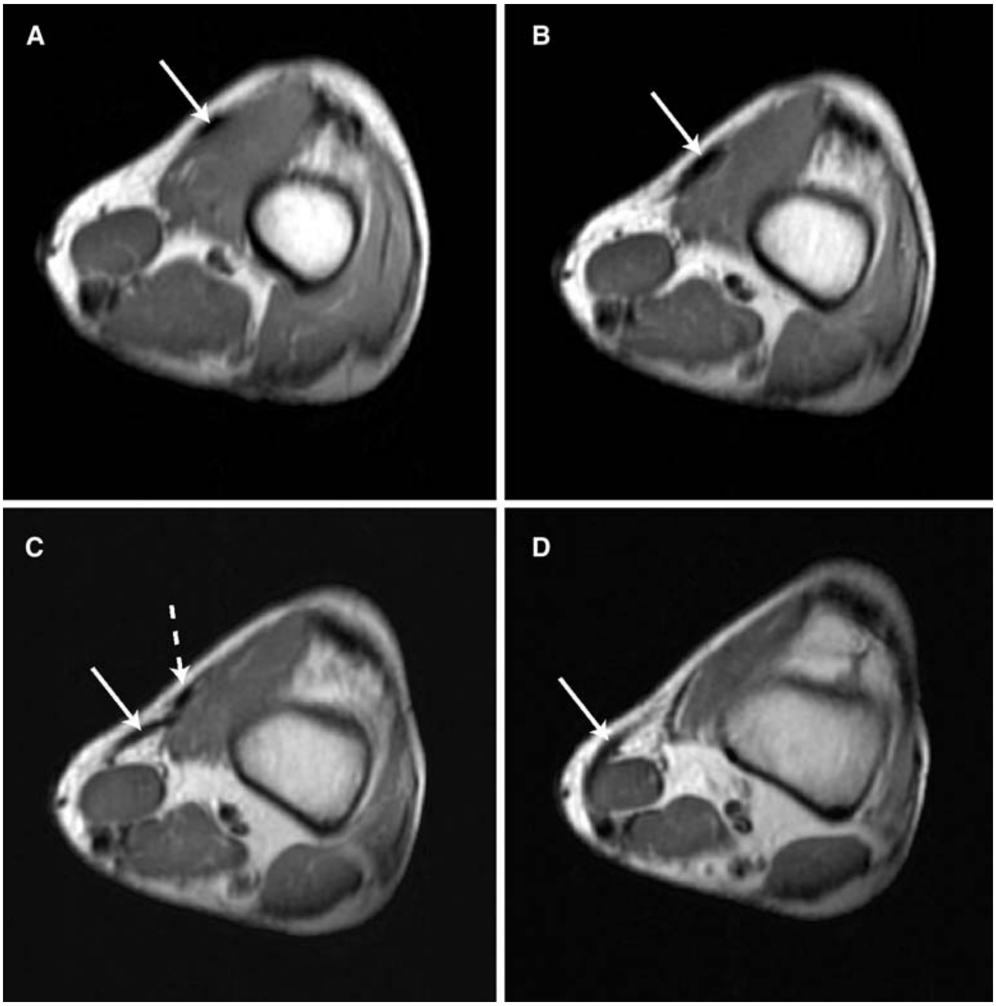

Fig. 2A–D Axial MR images of a transferred rectus femoris tendon with moderate (grade 3) low signal intensity tissue near the transfer site. Four axial plane proton density images (**A–D**) of the thigh at 1 cm intervals show the rectus femoris tendon (*solid arrows*) near the vastus medialis as it traverses to its new insertion into the semitendinosus tendon. Irregular tissue (*dashed arrow*) surrounds the rectus femoris tendon

supine on the table with the lower limb in approximately 40 degrees of hip flexion and 60 degrees of knee flexion. General-purpose phased array radiofrequency coils were used to image the thigh. Acquisition of the MR images required approximately 30 min. The Institutional Review Board approved the imaging protocols.

Axial plane images were acquired in a plane perpendicular to the femoral diaphysis. We acquired proton density fast spin echo (FSE) images (TR=4000 ms, TE=11.3 ms) with a 256×256 pixel matrix and a 24 cm×24 cm field-of-view (FOV) at 10-mm intervals from the inferior iliac spine to below the knee. Proton density weighting, rather than T1-weighting, was used to maximize the signal-to-noise for anatomic detail and to acquire all of the images in one acquisition. We then used the same imaging plane to acquire T2-weighted FSE images (TR=4000 ms, TE=75 ms) at the same locations with the same resolution and FOV as the proton density images. We also acquired sagittal-plane proton density FSE images with identical resolution.

Image processing

We constructed three-dimensional models from the axial-plane proton density images. The boundaries of the muscles were manually outlined, and the three-dimensional surfaces were generated from the two-dimensional outlines [9]. From the coronal view of the three-dimensional surface reconstruction (Fig. 1), we measured the angle of deviation of the transferred rectus femoris tendon in the coronal plane. Two independent measurements were taken, and the average was used.

Image evaluation

A musculoskeletal radiologist evaluated the MR images for evidence of signal changes that may have indicated post-surgical change or scar tissue near the transferred rectus femoris and the hamstring muscles. The amount of low signal intensity tissue on the proton density images was graded on a scale of 0–4, with 0 indicating no low signal intensity tissue present, 1 indicating minimal tissue, 2 indicating a mild amount of tissue, 3 indicating a moderate amount of tissue, and 4 indicating extensive and irregular low signal intensity tissue. Low signal intensity was defined as a signal lower than adjacent muscle or subcutaneous tissue. In distinguishing the low signal intensity tissue from the tissue in the transferred rectus femoris tendon itself, the shape of the tendon (irregular edges indicating additional tissue) and change in shape were considered, as was the smoothness of the interface between the transferred rectus femoris and the subcutaneous adipose tissue. The overall grade was based on the degree of irregularity and thickness and on the volume of abnormal tissue present.

The T2-weighted images were used in conjunction with the proton density images to investigate the presence of fluid in the

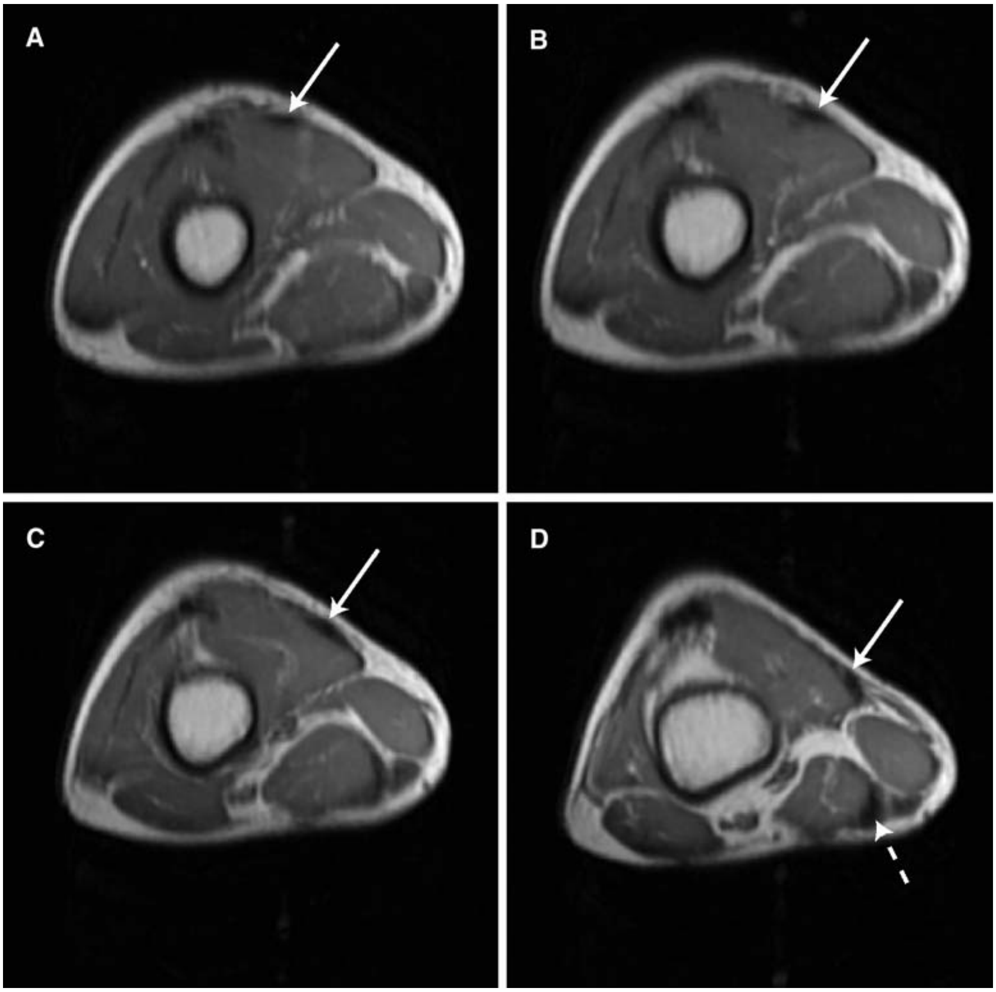

Fig. 3A–D Axial MR images of a transferred rectus femoris tendon with mild (grade 2) low signal intensity tissue near the transfer site. Four axial plane proton density images (**A–D**) of the thigh at 1 cm intervals show the rectus femoris tendon (*arrows*) near the vastus medialis as it traverses to its new insertion into the semitendinosus tendon. The rectus femoris tendon in this surgical subject appears smooth with little tissue between it and the vastis medialis. Low signal intensity is seen adjacent to the hamstring tendons (*dashed arrow*); this may indicate scarring as a result of hamstring lengthening

thigh of these subjects after orthopedic surgery. Fluid presence was qualitatively assessed on a scale of 0 indicating no fluid, 1 indicating minimal fluid, 2 indicating a mild amount of fluid, 3 indicating a moderate amount of fluid, and 4 indicating an extensive amount of fluid present.

Results

Transferred tendon course

The transferred rectus femoris was readily visible in the axial proton density images of all subjects. Three-dimensional reconstructions demonstrated the course of the transferred tendon (e.g., Fig. 1). The angular deviation of the distal portion of the transferred rectus femoris with respect to the proximal portion varied from 20° to 53° (Table 1). The three-dimensional reconstructions confirmed that the distal tendon of each transferred rectus femoris muscle had remained attached to its transfer site (sartorius or semitendinosus; Table 1).

Signal intensity results

All the post-surgical limbs showed some degree of low signal intensity tissue formation near the transferred rectus femoris muscle (Table 1). This tissue appeared as low signal areas with irregular edges on both the proton density and T2-weighted images. Low signal intensity tissue was seen at or distal to the point of angular deviation of the transferred tendon. The most common location of the tissue was between the transferred rectus femoris and the vastus medialis muscle (Figs. 2, 3). All subjects in this study showed low signal intensity areas posterior to the hamstring muscles, possibly as a result of hamstring lengthening (Figs. 3, 4). No abnormal low signal intensity tissue was seen in the non-surgical subjects.

Eight out of the ten post-surgical limbs showed fluid near the transferred rectus femoris tendon. Fluid was seen as a high signal area near the transferred tendon on T2-weighted images (Fig. 5). No fluid was seen near the lengthened hamstring tendons. No abnormal fluid near

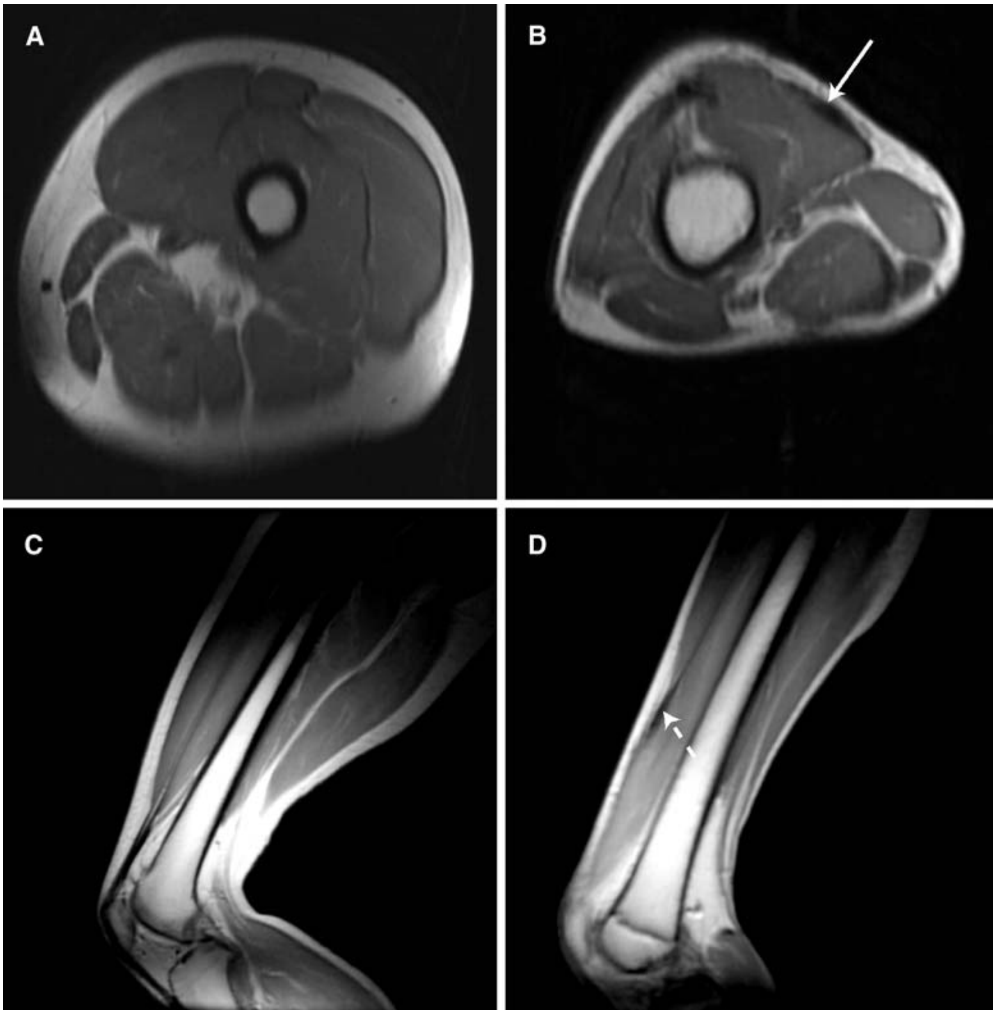

Fig. 4A–D Axial images from a non-surgical subject (**A**) and a subject with cerebral palsy after rectus femoris transfer and hamstring lengthening (**B**). Darkened bands around the hamstrings in the surgical subject may indicate scarring (grade 4) as a result of hamstring lengthening (*solid arrow*). In the sagittal images, the non-surgical subject (**C**) shows a normal-appearing quadriceps tendon. The surgical subject (**D**) shows thickened low signal intensity tissue in the quadriceps tendon; this may indicate scarring (grade 3) as a result of the rectus femoris transfer (*dashed arrow*)

the rectus femoris or hamstring tendons was seen in the non-surgical subjects.

Discussion

Several prior studies have reported the MR appearance of muscle and myotendinous strain in the upper and lower limbs [10, 11, 12], but no previous studies have examined MR images of muscles for evidence of scare tissue after surgery in cerebral palsy. The images in this study show that low signal intensity tissue can be present near the lengthened hamstring muscles and the transferred rectus femoris, and that fluid can be seen adjacent to the transferred rectus femoris tendon.

Measurements of muscle tissue motion in these same surgical subjects by using cine phase-contrast MRI revealed that the rectus femoris moved in the direction of the vasti during flexion and extension of the knee, even after the distal tendon of the rectus femoris had been transferred to one of the knee flexor tendons [5]. Based on this observation, we hypothesized that connective or scar tissue may have formed after rectus femoris transfer and adhered the rectus femoris to the underling muscles. In support of this hypothesis, we found evidence of abnormal low signal intensity that may represent scar tissue between the transferred rectus femoris muscle and the underlying vasti in each of the surgical subjects. These areas of low signal intensity were not seen in the non-surgical subjects.

The appearance of areas of low signal intensity in our subjects may represent scarring, adhesions, or postoperative muscle-tendon remodeling that may interfere with the function of the transferred or lengthened tendon. A previous report of MR imaging findings of complications of flexor tendon repair in the hand has shown that mature scar tissue seen on MRI can have low signal intensity [13]. In the late stages of muscle injury, areas of low signal intensity on MRI represent fibrosis and calcification [12]. Fluid near the transferred rectus fem-

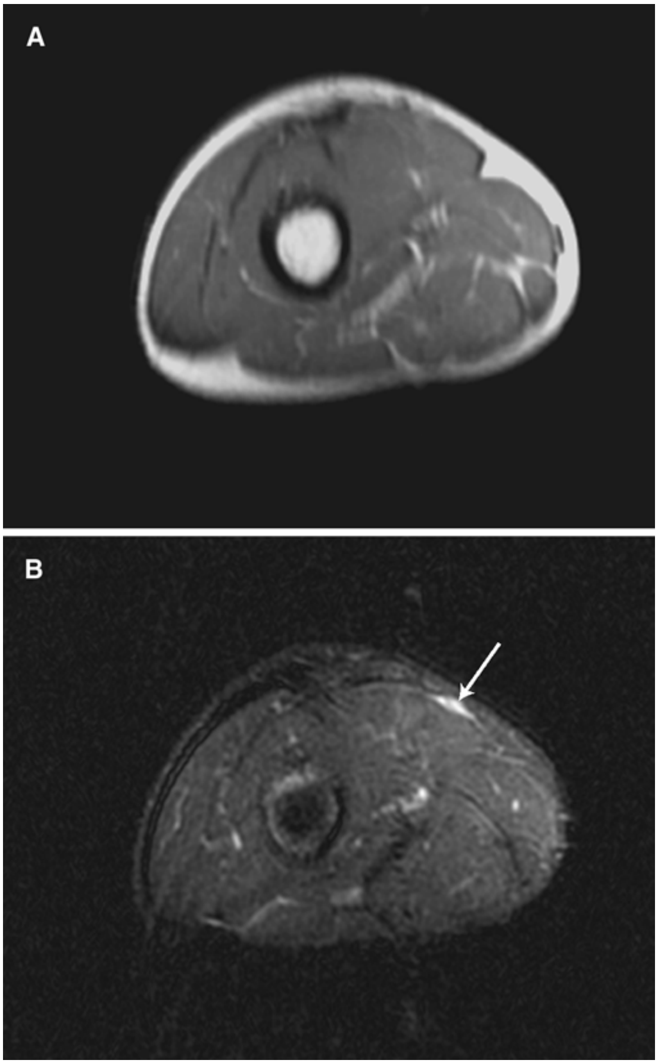

Fig. 5A, B Axial proton density (**A**) and T2-weighted (**B**) MR images at the same axial location from a subject with cerebral palsy. The T2-weighted image shows extensive fluid (grade 4) near the transferred rectus femoris tendon (*arrow*)

oris tendon, not seen in non-surgical subjects, may represent ongoing inflammation. The three-dimensional models showed that the transferred muscle paths had abrupt angular deviations, i.e., the transferred muscle did not follow a smooth direct path to its new insertion. The angular deviations in the muscle path suggest that portions of the transferred rectus femoris path are constrained, possibly by adhesions to the underlying vasti.

Scar tissue formation is recognized as a complication in many soft-tissue surgical procedures. For example, tenotomy has been shown to result in changes to the muscle, including increased intramuscular connective tissue [14]. When repeat surgical hamstring lengthening is performed, scarring of the hamstring tendons after lengthening has been observed at surgery [15]. A study of the semitendinosus tendon after harvest for anterior cruciate ligament reconstruction has shown that this tendon has the capacity to regenerate, with focal areas of scar tissue present [16].

There are three principal limitations in this study. First, no contrast agent was used to enhance the visibility of the scar tissue in the MR images, because the use of intravenous contrast agents in children was not approved for the purposes of this study. Second, there was no correlation between the amount of low signal intensity tissue present and the outcome of the surgery as measured by gait analysis. Given the variable types of surgery and surgical techniques, the complexity of gait disorders in cerebral palsy, and the small number of patients studied, specific conclusions about the effects of surgical technique or time since surgery could not be made. Finally, surgical evidence of scar tissue and inflammation in the rectus femoris transfer subjects was not available. However, dynamic MR images taken in these same subjects showed that the independent motion of the rectus femoris muscle was limited after surgery [5]. Therefore, whereas biopsy evidence is not available, the signal changes seen in our surgical subjects probably represent post-surgical connective tissue or scars and may be related to the observation of reduced motion postoperatively.

This study demonstrates that soft-tissue surgery performed on patients with cerebral palsy can result in abnormal MR signals that are evident several years after surgery. The appearance of the transferred rectus femoris and lengthened hamstrings may be important to the radiologist or surgeon assessing injury or function of the altered tendons in this population. The results of this study show that MR imaging can provide new insights into the effects of common surgical treatments for cerebral palsy.

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