Rectus Femoris to Gracilis Transfer with Fractional Lengthening of the Vasti Muscles: Surgical Technique

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Stiff knee gait is often seen in patients with upper motor neuron injury. It describes a gait pattern with relative loss of sagittal knee motion. This aberrant gait interferes with foot clearance during swing, often leading to inefficient compensatory mechanisms and ambulatory dysfunction. At our institution, we have been performing distal rectus femoris transfers and fractional lengthening of the vasti muscles in adult patients. The purpose of this paper was to describe our unique surgical technique.

Stiff knee gait describes a gait pattern with a relative loss of sagittal plane knee motion, which interferes with foot clearance during swing[1]. It may be seen in patients with upper motor neuron (UMN) injury, such as stroke or traumatic brain injury (TBI), and is commonly seen in children with cerebral palsy (CP) after hamstring lengthening surgery. Stiff knee gait is thought to result from abnormal timing of the rectus femoris muscle. Instead of its normal brief action from terminal swing into midstance and again in pre-swing, the rectus femoris in patients with stiff knee gait has a prolonged activity in swing phase or is active throughout the entire gait cycle[2]. This leads to inadequate knee flexion during swing and poor foot clearance. Consequently, patients often compensate with energy inefficient mechanisms such as hip circumduction, pelvic elevation, and vaulting of the contralateral lower extremity.

Additionally, increased vasti and decreased iliopsoas activity have also been proposed as potential causes of stiff knee gait. Perry demonstrated that the rectus femoris often assumes the role of a primary hip flexor in these patients[3]. In addition, there is inadequate action of the sartorius, gracilis, and short head of the biceps during swing phase[3].

Numerous surgical procedures have been proposed to manage stiff knee gait, including proximal release of the rectus femoris[4], fractional lengthening of the hamstrings[5], release of the distal rectus femoris (with or without release of the vastus intermedius)[6], and distal rectus transfer[7]. Perry proposed transferring the distal rectus femoris (to the sartorius) posterior to the knee axis in conjunction with hamstring lengthening for treating children with CP[7]. This procedure allowed knee extension in stance, while augmenting knee flexion in swing for foot clearance[7].

We have been performing distal rectus transfer to the gracilis tendon in conjunction with vasti lengthening in adult patients with stiff knee gait following stroke or TBI. This technique allows for a more secure fixation of the rectus femoris tendon, places the knee flexion force more posterior to the knee axis of rotation, and also treats the increased activity of the vasti muscles during early swing.

Surgical Technique

The patient is positioned supine on the operating table, and a pneumatic tourniquet is applied. A longitudinal incision measuring approximately 10 cm is made on distal anterior thigh over the distal rectus femoris. The distal quadriceps muscle is exposed medially and laterally. The rectus femoris is carefully dissected free from the other quadriceps muscles distally to the level of the mid patella (Figure 1). A locking stitch (Krackow) of heavy nonabsorbable suture is placed in the distal free end of rectus tendon (Figure 2). The rectus muscle is freed proximally to isolate it from the vasti muscles.

The vastus intermedius muscle is identified beneath the reflected rectus femoris. The tendon fibers over its muscle belly are incised. The myotendinous junctions on the undersurface of the vastus medialis and vastus lateralis are then dissected. These muscles are lengthened by transecting the tendon fibers over the muscle belly (Figure 3).

A second incision is made on the posteromedial distal thigh. The gracilis muscle and tendon is identified and isolated (Figure 4). The gracilis tendon is released proximally from the muscle belly; its tendon is left attached distally. A subcutaneous tunnel is created between the anterior and medial thigh incisions. The medial intramuscular septum is sharply divided for a distance of approximately 5 cm. The distal end of the rectus femoris tendon is passed subcutaneously through the tunnel to the posteromedial thigh incision. The rectus femoris and gracilis tendons are interwoven using a Pulvertaft technique and secured with multiple sutures of heavy, nonabsorbable suture (Figure 5).

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Figure 1. The rectus is identified and isolated.

Figure 2. A locking stitch (Krackow) of heavy, nonabsorbable suture is placed in the distal free end of rectus tendon.

Figure 3. The myotendinous junctions on the undersurface of the vastus medialis and vastus lateralis muscles then are dissected. These muscles are lengthened by transecting the tendon fibers over the muscle belly.

Figure 4. The gracilis muscle and tendon are identified and isolated.

Figure 5. The distal end of the rectus femoris tendon is passed subcutaneously through the tunnel in the intramuscular septum to the posteromedial thigh incision. The rectus femoris and gracilis tendons are interwoven using a Pulvertaft technique.

The tourniquet is released, and the incisions are irrigated. The wounds are closed in routine fashion.

Postoperative Protocol

A knee immobilizer is used postoperatively to allow healing of the tendon transfer.A continuous passive motion machine is used postoperative day one, and physical therapy is instituted for gait training and passive knee range of motion exercises. Patients are allowed to start full weight-bearing ambulation training. The knee immobilizer is weaned over the course of one to two weeks. Gait training emphasizes hip and knee flexion during swing phase. Active knee extension exercises without ankle weights should be started immediately to strengthen the quadriceps muscle. Hip flexor strengthening is started immediately after surgery.

Discussion

Although the knee has many functions during the gait cycle, its primary roles are to provide foot clearance during swing phase and shock absorption during the loading response. The knee normally begins stance phase in near full extension, flexes approximately 15 degrees during loading, and then gradually extends towards terminal stance. The vasti muscles counteract the ground-reaction flexion moment during the loading response. After mid-stance, knee extension is maintained by a plantarflexion/knee-extension couple under control of the triceps surae[1]. The knee rapidly flexes approximately 40 degrees at pre-swing, which increases to approximately 60 degrees at initial swing. The rectus femoris is active in pre-swing and initial swing and again from terminal swing to midstance[3]. It functions to accelerate the thigh and lower leg while restraining excessive knee flexion[1]. Swing phase sagittal knee motion is mostly passive at normal walking cadence but requires increasing muscle activity as cadence increases. In stiff knee gait, the rectus femoris has prolonged activity during swing phase, thus disturbing the precise balance of knee motor activity.

In addition to abnormal swing phase activity, Goldberg et al found that many patients with stiff knee gait have abnormally large knee extension moments during double support, which correlated with low knee flexion velocity at toe-off[8]. Subsequent study by Reinbolt et al confirmed that rectus femoris activity during pre-swing is equally as important as early swing activity and may be more responsible for the loss of swing knee motion in some patients[9].

The evolution of surgical management for stiff knee gait started with proximal release of the rectus femoris[10, 11]. In a series of eight patients with CP and spastic gait, Sutherland et al found that proximal tenotomy of the rectus femoris improved gait in patients with enough rectus spasticity to interfere with the initiation of swing phase and those with decreased knee flexion[4]. However, they did not find any benefits to proximal tenotomy to improve hip or pelvic biomechanics. Perry proposed that a rectus transfer would provide preservation of hip flexion, while also increasing knee flexion during swing[7]. Studies comparing the effectiveness of rectus femoris release and rectus femoris transfer have found that rectus femoris transfer has a greater influence on increasing knee flexion and improving post-operative knee range of motion[12].

Gage et al proposed transferring the rectus femoris to the sartorius in children with CP and inadequate knee flexion during swing and an internal foot progression angle in stance. Similarly, they proposed rectus femoris transfer to the posterior iliotibial band if there was inadequate knee flexion during swing and an external foot progression angle. Although they did not find a significant change in post-operative foot progression angle, they observed an improvement in swing phase knee flexion in both groups[1]. They concluded that the sartorius is not an ideal recipient for the transfer, since it inserts anteriorly on the tibia and thus has less of a rotation force. They also found the sartorius to be of poor structural integrity, which may lead to transfer failure[1]. Gage later stressed the importance of a posterior transfer to better augment knee flexion and described transferring the distal rectus femoris to either the semitendinosus or the posterior iliotibial band[13].

Other authors have demonstrated similar success of the distal rectus femoris transfer in children with CP and a stiff knee gait. It is capable of developing a knee flexion moment during swing, while preserving rectus femoris activity at the hip, which may further contribute to knee flexion via dynamic coupling of a flexion moment about the hip. Sutherland reported that the swing phase knee flexion increased an average of 16 degrees after transfer of the rectus femoris muscle[14]. Transferring the distal rectus femoris also prevents it from reattaching to the patella, which has been observed in rectus femoris release. Ounpuu et al investigated the effect of transfer location site (sartorius, gracilis, semitendinosus, iliotibial band) on the outcome of the rectus femoris transfer surgery and found no statistically significant difference between transfer sites in postoperative knee range of motion[15].

Similar to previous studies, we believe the sartorius to have inferior anatomic and biomechanical characteristics. The thin overlying fascia of the sartorius is often too fragile to accept a transfer. In comparison, the gracilis tendon is stout and can withstand adequate tensioning. The gracilis is also more posterior to the knee axis, thus potentially providing an improved mechanical advantage for knee flexion.

Fractional lengthening of the vasti muscles is often done concurrently by the senior author. Knee flexion depends on sufficient extensibility of the antagonists. Fractional lengthening of the quadriceps improves knee flexibility without compromising its strength. Weakening of the quadriceps is also a potential risk associated with a distal rectus transfer, since the rectus comprises approximately 12% of the total quadriceps mass[14]. The combination of quadriceps fractional lengthening with distal rectus transfer may theoretically cause increased stance phase knee flexion, especially at weight acceptance, leading to either knee instability or crouch gait. However, this has not been observed in our experience, and it is likely that the vasti muscles retain sufficient strength to compensate for the loss of rectus activity.

To our knowledge, this is the first description of distal rectus transfer in an adult population with stroke or TBI and stiff knee gait. Simultaneous fractional lengthening of the quadriceps has also not been previously described as a concurrent procedure. The combination of distal rectus transfer with fractional lengthening of the vasti muscles effectively improves swing phase knee flexion while not compromising stance phase knee stability. This may lead to fewer falls in this at-risk patient population.

Conclusions

We have found that adults with stroke or traumatic brain injury who develop stiff knee gait due abnormal rectus femoris activity benefit from a distal rectus femoris transfer with fractional lengthening of the vasti. Simultaneous fractional lengthening of the quadriceps offers improved knee flexibility without compromising knee stability.

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