MEDIUM TERM FOLLOW-UP OF ACHILLES TENDON LENGTHENING IN THE TREATMENT OF ANKLE EQUINUS IN CEREBRAL PALSY

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ABSTRACT

Introduction: The optimal treatment for equinus of the ankle in ambulatory patients with cerebral palsy is not known. This study assessed the medium term follow-up results of treatment of spastic ankle equinus deformity in cerebral palsy using Hoke or coronal Z-lengthening of the Achilles tendon. It was hypothesized that the use of Achilles tendon lengthening (TAL) as a treatment for spastic ankle equinus during gait results in a high rate of over-weakening of the triceps surae resulting in crouch gait. We also investigated patient characteristics that could identify which patients are at risk for crouch gait due to triceps surae weakening from Achilles tendon lengthening.

Materials and Methods: Seventy-nine patients (114 procedures) who had undergone Achilles lengthening were retrospectively reviewed to determine how many patients developed crouch gait with dorsiflexion of the ankle throughout stance phase requiring anterior-floor-reaction bracing. The following patient characteristics were evaluated: age at surgery, geographic type of cerebral palsy, length of follow-up, need for anterior-floor-reaction bracing, length of time after surgery when brace was prescribed, age at time of need for bracing, side of surgery, technique used, additional procedures performed at time of TAL, previous or later procedures performed, and walking ability.

Results: The average age at the time of TAL was 7 years and 3 months, and the average follow-up was seven years. The geographic type of cerebral palsy greatly affected the outcome. None of the twenty-three hemiplegic patients required bracing. Fourteen of 34 (41%) patients with spastic diplegia and seven of fourteen (50%) patients with spastic quadriplegia required bracing. There was no significant difference in outcome between the Hoke and the Z-lengthening procedures. Patients who underwent more procedures and bilateral procedures were more likely to require anterior-floor-reaction bracing.

Conclusions: Achilles tendon lengthening as practiced by the senior author results in a high rate of over weakening of the triceps surae as defined by the need for a floor reaction brace. Results are best in patients with hemiplegia and non-hemiplegic patients who require only single leg surgery, and who do not require concomitant or subsequent surgery. Alternative treatment, such as gastrocnemius fascial lengthening, or non-surgical treatment may be the optimal treatment of ambulatory patients with spastic diplegia and quadriplegia who have spastic ankle equinus during gait.

INTRODUCTION

Equinus deformity of the ankle is one of the most common problems encountered in cerebral palsy.[1,2,3,4] Equinus disrupts the gait cycle by decreasing stability in stance phase and causing inadequate clearance in swing phase.[5,6] Nonoperative treatments for an equinus deformity of the ankle include stretching exercises, serial casting, bracing,[7] and temporary or permanent denervation with botox,[8,9] alcohol, or phenol.[10] Operative treatments include surgical denervation, Achilles tendon lengthening, gastrocnemius and/or soleus fascial lengthening, and anterior advancement of the Achilles insertion.[11,12,13] Numerous heel cord-lengthening techniques have been described including tendon "slides" performed open or percutaneously, coronal Z-lengthening, and sagittal Z-lengthening.[14,15,16,17] Three of the most common gastrocnemius lengthening techniques are those described by Baker,[18] Strayer,[19] and Vulpius.[20] The Baker and Vulpius procedures may or may not include soleus fascial lengthening as well as gastrocnemius fascial lengthening.

Which technique is most appropriate for a given patient is still unknown and controversial.[21] Advocates of the selective gastrocnemius lengthening procedures stress the improved push off and decreased risk of over-lengthening,[15,22,23,24,25] while accepting the reported increased rate of recurrent deformity.[4,22] Advocates of Achilles tendon lengthening cite reported recurrence rates of equinus of 30 to 41 percent after gastroc-soleus fascial

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lengthening.[4,22] Rates of recurrence and over-lengthening are reported to be unaffected by technique of tendon lengthening or by the performance of concurrent procedures.[20,26,27,28,29,30] The amount of lengthening of the tendo Achilles is usually determined by bringing the foot into neutral, five, ten, or fifteen degrees of dorsiflexion during suturing of the lengthened tendon. Quantifying the appropriate length of fixation of the tendon is difficult, but attempts at standardization have been made based on an assessment of the patient's spasticity or on geometrical measurements.[2,27] Many surgeons assess these patients under anesthesia using the Silverskiöld test to determine whether to perform a gastrocnemius lengthening or an Achilles tendon lengthening.[31]

The goal of the treatment of ankle equinus is to obtain a plantigrade foot without compromising triceps surae function. Next to recurrence of equinus deformity, over-lengthening is the most common complication. The functional limitation created by over-lengthening of the Achilles tendon is crouched or calcaneus gait.[5] This occurs due to the inability of the weakened triceps surae to restrain the forward movement of the tibia when the center of gravity moves in front of the ankle center of rotation during gait. The patient loses the normal plantar-flexion/knee extension couple. The weight bearing line becomes anterior to the ankle and hip center and posterior to the knee joint resulting in flexion at both the knee and hip with dorsiflexion of the ankle (crouch gait).[5] Crouch gait results in increased work of gait, early fatigue, and decreased stride length. Secondary hip and knee flexion contractures develop over time. The increase in patellofemoral joint reaction force commonly results in patellofemoral pain, which is often severe and may precipitate the cessation of walking.

Uniformly successful treatment of crouch gait due to over-lengthening of the triceps surae has not been reported. The senior author treats children with crouch gait with anterior-floor-reaction bracing to substitute external bracing for weak triceps surae. These braces are cumbersome for the patient to doff and don. Most patients find getting up and down from the floor as well as stair climbing more difficult with anterior-floor-reaction braces. Although alignment and endurance may improve, stability may worsen due to the rigidity of the brace. In many patients, anterior-floor-reaction braces are not effective in alleviating crouch, particularly in patients with poor mechanical foot alignment.

The controversy over the best surgical technique has important implications for patient care. Specifically, proponents of gastrocnemius fascial lengthening maintain that weakening the soleus contributes to the development of crouch gait.[32] Crouch gait is the most common gait pattern in previously ambulatory patients with spastic diplegia/quadriplegia who abandon walking. This retrospective case series review was prompted by the senior author's observation that many of his older patients were crouching and requiring anterior-floor-reaction braces. The study was performed to assess the magnitude of the problem in his patient population.

The purpose of this study is to evaluate the post-surgical results of one surgeon in the treatment of spastic ankle equinus deformity in cerebral palsy at an intermediate postoperative follow-up. It was hypothesized that TAL as a treatment for ankle equinus during gait contributes to a high rate of crouch gait in adolescence. We also sought patient characteristics that distinguish patients who develop crouch gait after TAL from those who do not.

MATERIALS AND METHODS

From 1984 to 2000, 80 patients with cerebral palsy who had operations for ankle equinus during gait by the senior author (FRD) were identified from the hospital coding records (total of 115 procedures to lengthen the Achilles tendon). One patient did not return for follow up after cast removal and was excluded from the analysis. The charts of the remaining 79 patients (114 procedures) were retrospectively reviewed to identify the following: age at surgery, age at most recent follow-up, type of cerebral palsy, whether anterior-floor-reaction braces were prescribed for crouch gait, length of time after surgery brace was prescribed, age at time of brace prescription, side of surgery, surgical technique employed, concomitant procedures performed at time of TAL, and previous or later procedures performed. Type of cerebral palsy was identified as hemiplegia, diplegia, triplegic, quadriplegia, mixed athetoid/spastic, or dyskinetic based on the diagnosis in the clinical records from the orthopaedic and the developmental pediatrics clinics. Patients who had not been seen recently in clinic were contacted by phone to confirm the bracing status.

All patients in this case series were treated by a single physician with a philosophy of treatment of ambulatory children with cerebral palsy as follows: Bracing and physical therapy are the mainstays of treatment until the gait pattern has stabilized, usually between 4 and 7 years of age. When the gait pattern has stabilized, all sagittal and coronal plain deformities are corrected with soft tissue procedures in one operation. As needed, the psoas is lengthened at the brim of the pelvis for hip flexion contracture; the hamstrings are lengthened for knee flexion; the rectus femoris is transferred to the hamstrings for stiff knee gait; the Achilles tendon is lengthened for ankle equinus; and the adductor longus and gracilis are released for scissoring gait.

Bony procedures were performed only for hip instability and were not done at the same time because the senior author believes that rehabilitation is more rapid and successful if the soft tissue procedures are not combined with prolonged immobilization (typically 6 weeks in a spica cast) that he employs following VDO and/or San Diego acetabular osteotomy for hip instability.

Achilles tendon lengthening is accomplished by a coronal Z-plasty or by an open Hoke "sliding" lengthening. The Hoke lengthening is used in milder cases, and the Z-plasty is employed with more severe contractures too great to treat with a sliding lengthening without risk of tendon rupture. A patient was indicated for surgical intervention when bracing had failed to control the equinus deformity during gait.

The Hoke procedure was done through a posteromedial incision. Three cuts were made horizontally in the tendon. Two cuts were made medially (one proximal and one distal) half-way across the width of the tendon, and one cut was made laterally midway between the two medial cuts. The foot was then passively dorsiflexed to neutral. The leg was immobilized in either a below or above knee cast for a minimum of 6 weeks, with the exception of one patient who was immobilized for four weeks. Full weight bearing was encouraged.

The coronal Z-lengthening was also performed through a posteromedial incision. The tendon sheath was incised along the medial border of the tendon. One centimeter of the plantaris tendon was excised if present. The posterior aspect of the tendon was exposed with care taken to not expose the tendon anteriorly, preserving the peritendinous attachments of the proximal tendon in order to avoid excessive proximal migration. The tendon was then cut in a step cut fashion coming out anteriorly in the distal tendon and posteriorly in the proximal tendon. The ankle was dorsiflexed to neutral. The foot was then positioned in neutral while the tendon was sutured under maximum tension obtained by thumb forceps on both limbs of the tendon. The wound was then irrigated and closed in a standard fashion. Postoperative immobilization consisted of six weeks in a below or above knee cast with full weight bearing.

The clinical diagnosis of crouch gait was determined during follow-up visits by observational gait analysis by the senior author (FD). The diagnosis of crouch gait and treatment with anterior-floor-reaction braces was made when a patient exhibited more than 30 degrees of knee flexion throughout stance phase AND the ankle was in dorsiflexion throughout stance phase. The single outcome variable of interest is the prescription of anterior-floor-reaction braces for crouch gait.[33]

We assessed the incidence of crouch gait as reflected by the prescription of anterior-floor-reaction braces with respect to the following: Hoke vs. coronal Z-lengthening, type of cerebral palsy, bilateral vs. unilateral Achilles tendon lengthening, age at surgery; age at final follow up, and performance of concomitant procedures. Student's t-tests and Fisher exact test were used for comparative analyses as appropriate.

RESULTS

The average age at the time of surgery was 7 years and 3 months (range 18 months to 47 years). The average age at time of most recent clinic follow-up was 14 years and 2 months (range 4 years to 47 and 8 months). Twenty-three (29%) were classified as spastic hemiplegic. Thirty-four patients (43%) were spastic diplegic. Fifteen (19%) were spastic quadriplegic. Four (5%) had mixed cerebral palsy, two were triplegic, and one patient was diagnosed with dyskinetic cerebral palsy. Surgery was performed bilaterally in 34 patients (43%), on the right side only in 22 patients (28%), and on the left side only in 23 patients (29%). A Hoke lengthening was performed 56 times (49%) and the coronal Z-lengthening was performed 56 times (49%). One operative note did not specify which of the two types of lengthening procedures was performed. In a single procedure, a White type of lengthening (two rather than three step cuts) was performed. A total of 151 additional procedures were performed on fifty of the seventy-nine patients (63%) at the time of the TAL.

The patient's type of cerebral palsy had the greatest affect on the need for anterior-floor-reaction bracing. None of the 23 hemiplegic patients required bracing. Twenty-three of the 56 (42%) of the non-hemiplegics required anterior-floor-reaction bracing. Fourteen of the 34 spastic diplegic patients (41%) required bracing. Seven of fourteen quadriplegic patients (50%) required bracing. There was no significant difference in bracing incidence comparing the diplegic and quadriplegic patients ($p = 0.75$), but there was a significant difference between the hemiplegic and non-hemiplegic patients ($p=0.0003$). Two patients of the eight with "other" diagnoses required bracing (25%). Because hemiplegics never developed crouch gait and the "other" diagnoses group is small, all further evaluation was done only on the diplegic and quadriplegic groups.

The type of procedure employed to lengthen the Achilles tendon did not affect the need for anterior-floor-reaction bracing. Because some patients had a Hoke lengthening of one side and a coronal Z lengthening of the other, the different procedures were compared by limb rather than by patient. Following a Hoke procedure, 17 of 40 limbs were braced (43%), while 23 of 43 limbs were braced (53%) following coronal Z-lengthening ($p<1.00$ for the right side and $p<0.35$ for the left side).

Surgical lengthening of both Achilles tendons tended to affect the likelihood of patients' requiring anterior-floor-reaction braces. Eighteen of 33 patients (55%) undergoing bilateral TAL's were prescribed anterior-floor-reaction braces, while only 4 of 17 patients (24%) with unilateral procedures were braced ($p<0.086$).

Patients who underwent concomitant procedures tended to require braces more often. Three of 11 patients (28%) without concomitant procedures were braced, while 19 of 36 patients with concomitant procedures were braced (53%) ($p<0.06$). Patients requiring subsequent orthopaedic surgery did not have a statistically higher rate of anterior-floor-reaction bracing. Twelve of 22 patients (55%) were braced who had subsequent orthopaedic surgery, whereas 10 of 18 patients (36%) without subsequent orthopaedic surgery were braced ($p<0.25$).

There was no statistical difference in the age at surgery or the age at follow-up. Mean patient age at the time of surgery was 7.7 years (standard deviation of 8.5 years) for the un-braced patients and 6.8 years (standard deviation of 2.2 years) for the braced patients ($p=0.64$). Mean patient age at final follow up was 13.1 years (standard deviation of 8.5 years) for the un-braced patients and 14.5 years (standard deviation of 4.5 years) for the braced patients ($p=0.50$). Mean time after surgery when anterior-floor-reaction braces were prescribed was 3.5 years (standard deviation of 2.2 years).

DISCUSSION

A single surgeon case series study has limited scientific value, except perhaps as a warning if poor results are found. We believe that a 50% incidence of crouch gait requiring the prescription of anterior-floor-reaction braces is a poor result in the treatment of ambulatory patients with spastic diplegia and quadriplegia. Alone, this study is a modest warning. Coupled with the results of Borton's report of H. Kerr Graham's results of Achilles tendon lengthenings, we think this constitutes a strong warning.[34] Borton et al. reported on 65 diplegic and 45 quadriplegic patients treated by percutaneous Hoke, open TAL, or Baker gastroc-soleus fascial lengthening as isolated procedures for spastic equinus gait. Treatment was performed at an average age of 7.5 years and follow-up was almost 7 years. Forty percent of their diplegic patients and 60% of their quadriplegic patients showed calcaneus gait. Our conclusion is that treatment of ankle equinus by lengthening the Achilles tendon contributes to the development of crouch gait in an unacceptably large number of spastic diplegic and quadriplegic children. The extent of this contribution is uncertain. Johnson et al. have documented gradual deterioration as the natural history of gait in many ambulatory patients with spastic diplegia.[35] Some of our patients were probably destined to develop crouch gait regardless of the type of intervention. We cannot, at present, distinguish these patients from those with a good long-term prognosis for functional walking with optimal treatment. We did find a trend toward more severely involved patients developing crouch gait after TAL.

The literature on triceps surae lengthening for equinus gait is difficult to evaluate. The reported rates of over-lengthening of the Achilles tendon vary from 0-60%.[4,12,14,15,17,18,19,20,25,26,27,28,29,30,34,36,37,38] Many reports fail to mention this complication at all. Indications for surgery, outcome assessment methods, and patient populations are quite varied. Many studies have 3 years or less of follow-up after surgery.[2,16,26,27,39,40] In our series, the diagnosis of over-lengthening was made most often within the first five years after surgery. However, a significant number were diagnosed up to ten years post-operatively. A multidisciplinary workshop was convened in 2000, sponsored by the American Academy of Cerebral Palsy and Developmental Medicine and the United Cerebral Palsy Research and Educational Foundation to "explore the current state of knowledge, best clinical practice, and research needs for the management of equinus gait associated with cerebral palsy."[21] This group concluded that there is not enough evidence to recommend a best clinical practice. The senior author sent a survey to all members of the Pediatric Orthopaedic Society of North America (POSNA) with active e-mail addresses querying the treatment of spastic ankle equinus. One hundred and six pediatric orthopaedic surgeons responded and 78% performed TAL's or Hoke Achilles lengthening as part of their treatment for spastic ankle equinus. Only eight (7.5%) practitioners reported using gastrocnemius lengthening as their sole treatment for this problem.

Many variables could alter the outcome reported here for the treatment of ankle equinus during gait. Gastrocnemius lengthening/recession alone or, if necessary, separate lengthening of the gastrocnemius and soleus muscles may result in amelioration of ankle equinus with a decreased risk of over-weakening as argued by Gage et al.[32] Delaying surgery to an older age might improve results. Assiduous attention to mechanical alignment, especially correction of plano-abductus feet, might improve results of heel cord lengthening. Only lengthening mildly affected patients would doubtless improve results. Prolonged AFO bracing after TAL might decrease the incidence of excessive weakening the triceps surae. It is clear that some spastic patients will walk indefinitely with ankle equinus if untreated from personal observations of adults with cerebral palsy.[21,39] It seems likely that some children with ankle equinus, if untreated, will become plantigrade with increasing age and weight. On the other

hand, some patients with ankle equinus in childhood will develop crouch gait with increasing age and weight. Distinguishing between these groups would be important in designing optimal treatment protocols. Another group of patients probably exists who walk reasonably well during childhood and are aided in their walking while young by eliminating the equinus ankle, but are destined to not walk as adolescents or adults regardless of treatment.[35]

We must consider the possibility that lever arm dysfunction at the hip, knee, or foot may predispose these patients to crouch gait as well. Further study is needed to evaluate the indications for each type of lengthening procedure. A randomized prospective trial including these varying procedures is conceivable considering most surgeons self-report performing Achilles tendon lengthening as well as gastroc-soleus fascial lengthening.

CONCLUSIONS

This retrospective, non-randomized, single surgeon case series study shows that questions exist regarding the complications of Achilles tendon lengthening procedures performed on children with a diagnosis of cerebral palsy. This is a single-surgeon assessment of the incidence of crouch gait, which cannot reliably be treated well. The high rate of over-lengthening after either a Hoke or coronal Z-lengthening resulting in crouch gait requires further examination. The increasing incidence of crouch gait in this series as these children get older lends itself to the conclusion that these patients are overpowering their triceps surae as they become older and heavier. Overall, the Achilles tendon lengthening procedure carries with it a high rate of failure as defined by the need for an anterior-floor-reaction brace. Results are best in patients with hemiplegia, in non-hemiplegic patients who require only single leg surgery, and in patients who do not require concomitant or subsequent surgery.

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