Ninety Degree Straight Leg Raising Hamstring Lengthening in Non-Ambulatory Patients with Cerebral Palsy.

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ABSTRACT:

BACKGROUND:

A 90 degree straight leg raising hamstring lengthening was conducted in a consisted and prospective manner in non ambulatory children with Cerebral palsy.

OBJECTIVE:

A particular attention paid to evaluate clinical crouch recurrence, postoperative recurvatum, and overall improvement in functional capacity.

PATIENTS AND METHODS:

Sixty eight patients ages ranged from four to ten years have spastic neuromuscular involvement. A 90 degree straight leg hamstring lengthening performed in a specified manner. The mean length of follow up was 7 years 3 months (range 2years 4months -13years).

RESULTS:

Fifty-one of the sixty-eight patients had at least one level improvement in their Gross Motor Function Classification score.

The popliteal angle and straight leg raising improved postoperatively measured at the most recent follow up ($p<0.0005$).Non of our patients had regression of the popliteal angle to the preoperative level.

Nineteen patients (27.9%) had a mean recurvatum of 6 degrees. With the most recent follow up only eleven (16.1%) patients persisted with recurvatum at stance and gait**.**

CONCLUSION:

The 90 degrees straight hamstring lengthening may be considered a safe, simple and effective procedure with comparable or lesser complication rate.

KEY WORDS: cerebral, palsy, hamstring, crouch.

INTRODUCTION:

Hamstring lengthening has long been used as a gait improvement surgery in patients with cerebral palsy [1,2,3,4,5,6,7]. Spastic hamstrings produce flexion deformity of the knee, shortens stride length, produces crouch gait pattern and interferes with sitting balance [8,9,10,11]. In cerebral palsied children the tremendous increase in the energy that is needed for walking when the knee is flexed more than 20 degrees to prevent the patient from collapsing may further compromise their ambulatory status [8,9]. Furthermore, secondary compensatory flexion of the hip or pelvic tilt and ankle equinus may render potential ambulators nonfunctional [10,12]. Persistent crouch gait in patients with spastic diplegia causes excessive loading of the patellofemoral joint and may result in anterior knee pain, gait deterioration and progressive loss of control [8,9].

Surgery for hamstring dysfunction has traditionally consisted of proximal or distal lengthening of the hamstrings[1,6,13,14]distal transfer of the hamstrings and distal tenotomy[3,4]. Fractional lengthening of medial or combined medial and lateral hamstrings till SLR during surgery is 70 degrees has its specific indications to improve gait in ambulatory children with cerebral palsy [5,7,15]. However, to prevent possible persistent crouch and knee flexion in non ambulatory children but with potential voluntary control, a more aggressive approach was undertaken. Fractional lengthening of both medial and lateral hamstrings till SLR is 90 degrees was performed. Particular attention was paid to the rate of postoperative recurvatum, rate of which tightness of the hamstrings recurred, improvement in SLR and decreased crouch, improvement in the functional ambulatory status and walking ability.

PATIENTS AND METHODS:

A prospective study was performed to review the long term results of distal hamstring fractional lengthening performed in a specific and consisted

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manner between July 1997 and January 2010 at a single institution. Inclusion criteria include patients with spastic cerebral palsy with an evident excessive flexion of the knee during stance and of contracture of the hamstrings severe enough to impair the patient ability to walk or the sitting balance, or a crouch gait pattern.

All the cases were chosen among patients who had no sight or cooperation problems, with trunk control on sitting, no mental retardation or extra pyramidal manifestations and with no previous operations.

The study included 68 patients (47 males, 21 females), the ages of the patients ranged from four years to ten years. With a mean age of 5 years 3 months. All patients have spastic neuromuscular involvement. Fifty three patients had diplegia, fifteen had quadriplegia.

All patients included were levels three, four and five on Gross motor function classification score (GMFCS) [16,17]. Patients in level one can walk unlimited distances without support, but have problems with fine motor skills. Patients in level two can walk unlimited distances without support, but have limitations outside home and in crowds. Patients in level three can walk with a gait support (orthosis, walker, crutches) but have significant problems outside home and in crowds. Patients in level four have limitations in ambulation on their own, they can walk short distances with gait supports on smooth surfaces, and usually they are carried by others, while patients in level five do not have the ability to ambulate independently and they have to be carried by others (usually they can not sit without support)[16,17,18].

Of the sixty-eight patients included in the study, forty-eight had grade four GMFCS, fourteen patients had grade five, while six patients had grade three.

Popliteal angle was used to asses hamstring spasticity. It is measured with the patient supine and the hip in 90 degrees of flexion with the contralateral limb extended; the knee is then extended passively [18]. The angle between the posterior aspects of the thigh and leg determines the popliteal angle degree. The severity of limitation in the popliteal angle was graded as severe between (90-120), moderate between (120-150), and mild between (150-180). Preoperatively the popliteal angle averaged (118.1) degrees with a range of (90.3) to (152) degrees. Twenty-four patients had an extension lag of (5) to (35) degrees (mean 22 degrees).

Passive straight leg raising test was measured with the patient supine and the contra lateral limb extended. The severity of straight leg raising restriction was graded as sever from (0-30), moderate from (30-60), and mild between (60-90). Preoperatively, passive straight leg raising ranged from (40) to (70) degrees, with a mean of (53.2). Thirty-six patients had severe limitation, while thirty-two patients had moderate involvement.

At the time of the index surgery, fifty-nine patients had concomitant surgical procedures. Thirty-eight patients had bilateral and four had unilateral Vulpius or z-lengthening of the Achilles tendon. The decision to lengthen the gastrosoleus is based on actual contracture of the tendoachilles because functionally tight tendoachilis may be secondary to tight hamstring; this is thought important to prevent calcaneus gait. Eleven patients had bilateral iliopsoas intramuscular tenotomy.

The decision is based on actual hip flexion contracture causing excess lumbar lordotic posturing when examined under anesthesia.

A concomitant adductor myotomy was performed in forty-three patients who have abduction less than 35 degrees.

Quadriceps strength was evaluated using MRC grading preoperatively and at the most recent follow up. Improvement in stride length expressed in meters was also conducted.

Particular attention was paid to the rate of correction maintained reflected through improvement in popliteal angle, straight leg raising, postoperative recurvatum, rate at which tightness of the hamstrings recurred, overall improvement in functional capacity reflected through GMFCS, crouch knee gait, stiff knee gait all with special tests.

The mean length of follow up was 7 years 3 months (range 2years 4months-13years).

Source of Funding: There was no external funding source for the study.

Operative technique:

A standard operative technique was used for all patients. The operation was performed with the patient supine. The degree of all contracture of muscle groups (Hip flexors, hamstrings and tendoachilles) were assessed and confirmed with the patient under general anesthesia. A 3cm incision in made in the posteromedial thigh at the prominence of medial hamstrings at the junction of the middle and distal thirds of the thigh. Muscles were identified by blunt dissection; fractional lengthening of the gracilis, semitendinosus by sectioning the tendon only high enough was done with care taken to preserve adequate muscle mass attached to the sectioned tendon after the lengthening. Fractional lengthening of the semimembrinosus was achieved by making an oblique incision in the opponeurosis. The procedure was then done on the biceps femoris, at the same level through a separate posterolateral incision with aponeurotomy similar to that performed on the semimembrinosus muscle; in addition in patients with severe straight leg raising limitation sectioning at the iliotibial tract and the lateral intermuscular septum was performed at the same level of the lateral incision. Straight leg raising was performed to stretch the muscles to 90 degrees.

Postoperatively the patients wore a Plaster of Paris casts for four weeks. All patients were placed in a postoperative program of rehabilitation that involves active participation of the family. This is because of lag of specialized cerebral palsy rehabilitation units in our territory.

RESULTS:

The SPSS version 19, for windows statistical package was used for statistical analysis.

Fifty-one (75%) of the sixty-eight patients who were non-ambulatory became functional ambulators at the time of most recent follow up with at least one level improvement in their GMFCS. Thirty-three patients were able to walk about the community; eighteen patients were limited community ambulators in that they required hand held aids (walker or a cane).

All the six patients with grade III GMFCS became grade II and I, while only thirty-eight patients from forty-eight with grade IV became grade III, and seven patients with grade V became grade III .

Postoperatively sixty-two patients were able to walk erect (with or without support) with the hips and knees extended compared to non preoperatively, but with follow up to the most recent visit they declined to fifty-one with recurrence of crouch posturing and gait. The seventeen patients (25%) with recurrence had preoperative level four GMFCS in (ten patients) and level five GMFCS in (seven patients).

Postoperatively the popliteal angle improved from a mean of (118) degrees to (164) degrees. Straight leg raising improved from a mean of (53) degrees preoperatively to (70) degrees postoperatively measured at the most recent follow up, those with severe involvement showed a greater improvement in both popliteal angle and straight leg raising. A one way repeated measures analysis of variance was conducted to compare SLR and popliteal angles on preoperative and different times of follow up which shows a significant effect for the intervention ($P<0.0005$) .(Table (1).

A paired-sample t-test was conducted to evaluate the improvement in quadriceps strength using MRC muscle power grading. Thirty-two patients get some improvement in quadriceps strength measured at the most recent follow up time; the improvement did not reach statistical significance (P 0.2).

Fifty-two patients walked with a stiff knee gait postoperatively with pelvic swing to transmit the opposite swinging leg, with further follow up and build of antagonists' power and control over gait only twenty three patients had the persistent stiff knee gait.

None of our patients had regression of the popliteal angle and straight leg raising to the preoperative level. Seventeen patients (25%) got regression of their improvements over the follow up period with recurrence of knee flexion of more than ten degrees with crouch posturing and gait. This regression with crouch is considered a clinical recurrence. Direct logistic regression was performed to asses the impact of several preoperative variables that include the severity of straight leg raising, age of the patient at operation, preoperative GMFCS, and popliteal angle on the rate of recurrence. The full model was statistically significant and correctly classified 88% of cases. Only preoperative SLR variable made a statistically significant contribution to the model ($P<0.03$).(Table 2)

Variables in the Equation

Table 1: Descriptive statistics that shows all variables studied for the 68 patients with the means at the time of presentation(1), and the most recent follow up(13). (pop=popliteal angle),(slr=straight leg raising).

	Number of patients	Minimum	Maximum	Mean	Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic
Age(in years)	68	4.00	10.00	5.3868	1.34119
Sex(0=male,1=female)	68	.00	1.00	.5000	.50372
pop1(popliteal angle in degrees)	68	90.30	152.00	118.1809	16.10556
pop13	68	140.00	190.00	164.5294	12.75892
slr1(straight leg raising in degrees)	68	40.00	70.00	53.2059	8.15989
Slr13	68	50.00	90.00	70.8676	11.86731
gmfcs1(Gross motor function score)	68	3.00	5.00	4.1324	.54374
gmfcs13	68	1.00	5.00	3.2500	.98307
Valid N (listwise)	68				

Table 2: Direct logistic regression was performed to asses the impact of several preoperative variables upon the rate of recurrence as shown . The full model was statistically significant and correctly classified 88% of cases .Only preoperative SLR variable made a statistically significant contribution to the model(P<0.03).

variables		B	S.E.	Wald test	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1a	Age	-.340-	.301	1.275	1	.259	.712	.394	1.285
	pop1	-.001-	.061	.000	1	.983	.999	.887	1.125
	slr1	.290	.134	4.681	1	.031	1.337	1.028	1.739
	gmfcs1	-.204-	1.178	.030	1	.862	.815	.081	8.210
	Constant	-10.480-	10.833	.936	1	.333	.000		

a. Variable(s) entered on step 1: Age, pop1(popliteal angle), slr 1 (straight leg raising angle), gmfcs1 (Gross motor function classification score) .
b. Wald test : providing information about the contribution of predictor variables.
c. Sig. value of the preoperative (slr 1) , that only significantly contributes to the prediction of recurrence.
d. B values : the likelihood of positive values (slr1) , as a predictive variable upon the rate of recurrence.
e. Exp(B): These are the odds ratios for each of the independent variables.
f. (95% confidence interval): this is the range of values that we can be 95% confident encompasses the true value of the odds ratio.

Stride length expressed in meters which is the distance from initial contact of one foot to the following initial contact of the same foot was statistically significantly improved over preoperative values (p<0.001).The other important variable of genu recurvatum was evaluated in our patients for the whole follow up period; nineteen patients (27.9) had recurvatum with a mean of 6 degrees measured fifteen days after cast removal, range (4-10). With the most recent follow up only eleven patients persisted with recurvatum at stance and gait. All the aforementioned variables as patient age, GMFCS, the popliteal angle and straight leg raising showed no statistically significant correlation on the rate of recurvatum.With the mentioned period of follow up none of our patients developed new tortional leg deformity whether static or dynamic during gait. Of the 68 patients operated on, twenty four are now at school as functional ambulators. Families are satisfied with the cosmetic and functional improvement after surgery.

DISCUSSION:

Hamstrings are two joint muscles transferring energy between lower limb segments [19].At initial stance of gait cycle, the hamstrings with gluteus maximus exerts a pelvic extension moment, while the quadriceps is active to stabilize the knee [8]. With muscle imbalance existing between hamstrings assisted by gravity and postural reflexes and quadriceps, a secondary knee flexion contracture may develop. This deviation from normal gait greatly increases energy expenditure by approximately 25% with a [15] degree knee flexion contracture [9,20]. This greatly compromises ambulatory status in an already disabled child.During midstance, both the hip and knee are inherently stable due to their ligaments and capsules, knee posterior capsule and cruciate ligaments prevent hyperextension of the knee [19,21]. In normal walking and in swing phase, the leg acts as a simple pendulum with its point of fixation at the knee, the period of pendulum action would be dependant on gravity and moment inertia of the limb, however Cadence variance (no. of steps per unit of time) is controlled by coordinated muscle function between the rectus femoris and hamstrings [7]. Midswing is a switching period between the hamstrings and the rectus femoris with no muscle activity across the knee joint. Eccentric hamstring activity in terminal swing decelerates both the hip and knee[7].These aforementioned functions make hamstrings important in controlling cadence and foot clearance, gait velocity and stride length. These quality functions are difficult to achieve in a child with greatly compromised ambulatory status in whom real achievements from surgery are independence and improved ambulatory state.Arguments about hamstring lengthening site mainly at whether mean improvement in knee extension at stance is accompanied by a proportional decrease in flexion of the knee during swing, second, whether weakness of hip extension caused by hamstring lengthening will cause excessive hip flexion or increase lumbar lordosis, and third is the effect of medial or lateral hamstring lengthening on limb rotation during gait and the influence of hamstrings as important posterior knee stabilizer [7,11,19,22,23,24]. Patients enrolled in the study were severely affected as reflected in their GMFCS. In a third world country severe presentation of patients is common. Improvement in GMFCS of at least one score is a significant achievement for the patient and the family regarding their level of independence. In our patients both medial and lateral hamstring released by intramuscular tenotomy at least 10 cm from the popliteal flexion crease was done. No direct tenotomy was done and all muscles were kept in continuity to keep hamstrings integrity as important posterior knee stabilizers.

The intramuscular tenotomy may decrease sensory input of the stretch reflex and reduce spasticity. A novel technique of 90 degrees of straight leg raising lengthening was done in all these severely affected patients as previously defined.The standard recommended hamstring straight leg raising lengthening in the literature is 70 degrees [1,5,6,7,21,25,26]. It was thought that 90 degree SLR elongation is extreme and results in excessive loss of hamstring function, however, this has not been validated in prospective studies and the recurvatum as a risk factor for excessive hamstring elongation was described in heterogeneous patient populations [7,8,11,24,27]. Another important notice is the varied recurrence rate of knee flexion contracture reported in the literature(0-40%)with the 70 degree SLR lengthening.[7,8,11,24,27], with inconsistent results specifying recurrence rate in severely affected children, in addition, the definition of recurrence varied between exact knee flexion angle recurrence to regression to preoperative knee flexion values.Indisabled children with high GMFCS a persistent knee flexion and crouch greatly increases energy expenditure, compromises their functional ability and may contribute to contracture at other joints.In our series the recurrence rate (25%) defined as clinical recurrent knee flexion of more than 10 degrees with recurrent crouch pattern of gait. None of these patients had hip flexion contracture or ankle equinus. The significant improvement in SLR and popliteal angle was maintained throughout the follow up period. The preoperative SLR significantly correlated with the recurrence rate. J. Thometz et al [7].,in his study have shown that there is a strong correlation between improvement in SLR and improvement in maximum extension of the knee during gait. The significant improvement in stride length add to improvement of knee extension in swing phase so that adequate step length is achieved. Gait analysis lab was not available in our territory because of inadequate resources. Although it is important regarding decision making in ambulatory children with cerebral palsy, Studies has shown that the outcome after treatment was not necessarily changed by gait analysis, but is beneficial in fine tuning [18].Antagonists (quadriceps muscles) build up strength over time when knee flexion contracture had resolved [28,29,30,31]. This has not reached statistical significance in our series. In patients with persisted crouch, the increased quadriceps forces required to stabilize the flexed knee increases patellofemoral compressive forces causing knee pain and/or eventual patellar pole or tibial tubercle fracture.Evaluation of gait improvement in cerebral palsy is dynamic and correlates with brain maturation, evaluation of most variables is not an easy task because of impaired motor balance mechanisms and complex reflex control patterns and the varied combinations of primary motor deficiencies and their secondary adaptive changes, all explaining the notorious inconsistency of surgical outcome in cerebral palsy[2,21,32,33].Genu recurvatum measuring from (3-10) degrees developed in nineteen patients (27.9%) measured fifteen days after cast removal, this number regressed to eleven patients (16.1%) at the most recent follow up. This rate bears comparison with the rate of 8% reported by Dhawliker et al. (using 70degree SLR lengthening) [19]; In J. Thometz series of thirty-one patients using the same technique, five patients developed recurvatum, hamstring lengthening was rather done to improve internal rotation gait in two patients(7). Drummond(13) reported 28% recurvatum after proximal release of hamstrings, Lotman reported a 32% rate and Campos Da Paz reported 40% rate of recurvatum in his series (2,7). Patients enrolled in these studies were heterogenous regarding disability, and with different techniques of hamstrings lengthening. The change in recurvatum rate over the follow up time in our series is a reflexion of the dynamic state of gait changes; however, this may correlate with brain maturation, build up of muscle strength and change of motor balance between the hamstrings and antagonist muscles with time. The intramuscular tenotomy lengthening without actual tendon sectioning at a distance from the popliteal crease keeps muscles in continuity, preserving their stabilizing function, while effectively lengthening the muscle and decreasing sensory input. In our series no attempt at hamstring lengthening was done when the patient has adequate knee extension in stance phase or in patients with solely transverse plane malrotations.Hamstrings are two joint muscles [34,35]. The pelvic position in patients with their hamstrings lengthened is a difficult variable to evaluate; some have advocated concomitant intramuscular iliopsoas tenotomy when both medial and lateral hamstrings are lengthened to maintain balance between hip flexors and extensors[7,12]. In our series this was done in eleven patients having fixed hip flexion contracture when examined under anesthesia. No attempt was done for routine iliopsoas tenotomy because of three reasons, first: possible loss of hip active flexion strength which in turn leads to insufficient clearance of the foot especially when patients got their hamstrings weakened by lengthening [7], in addition power generation at the hip in stance is pointed to be an important mechanism for propulsion during walking; second, functional hip flexion contracture evaluated by the sever posterior pelvic tilt created during static Thomas testing does not correlate with pelvic position during standing, relaxed or during gait. Pelvic and hip position during standing and gait is a result of the complex relationship between trunk and lower extremity position [32,35,39]; and third, the difficulty of comparable evaluation of hip extensor and flexor strength and the possible time dependant improvement in muscle strength [7,12,19,36,37,38,40].

CONCLUSION AND RECOMMENDATIONS:

1- Distal hamstring lengthening as described in severely affected patients may show lesser recurrence rate when clinical recurrence, as defined, is considered.

2- Recurvatum as a risk factor for excessive hamstring lengthening is mild and with a low prevalence and the procedure may influence the significant improvement in GMFCS in (75%) of patients.

3- With the selected and well defined patient population and procedure in this study, a 90 degrees straight hamstring lengthening may be considered a safe, simple and effective procedure with comparable or lesser complication rate.

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