RESEARCH ARTICLE

Percutaneous Versus Open Hamstring Lengthening in Spastic Diplegic Cerebral Palsy

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Abstract

Background: Open hamstring lengthening (oHSL) is commonly performed to decrease knee contracture and improve gait and posture for children with spastic diplegia. Furthermore, percutaneous hamstring lengthening (pHSL) is also gaining popularity as an alternative to the open approach. This study aimed to compare the results of pHSL versus oHSL and to determine the efficacy and safety of the percutaneous approach.

Methods: This retrospective included 54 patients (108 knees) with spastic diplegia operated for flexed knee gait with either open or percutaneous HSL. The mean age of the participants at the time of surgery was 10.3±1.7 years (age range: 5-25 years) for the open and 8.5±1.5 years (age range: 7-23 years) for the percutaneous group. Overall, 29 and 25 children were subjected to oHSL and pHSL, respectively.

Results: The mean durations of follow-up were 19.1 months (range: 12-49 months) and 18.3 months (range: 14-45 months) for oHSL and pHSL groups, respectively. In the open group, the mean of preoperative popliteal angle decreased from 64.3±3.6 to 28.4±4.3 (*P<0.001*), and in the percutaneous group from 63.8±2.7 to 29.5±2.3 (*P<0.001*). The obtained results revealed no significant differences between the two approaches leading to a similar improvement among the investigated patients (*P=0.83*).
Although the Gross Motor Function Class Score improved significantly within each group (*P<0.001*); this improvement was insignificant between the groups (*P=0.88*). The mean of hospital stay for the percutaneous group was 1.6 days (range:1-3 days) compared to 3.6 days (range: 2-6 days) for the open group, which indicated a significant difference (*P=0.001*). The mean values of total cost were $333 and $473 in the percutaneous group and open group (*P=0.001*), respectively. There was no significant difference between the groups regarding the complication rate (*P=0.85*).

Conclusion: Percutaneous HSL is a safe, easy, rapid, and brief procedure that is as effective as the open technique for children with spastic diplegia in a short period of time. However, it is essential to examine the effects of this approach during longer follow-ups to generalize the findings of the current study.

Level of evidence: III

Keywords: Cerebral palsy, Diplegia, Hamstring lengthening, Percutaneous, Popliteal angle

Introduction

A common disorder in the lower extremity of children with spastic diplegic cerebral palsy (CP) is knee flexion deformity caused by the contracture of the hamstring muscles. This flexion deformity leads to crouch or jumping posture/gait. The standard surgical procedure for the correction of knee flexion deformity is open hamstring muscle-tendon lengthening (1-5). Muscle-tendon lengthening procedures reduce the

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strength of hamstring muscles (6, 7). These procedures consist of a Z-lengthening of the tendon or the fractional lengthening of the musculotendinous junction of the medial hamstrings alone or combined with medial and lateral hamstring release (8, 9). Traditionally, these procedures were performed openly as a single event multilevel surgery, which is likely to increase morbidity rate, prolong recovery period, and weaken the knee flexors (10). Percutaneous surgical release of hamstring tendon-muscle has recently become an alternative to the open release. Percutaneous approaches have been found to maximize residual muscle strength with faster recovery and reduced morbidity rate (11-17). However, there is a dearth of research on the advantage and effectiveness of the percutaneous approach in spastic diplegic CP patients. The present study aimed to evaluate the results of percutaneous hamstring lengthening (pHSL) in spastic diplegia versus open hamstring lengthening (oHSL) regarding the motion range and limb function.

Materials and Methods

This retrospective study was approved by the institutional research ethics board. Gait analysis and clinical data were retrospectively collected for 54 children (108 knees) with spastic diplegic CP with crouch, jumping, or scissor gait (flexed knee gait). These patients were managed with surgical hamstring lengthening using the single event multilevel surgery technique performed by two surgeons at a university referral hospital (during 2008-2016). One of the surgeons would always use a percutaneous technique and the other would always carry out the open approach. All patients were spastic diplegia with the similar affection of both lower limbs.

Out of the 54 participants, 24 (44.5%) patients were girls. The mean ages of the participants at the time of surgery were 10.3±1.7 years (range: 5-25 years) and 8.5±1.5 years (range: 7-23 years) for the open and percutaneous groups, respectively. All cases were preoperatively evaluated for the Gross Motor Functional Classification System (GMFCS, Levels I to V), the popliteal angle (PA), and knee extension in static status and in the stance phase of the gait. Patients' gaits were classified into three classes, including crouch, jumper, and scissor gait. Gait assessment and knee flexion contracture measurement in stance phase were performed using clinical examinations before the surgery. After the neurological evaluation of the children in this study, they were subjected to the single-event multilevel approach. Operation time (min), hospital stay (day), and the total cost of treatment (US$) were evaluated for all patients. All assessments were repeated at the end of the follow-up for comparison. Table 1 shows the statistical description

Table 1. Statistical description of the patients

		[n(%)]		*P*
		oHSL (n=29)	pHSL (n=25)	
Age (SD)(years)		10.3 (1.7)	8.5 (1.5)	0.82
Gender				0.85
Female		12 (41.3)	12 (48)	
Male		17 (58.7)	13 (52)	
BMI (kg/m2)		17.6 (1)	17.9 (1)	0.71
GMFCS				0.08
I		3 (10.3)	4 (16)	
II		10 (34.5)	7 (28)	
III		11 (38)	9 (36)	
IV		3 (10.3)	3 (12)	
V		2 (6.9)	2 (8)	
Gait				0.91
Crouch		15	12	
Jumper		14	13	
Scissoring		20	18	
Hamstring lengthening				
Medial		17 (58.7)	14 (56)	0.34
Mediolateral		12 (41.3)	11 (44)	0.72
Other procedure				
No		5 (17.2)	7 (28)	0.81
Yes		24 (82.8)	18 (72)	0.09
	Volpious	10	4	
	ATL	8	5	
	Adductor tenotomy	20	18	
	TP transfer or lengthening	4	0	
Follow up (months)		19.1	18.3	0.86

BMI: body mass index, oHSL: open hamstring lengthening, pHSL: percutaneous hamstring lengthening, GMFCS: Gross Motor Function Classification System, ATL: Achilles tendon lengthening, TP: tibialis posterior of the investigated variables

Patients were divided into two groups of oHSL and pHSL. The former consisted of 29 children undergoing open hamstring lengthening (oHSL) and the latter composed of 25 children subjected to percutaneous hamstring lengthening (pHSL). All cases were operated under general anesthesia and supine position for the pHSL group and in the prone position for oHSL group. In both groups, the treatment was initiated by medial hamstring release, including semitendinosus and gracilis with or without semimembranosus release. Lateral hamstring release would be performed if knee flexion deformity was not corrected sufficiently (PA>20).

In the open group, a midline posterior approach was implemented just proximal to the popliteal crease of the knee. The treatment procedure included the classic Z-lengthening of semitendinosus and gracilis muscle as well as the levels 1 or 2 transverse incision (aponeurotic lengthening) of semimembranosus fascia. In the next step, the popliteal angle could be assessed intraoperatively if residual flexion deformity was more than 20 degrees. In addition, lateral hamstring biceps femoris was also lengthened with levels 1 or 2 fractional aponeurotic lengthening.

For pHSL, the patient was positioned in the supine position. The tendinous portion of semitendinosus was subcutaneously identified at a few centimeters proximal to the popliteal crease. The tenotomy of the semitendinosus was percutaneously performed with a no.11 blade. Gracilis was released in many cases since it has some flexor action on the knee and is often tight. We would then carry out the single level partial tenotomy of the tight parts of semimembranosus in case the knee did not extend to at least 20 degrees (i.e., falling short of full extension). In patients with markedly tight biceps femoris at this position, a single level partial tenotomy was conducted percutaneously via another incision.

Simultaneous procedures were performed on 42 patients, including bilateral adductor tenotomy for 38 patients, 13 bilateral Achilles tendon lengthening in 27 patients with equines deformity, and the Baumann procedure (isolated recession of the gastrocnemius muscle) in 14 patients. The bilateral knee plaster cast with the knees in full extension was applied and maintained for 6 weeks with an abduction bar in between, in case of having performed adductor tenotomy. The patients were allowed to bear weight as tolerated immediately after the surgery. Physiotherapy or occupational therapy started after cast removal with the emphasis on active exercises. Following cast removal, above-knee night splint was used for 3 months.

All patients were re-evaluated 6 and 12 months after the surgery and yearly thereafter, for the postoperative range of motion, popliteal angle, knee flexion in stance, and GMFCS. The total cost of in-hospital care was calculated for each patient using the CPWC method. Outcome variables before and after the surgery were compared within and between the groups using paired t-tests. The Chi-square tests were employed to test the relationships between continuous and categorical variables. *P-value* less than 0.05 was considered statistically significant.

Results

The mean values of age, GMFCS, and follow-up time were similar in both groups at the time of operation with no significant difference. In addition, both groups shared similar baseline characteristics [Table 1]. The preoperative values of range of motion and GMFCS were similar in both groups [Table 2]. Five patients in each group were non-ambulatory (GMFCS IV or V). Regarding the open group, 17 patients underwent medial hamstring release and the other 12 needed medial plus lateral HSL (biceps femoris fractional lengthening). In the percutaneous group, 14 patients needed medial HSL and 11 patients were subjected to medial plus lateral HSL [*P=0.72*; Table 1]. Totally, 42 patients needed other simultaneous procedures, including hip adductor release in 38, fractional lengthening of the gastrocnemius for 14, Achilles tendon z-lengthening for 13, and posterior tibialis lengthening or transfer for 4 cases [Table 1]. At a mean follow-up of 19.1 months (range: 12-49 months), the mean preoperative popliteal angle of 64.3±3.6 (54-72) decreased to 28.4±4.3 (24-33) for the oHSL group (*P<0.001*). In the pHSL group, the mean preoperative popliteal angle decreased from 63.8±2.7 (56-70) to 29.5±2.3 (25-35) (*P<0.001*) at a mean follow-up of 18.3 months (range: 14-45 months). There was no significant difference between the groups in terms of popliteal angle

Table 2. Preoperative popliteal angle and Motor Function Classification System Between the investigated groups

	n (%)		*P*
	oHSL (n=29)	**pHSL (n=25)**	
Popliteal angle (mean/SD; degree)	64.3 (3.6)	63.8 (2.7)	0.831
GMFCS			
I	3 (10.3)	4 (16)	0.08
II	10 (34.5)	7 (28)	
III	11 (38)	9 (36)	
IV	3 (10.3)	3 (12)	
V	2 (6.9)	2 (8)	

ROM: range of motion, GMFCS: Gross Motor Function Classification System, oHSL: open hamstring lengthening, pHSL: percutaneous hamstring lengthening, SD: standard deviation

Table 3. Change of variables within and between the investigated groups

	[n(%)]						P Between Groups
	oHSL (n=29)			pHSL (n= 25)			
	Pre [mean (SD)]	Post [mean (SD)]	P (within)	Pre [mean (SD)]	Post [mean (SD)]	P (within)	
Popliteal angle (deg)	64.3 (3.6)	28.4 (4.3)	<0.001	63.8 (2.7)	29.5 (2.3)	<0.001	0.83
GMFCS [n (%)]							
I	3 (10.3)	8 (27.5)	<0.001	4 (16)	8 (32)	<0.001	0.88
II	10 (34.5)	13 (44.8)		7 (28)	10 (40)		
III	11 (38)	6 (20.6)		9 (36)	5 (20)		
IV	3 (10.3)	2 (6.8)		3 (12)	2 (8)		
V	2 (6.9)	0		2 (8)	0		
Op. time (range, min)	17 (15-21)			56 (30-75)			*P<0.001*
Hospital stay (day)	1.6			3.6			0.001
Cost ($)	473			333			0.001

oHSL: open hamstring lengthening, pHSL: percutaneous hamstring lengthening, Pre: preoperative, Post: postoperative, GMFCS: Gross Motor Function Classification System, Op: operation

improvement (*P=0.83*).

The GMFCS within each group improved with the mean of functional class improvement obtained at 0.62±0.49 (*P<0.001*) in the oHSL group and 0.64±0.49 in the pHSL group (*P<0.001*). These findings revealed no significant difference between the two groups [*P=0.88*; Table 3]. In both groups, non-ambulatory patients had at least one class of functional enhancement [Table 3]. The mean of hospital stay in the pHSL group was 1.6 days (range: 1-3 days), comparing to 3.6 days (range: 2-6 days) for the oHSL group with a significant difference (*P=0.001*). The mean total cost in pHSL group was $333 (range: $289-372) while it was $473 (range: $435-520) in the oHSL group. A significant difference was found in the treatment cost between the two groups (*P=0.001*). Mean operation time was respectively 17 min (range: 15-21 min) in the pHSL and 56 min (range: 30-75 min) in the oHSL group, showing a significant difference [*P<0.001*; Table 3].

The obtained results were indicative of two complications in each group. In the open group, peroneal nerve palsy occurred in one patient that recovered after 6 months. Another patient developed stiff knee gait that was treated with hamstring strengthening exercise and anti-recurvatum brace for 6 months. However, the outcome of the treatment was no successful enough, leading to the distal transfer of rectus femoris.

The latter led to remarkable improvement after 12 months enabling the patient to walk without a brace, providing foot clearance during the swing phase. In the percutaneous group, there was a patient suffering from peroneal nerve palsy after surgery that recovered spontaneously after 3 months. Another patient developed hamstring weakness resulting in hip extensor weakness and extensor lurch that was treated nonoperatively with the incomplete recovery at a 3.5-year-follow-up. Complication rate difference was statistically insignificant between the groups (*P=0.85*).

Discussion

The underlying neurological lesions in spastic cerebral palsy are non-progressive. On the other hand, musculoskeletal abnormalities (e.g., abnormal posture, gait disturbance, joint ROM, and deformity) are usually progressive until skeletal maturity, after which they mostly stop progression. Therefore, most of the procedures are performed during childhood before skeletal maturity.

Hamstring lengthening surgery is an essential operative treatment for spastic CP. It can be used to ameliorate the gait, posture, and function in ambulatory spastic CP children. Furthermore, these procedures can be helpful in the improvement of posture and hygienic activities in non-ambulatory CP patients. As was observed, the percutaneous technique is safe and effective if it is carefully performed in the tendinous portion of the muscles by an experienced surgeon. In the current study, the correction of the popliteal angle in the pHSL group was the same as oHSL group. In addition, knee extension in stance phase and GMFCS changes in both groups were similar. There was one case of knee recurvatum deformity after an open HSL; however, no recurvatum happened after percutaneous HSL. The obtained results revealed one case of extension lurch after pHSL due to hip extensor weakness. The operation time, anesthetic time, hospital stay, and total cost were significantly reduced with the use of the percutaneous technique.

The existing literature supports the obtained results of the current study. Alexander et al. reviewed 87 ambulatory children with CP who underwent open or percutaneous HSL. The findings showed no significant difference between the open and percutaneous groups regarding ultimate popliteal angle, knee kinematics, and knee extension in the stance phase of the gait (15). Gordon et al. reported that pHSL was a helpful surgical option in ambulatory spastic CP children undergoing a single event multilevel operation (16). They showed markedly improved popliteal angle and knee extension in stance phase; however, their study did not have a control group for comparison.

Mansour et al. compared the anatomic effect and safety of percutaneous medial hamstring myofascial lengthening versus open procedure of 31 knees in 18 CP patients (17). They showed that both oHSL and pHSL would result in notable improvement of popliteal angle in spastic CP children. They did not recommend percutaneous HSL because of undesirable damage to the muscular portion of medial hamstring muscles and the possibility of permanent hamstring weakness in the long term. This is in contrast to our experience of low hamstring weakness rate in the percutaneous group. This can be contributed to the fact that we used partial tenotomy of semimembranosus and biceps femoris (if any) instead of fractional lengthening and a more distal location for tenotomy instead of the musculotendinous junction.

One potential concern with a tendinous release during a pHSL (rather than lengthening or recession typically performed in oHSL) would be the possibility of hamstring over-weakening. However, this was not confirmed since symptomatic hamstring weakness was not more common in the pHSL group. A repair process may also occur in hamstring tendons after pHSL similar to what occurs after Achilles tenotomy during the treatment of club foot using Ponseti's method. This leads to the re-establishment of the tendons continuity in the appropriate length and a more balanced muscle function (18).

The limitations in the current study included a short period of follow-up and retrospective nature of the study. For instance, we did not have the information about the individual muscles released in each patient. Moreover, other simultaneous surgeries could have a confounding effect on the assessment of the muscle function, making it difficult to assess the pure effect of hamstring release on the patient's functional change. There was also no laboratory gait analysis.

In conclusion, the percutaneous HSL is a safe, easy, rapid, and brief procedure that is as effective and safe as the open technique in spastic diplegic CP children in a short term follow-up. There is still a need for a long term follow-up to confirm the effectiveness and safety of the procedure.

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