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Original article

Intramuscular psoas lengthening during single-event multi-level surgery fails to improve hip dynamics in children with spastic diplegia. Clinical and kinematic outcomes in the short- and medium-terms

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ABSTRACT

Background: In children with spastic diplegia, hip extension in terminal stance is limited by retraction of the psoas muscle, which decreases stride propulsion and step length on the contralateral side. Whether intramuscular psoas lengthening (IMPL) is effective remains controversial. The objective of this study was to assess the impact of IMPL as a component of single-event multi-level surgery (SEMLS) on spatial and temporal gait parameters, clinical hip flexion deformity, and hip flexion kinematics.
Hypothesis: IMPL as part of SEMLS does not significantly improve hip flexion kinematics.
Materials and methods: A retrospective review was conducted of the medical charts of consecutive ambulatory children with cerebral palsy who had clinical hip flexion deformity (> 10°) with more than 10° of excess hip flexion in terminal stance and who underwent SEMLS. The groups with and without IMPL were compared. Preoperative values of the clinical hip flexion contracture, hip flexion kinematics in terminal stance, and spatial and temporal gait parameters were compared to the values recorded after a mean postoperative follow-up of 2.4 ± 2.0 years (range, 1.0–8.7 years). Follow-up was longer than 3 years in 6 patients.
Results: Of 47 lower limbs (in 34 patients) included in the analysis, 15 were managed with IMPL. There were no significant between-group differences at baseline. Surgery was followed in all limbs by significant decreases in kinematic hip flexion and in the Gillette Gait Index. In the IMPL group, significant improvements occurred in clinical hip flexion deformity, walking speed, and step length. The improvement in kinematic hip extension was not significantly different between the two groups. Crouch gait recurred in 3 (8%) patients.
Discussion: The improvement in kinematic hip extension in terminal stance was not significantly influenced by IMPL but was, instead, chiefly dependent on improved knee extension and on the position of the ground reaction vector after SEMLS. IMPL remains indicated only when the clinical hip flexion deformity exceeds 20°.
Level of evidence: IV, retrospective study.

1. Introduction

Restricted hip extension in terminal stance is a common abnormality of gait kinematics in ambulatory children with spastic diplegia. In patients with distal neurological impairments, this abnormality is due to alterations in ankle and knee position, with compensatory changes in hip and pelvis positions that align the torso on the ground reaction force vector (GRFV). In patients with proximal impairments, the excessive hip flexion in terminal stance may be related to spasticity or contracture of the hip flexor muscles (the iliopsoas muscle) or to weakness of the hip extensor muscles (gluteus maximus muscle) [1]. Excessive hip flexion in terminal stance diminishes limb propulsion power, thereby adversely affecting swing, balance, and contralateral step length [2].

Contracture of the iliopsoas muscle is the main cause of excessive hip flexion in terminal stance [3]. Intramuscular lengthening of the psoas muscle over the pelvic brim is a reliable technique that theoretically improves the clinical hip flexion deformity while

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Table 1
Preoperative and postoperative data in the patients managed with and without intramuscular psoas lengthening.

Mean (± SD)	IMPL− *n* = 32 limbs			IMPL+ *n* = 15 limbs			Comparison of preoperative data in the IMPL− and IMPL+ groups Mann-Whitney test significant if $P < 0.05$
	Preoperative values	Postoperative values	Wilcoxon test, significant of $P < 0.05$	Preoperative values	Postoperative values	Wilcoxon test, significant if $P < 0.05$	
Age at surgery, years	12.6 (± 2.8)	NA	NA	13.8 (2.8)	NA	NA	$P = 0.25$
Number of surgical sites/side	5.5 (± 4.2)	NA	NA	6.3 (± 5.4)	NA	NA	$P = 0.52$
GGI	448 (± 176)	220 (± 130)	$P = 0.05$	328 (± 175)	190 (± 95)	$P < 0.05$	$P = 0.06$
GMFCS, number of patients	II: *n* = 15 III: *n* = 1	NA	NA	II: *n* = 15 III: *n* = 3	NA	NA	NA
Clinical hip flexion deformity,°	14 (± 6)	14 (± 6)	$P = 0.22$	17 (± 6)	2 (± 4)	$P < 0.001$	$P = 0.09$
Kinematic hip flexion,° (at 50% of the gait cycle)	19 (± 7)	13 (± 10)	$P < 0.001$	23 (± 6)	14 (± 7)	$P < 0.001$	$P = 0.09$
Step length, cm	38.2 (± 10.8)	38.6 (± 12.1)	$P = 0.2$	42.5 (± 11.0)	45.0 (± 9.1)	$P < 0.05$	$P = 0.51$
Walking speed, cm/s	71.9 (± 30.8)	69.4 (± 30.2)	$P = 0.5$	80.4 (± 21.9)	85.2 (± 23.1)	$P < 0.05$	$P = 0.47$
Kinematic knee flexion,° (at 50% of the gait cycle)	50 (± 19)	33 (± 15)	$P < 0.001$	46 (± 14)	36 (± 11)	$P < 0.05$	$P = 0.42$

GGI: Gillette Gait Index; GMFCS: Gross Motor Function Classification System; NA: not applicable.

preserving the strength of the iliac muscle, which is, on the contrary, impaired after psoas tenotomy [1,3,4]. However, published data on the outcomes of intramuscular psoas lengthening (IMPL) are scant, and most studies had small numbers of patients with no control group. Moreover, the indications of IMPL during SEMLS remain unclear, controversial, and often based on the surgeon's experience and subjective intraoperative assessment [5].

The objective of this study was to evaluate outcomes obtained after IMPL as part of SEMLS in children with spastic diplegia. The study hypothesis was that IMPL as part of SEMLS did not significantly improve hip flexion kinematics.

2. Materials and methods

2.1. Patients

Consecutive ambulatory children with cerebral palsy classified level I to III in the Gross Motor Function Classification System (GMFCS) [6] and managed with SEMLS were included in this retrospective chart review. Inclusion criteria were clinical hip flexion deformity and excess kinematic hip flexion in terminal stance both > 10°. A physical examination and quantitative gait analysis (QGA) were performed within 6 months before surgery. Exclusion criteria were lower limb surgery or botulinum toxin injection within the past 6 months. Of the 178 lower limbs treated from 2004 to 2009, 47, in 34 patients, met the study selection criteria. There were 26 boys and 8 girls (male-to-female ratio, 3.3). Of the 34 patients, 30 were level II and 4 were level III in the GMFCS. Mean age at surgery was 13 ± 2.8 years (range, 6.8–18.5 years). Two senior specialised paediatric orthopaedic surgeons performed all the procedures. One of them usually performed IMPL and managed 15 limbs (IMPL+ group); this fact ensured that IMPL was performed reproducibly. The other did not use IMPL and managed 32 limbs (IMPL− group). Mean time from surgery to the last evaluation (which included QGA) was 2.4 ± 2 years (range, 1.0–8.7 years). Only 6 patients were re-evaluated more than 3 years after surgery. The IMPL+ and IMPL− groups were comparable for all baseline study parameters (Table 1) and for the concomitant surgical procedures (Table 2). No patient experienced intraoperative or postoperative complications.

Table 2
Frequency of each of the surgical procedures performed during multisite surgery in the groups with and without intramuscular psoas lengthening.

Concomitant surgical procedures	IMPL− (*n* = 32)	IMPL+ (*n* = 15)	Chi^2 test, significant if $P < 0.05$
Myotomy of the gracilis muscle ± lengthening of the adductor longus muscle	32 (100%)	13 (87%)	$P = 0.6$
Lengthening of the medial hamstring muscles ± biceps femoris muscle	28 (88%)	15 (100%)	$P = 0.48$
Tenectomy of the rectus femoris	28 (88%)	15 (100%)	$P = 0.48$
Femoral derotation	15 (47%)	4 (27%)	NA
Fasciectomy of the gastrocnemius ± soleus muscles	27 (84%)	12 (80%)	$P = 0.24$
Lengthening of the tibialis posterior and/or peroneus muscle and/or hemi-tibialis anterior transfer	30 (94%)	7 (47%)	$P < 0.05$
Tibial derotation	10 (31%)	5 (33%)	$P = 0.80$
Bone surgery on the foot	5 (16%)	2 (13%)	NA
Distal femoral extension osteotomy	4 (12.5%)	2 (13%)	NA

NA: not applicable, because of a sample size < 5.

2.2. Operative technique for intramuscular psoas lengthening (IMPL)

IMPL over the pelvic brim was performed using the technique described by Skaggs et al. [4] and modified by Novacheck et al. [1].

2.3. Assessment methods and study parameters

During the physical examination, hip flexion deformity related to the psoas muscle was measured using the Thomas test: with the patient supine and the contralateral limb flexed, the knee of the