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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A B S T R A C T

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.

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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
preserving the strength of the iliopsoas 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 1 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); his 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.

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
limb being examined was extended and the deficit in hip extension was measured. Kinematics were evaluated by performing QGA using a VICON MX+ optoelectronic motion capture system (Vicon; Oxford Metrics, Oxford, UK) comprising eight infrared cameras that tracked reflective markers positioned on pre-defined anatomical landmarks [7]. QGA involved recording the following five parameters: the Gillette Gait Index (GGI) [8], based on 16 kinematics parameters and used to characterise gait function before and after surgery (normal value, <15); hip flexion in terminal stance; knee flexion in terminal stance; walking speed (in cm/s); and step length (in cm). In each group, these clinical and QGA parameters were compared between baseline and at follow-up at least 1 year after surgery. Then, the changes in these parameters from baseline to follow-up were compared between the two groups.

2.4. Statistical analysis

The Shapiro-Wilk test results showed that the study parameters had non-normal distributions. To assess comparability of the two groups, the non-parametric Mann-Whitney test was chosen to compare preoperative variables. The Chi² test was applied for between-group comparisons of the frequency of concomitant surgical procedures during multisite surgery. For the comparison in each group of variable values at baseline and at follow-up, the non-parametric Wilcoxon test was used. Finally, between-group comparisons of changes from baseline to follow-up in each of the study variables were performed with the Mann-Whitney test. Values of $P<0.05$ were considered significant with all tests. All statistical analyses were run using SPSS software version 12.0 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Comparison of preoperative and postoperative data in each group

Table 1 lists the preoperative and postoperative data in each of the two groups.

3.1.1. Clinical data

The clinical hip flexion deformity improved significantly from baseline to follow-up in the IMPL+ group but not in the IMPL− group ($P<0.01$).

3.1.2. Kinematics

In both groups, SEMLS was followed by a significant improvement in the GGI and a significant decrease in kinematic hip flexion ($P<0.05$). In addition, kinematic knee flexion decreased significantly ($P<0.05$). However, kinematic hip and knee flexion remained excessive in both groups.

Among spatial and temporal gait parameters, significant improvements in step length and walking speed were found only in the IMPL+ group ($P<0.05$). However, no significant between-group differences were noted for the change from baseline to follow-up, i.e., in the postoperative improvements in spatial and temporal parameters or hip kinematics (Table 3). Neither did the kinematic hip flexion persisting after surgery differ between the two groups.

3.2. Influence of concomitant femoral derotation

Concomitant femoral derotation was associated with significantly less kinematic hip flexion after surgery in the IMPL− group but had no significant influence on any of the other postoperative parameters (Table 4). In the IMPL+ group, the results are inconclusive, because of the small numbers of patients in the two subgroups ($n=4$ and $n=9$).

3.3. Revision surgery

Of the 34 patients, 3 (8%) experienced recurrent crouch gait, after a mean interval of 5.3 years. All 3 were younger than 12 years at surgery, and 2 were in the IMPL− group. These patients required a second SEML procedure. IMPL was not performed during this second procedure in any of the 3 patients.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Mean difference between preoperative and postoperative values in the groups managed with and without intramuscular psoas lengthening.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>IMPL− ($n=32$)</td>
</tr>
<tr>
<td>Clinical hip flexion deformity,</td>
<td>−5% $(−1 ± 4)$</td>
</tr>
<tr>
<td>Kinematic hip flexion,</td>
<td>−32% $(−6 ± 7)$</td>
</tr>
<tr>
<td>GGI</td>
<td>−51% $(−228 ± 164)$</td>
</tr>
<tr>
<td>Walking speed (cm/s)</td>
<td>−3% $(−3.0 ± 22.1)$</td>
</tr>
<tr>
<td>Step length, cm (cm)</td>
<td>+1% $(0.2 ± 9.2)$</td>
</tr>
</tbody>
</table>

GGI: Gillette Gait Index.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Influence of performing femoral derotation on postoperative outcomes.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IMPL− Without femoral derotation ($n=16$)</td>
</tr>
<tr>
<td>Postoperative clinical hip flexion deformity,</td>
<td>0.3 $(±1.2)$</td>
</tr>
<tr>
<td>Postoperative kinematic hip flexion, $(at 50% of the gait cycle)$</td>
<td>17.5 $(±5.9)$</td>
</tr>
<tr>
<td>Postoperative GGI</td>
<td>187.9 $(±91.9)$</td>
</tr>
<tr>
<td>Postoperative step length, cm</td>
<td>39.6 $(±12.7)$</td>
</tr>
<tr>
<td>Postoperative walking speed, cm/s</td>
<td>68.6 $(±31.0)$</td>
</tr>
<tr>
<td>Postoperative knee flexion in terminal stance, $(at 50% of the gait cycle)$</td>
<td>30.7 $(±9.4)$</td>
</tr>
</tbody>
</table>
4. Discussion

The only significant difference between the two study groups was better (nearly complete) correction of the clinical hip flexion deformity in the IMPL+ group. This finding is consistent with previous reports of a 6° to 20° improvement in clinical hip flexion deformity after IMPL [2,9,10]. In contrast, the two groups showed no significant differences regarding the improvements in kinematic hip extension (Figs. 1 and 2), GGI, or spatial and temporal gait parameters. These results suggest that performing IMPL as part
of SEMLS does not play a major role in correcting kinematic hip flexion.

Insufficient hip extension in terminal stance may be related not only to contracture of the psoas muscle, but also to a GRFV position anterior to the centre of rotation of the hip. The position of the GRFV depends on the position of the infra-jacent joints. In both of our study groups, the significant decrease in kinematic hip flexion was accompanied with a significant decrease in excessive knee flexion in terminal stance. However, this decrease was too small to shift the GRFV behind the centre of rotation of the hip and to fully correct kinematic hip flexion (Fig. 3). The position of the GRFV and, therefore, of the infra-jacent joints exerts a major influence on hip position during the gait cycle, a fact that may call into question the usefulness of IMPL during SEMLS. In contrast, hip kinematics may be improved by procedures that benefit knee and ankle kinematics in the sagittal plane, such as muscle lengthenings and/or procedures on the bones at the knee and ankle (e.g., hamstring lengthening, extension osteotomy, and fasciectomy of the gastrocnemius and/or soleus muscles).

A strong feature of our study is the comparison with a group managed without IMPL. This design feature allowed us to demonstrate that IMPL had no major influence on outcomes. The limitations of our study include the limited reliability of the method used to measure clinical hip flexion deformity [11]. Consequently, in our opinion, the measurement of kinematic hip flexion is the most relevant parameter [11,12]. Another limitation is the wide inter-individual variability in baseline walking function scores, particularly as only 4 patients were GMFCS level III and a statistical assessment of correlations between functional scores and postoperative outcomes was not feasible. Finally, our patients were not randomised, and whether IMPL was performed or not depended solely on the surgeon preference. As with all studies using QGA, the reliability of the kinematic measurements was limited by the accuracy in identifying the joint centres. However, reproducibility testing is performed routinely in QGA laboratories. Finally, IMPL was studied only as one component of SEMLS. The other procedures performed concomitantly may have influenced hip kinematics (procedures to correct knee flexion deformity or femoral derotation procedure) [13]. However, these concomitant procedures were similar in the two groups. Distal rectus femoris tenectomy was performed in most patients and had no effect on the power generated by the rectus femoris to flex the hip.

Whether distal psoas tenotomy would have produced similar results is unclear. However, there is a strong current of opinion [2–4] that this procedure should be discarded because of the risk of muscle weakness.

No unambiguous data on the exact indications of IMPL are available in the literature. According to one opinion, clinical hip flexion deformity > 15° is the only indication [14]. Others [3,5,9,15] contend that attention should also be directed to hip kinematics, particularly excessive anterior pelvic tilt and insufficient hip extension in terminal stance [5,15]. Davids et al. [15] pointed out that these abnormalities may be tertiary, i.e., developed to compensate for secondary and/or primary impairments such as limited plantar ankle flexion or knee flexor overactivity. In this situation, correcting these primary and secondary impairments is the only means of correcting hip flexion.

In contrast to Truong et al. [5], we believe that IMPL is not indicated in patients who are GMFCS level III or IV, i.e., who cannot walk without assistance. These patients exhibit a tendency towards anterior tilting of the torso and therefore, use excessive hip flexion as a means of ensuring stability, as underlined by both Morais Filho et al. [9] and Sutherland et al. [3].

5. Conclusion

IMPL is only very rarely indicated as part of SEMLS for children with spastic diplegia. IMPL fails to provide additional improvements in spatial and temporal gait parameters, the GGI, or hip extension in terminal stance compared to multisite surgery without IMPL. The only significant contribution of IMPL is better correction of the clinical hip flexion deformity. Consequently, IMPL is indicated only in patients whose clinical hip flexion deformity exceeds 20° when measured under general anaesthesia before surgery.

Disclosure of interest

The authors declare that they have no competing interest.

References


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