Radical Posterior Capsulectomy Improves Sagittal Knee Motion in Crouch Gait

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Published online: 4 December 2010
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Abstract

Background Knee flexion contracture leading to crouch gait is commonly seen in children with myelomeningocele. Progressive increase in knee flexion contracture increases energy cost, which interferes with efficient, functional ambulation. To prevent this, surgical release has been recommended when a knee flexion contracture exceeds 15° to 20°. **Questions/purposes** We therefore asked whether knee flexion contracture release improved dynamic sagittal motion and walking velocity using computerized gait analysis.

Patients and Methods We retrospectively studied 11 patients (20 knees) with high-sacral-level or low-lumbar-level myelomeningocele and knee flexion contracture of greater than 15°. All patients underwent dynamic gait analysis pre- and postoperatively. Surgery consisted of selective hamstring lengthening (medial and lateral), gastrocnemius release from the femoral condyles, and posterior knee capsulectomy.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained. This work was performed at the Northwestern University Feinberg School of Medicine.

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Results We observed improvements postoperatively in clinical measurements and sagittal kinematics. The clinical knee flexion contracture improved from a mean of 24.9° preoperatively to 5.9° postoperatively. The knee flexion at initial contact improved from 37.6° to 9.0°, and minimum knee flexion in single-leg stance improved from 48.2° to 16.4. Walking velocity improved from 72.2% to 80.0% of age-matched normal.

Conclusions Surgical treatment of knee flexion contracture in patients with myelomeningocele using radical posterior knee capsulectomy leads to improvement in clinical knee flexion contracture, dynamic sagittal kinematics, and walking velocity.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

The main goal in the orthopaedic management of myelomeningocele is to correct a child's musculoskeletal deformities to improve gait efficiency and allow the child to maintain the ability to walk. One of the well-recognized deformities in children with myelomeningocele is knee flexion contracture, which leads to a crouch gait [4, 5, 18]. Progressive increases in knee flexion contracture cause progressive increases in energy cost, interfering with a child's walking efficiency and impairing the ability to ambulate independently [6, 17]. Accordingly, Dias [5] recommended surgical release when the contracture exceeds 15° to 20°.

Dynamic gait analysis has become an integral component of the evaluation of children with neuromuscular

disorders [1, 9, 16, 19]. Dynamic gait analysis has been used to quantify differences between pathologic gait patterns [2, 5, 19] and to correlate structural deformity and functional impairment [14] and adds information in surgical decision making [7, 8]. Recent literature also suggests in children with myelomeningocele the degree of knee flexion during gait is greater than the knee flexion contracture measured on clinical examination [14].

We therefore asked whether radical posterior knee capsulectomy improved dynamic knee sagittal kinematics and walking velocity using computerized gait analysis.

Patients and Methods

We studied 11 patients (20 knees) with myelomeningocele and knee flexion contractures treated from 1999 to 2001. Five patients had sacral-level myelomeningocele; six patients had low-lumbar-level myelomeningocele. Ambulatory patients with high-sacral-level or low-lumbar-level myelomeningocele were included in the study if they met the following criteria: (1) they had a knee flexion contracture of 15° or more, (2) underwent radical posterior knee capsulectomy, and (3) underwent dynamic gait analysis both pre- and postoperatively. All patients with sacral-level myelomeningocele were ambulatory with ankle foot orthoses (AFOs) and no external support, and all patients with low-lumbar-level myelomeningocele were ambulatory with AFOs and external support. The mean ($\pm$ SD) age at the time of surgical treatment was 12 ± 1.2 years.

All patients underwent a complete medical evaluation by the senior author (LD), as well as a clinical examination and manual muscle testing by the same physical therapist (CKL). The degree of knee flexion contracture was measured according to the methods described by Norkin and White [15] with the patient in the supine position, the knee in maximum extension, and the hip at neutral. After the physical therapist's clinical examination, the patient underwent a dynamic gait analysis performed with a Vicon 370 motion capture system (Vicon Motion Systems Inc, Lake Forest, CA). After application of reflective markers according to Kadaba et al. [12], the patient walked along a walkway in the laboratory at a self-selected speed. Three-dimensional joint kinematics data were obtained for the hip, knee, and ankle. The kinematic data were determined according to the model described by Kadaba et al. [12]. A minimum of three trials were captured for each patient and a representative trial was chosen to address intrasubject variability [10, 14]. The amount of knee flexion during gait was measured at two points: initial contact and minimum knee flexion in single-limb stance.

All patients then underwent a selective intramuscular lengthening of the hamstrings, gastrocnemius release from

the femoral condyles, and posterior knee capsulectomy. A transverse incision was made approximately 1 cm proximal to the posterior flexor crease extending from just medial to the medial hamstrings to just lateral to the lateral hamstring. Beginning medially, the hamstring tendons were identified. If tight, the semitendinosus and gracilis were sectioned transversely, and the semimembranosus was lengthened intramuscularly. The fat overlying the medial head of the gastrocnemius was carefully reflected to reveal the medial gastrocnemius tendon. This tendon was sharply detached from the femoral condyle exposing the underlying posterior knee capsule. The joint was taken through a ROM while palpating the capsule to identify the level of the joint and also to identify and protect the meniscus. Placing the knee in slight flexion to protect the underlying cartilage, a scalpel was used to remove a 1-cm-square portion of the medial posterior capsule overlying the joint. Under direct vision, the capsule was then opened as far medial as possible using Metzenbaum scissors. Taking care to retract the midline structures and protect the posterior cruciate ligament, the cut was then extended toward the lateral compartment as far as direct vision could allow. Next, the lateral aspect of the incision was addressed, the biceps femoris tendon was identified, and an intramuscular lengthening was performed if the tendon was tight. Similar to the medial side, the posterior capsule of the lateral aspect of the knee was exposed by detaching the lateral head of the gastrocnemius from the femoral condyle. Again, a 1-cm-square portion of lateral posterior capsule was removed. Next, the capsule was opened as far lateral as possible using Metzenbaum scissors. The capsular cut was then extended toward the midline until a finger could be passed from the lateral compartment into the medial compartment under the neurovascular structures. The posterior cruciate ligament was left intact. The wound was closed using interrupted, nonabsorbable sutures. Additional procedures performed in the same setting included iliopsoas lengthening (nine), adductor myotomy (four), anterolateral ankle release (three), and tibial derotation osteotomy (one).

Postoperatively, all children were immobilized in long-leg casts for 3 weeks in maximum extension. Care was taken to provide adequate padding over pressure points, especially the patella and the heel. If full knee extension could not be achieved after the surgical release, we changed the cast 7 to 10 days after surgery in the outpatient clinic to further extend the knee. After casting, patients were transitioned to removable knee immobilizers and underwent an intensive physical therapy program emphasizing strengthening of the gluteal and quadriceps muscles. The intensive physical therapy was typically of a duration of 2 to 3 months.

At 1 year postoperatively, all patients underwent a repeat clinical and dynamic gait evaluation as described. The mean age at the time of postoperative dynamic gait analysis was 14 ± 1.2 years.

Pre- and postoperative values for clinical knee flexion contracture and knee flexion at initial contact and minimum knee flexion in single-limb stance were compared using a paired t test, since the pre-operative and post-operative variances were similar. Post-operatively the variances decreased but remained similar. In addition, in other studies published from the same motion analysis laboratory which included a greater number of patients, the data have always been found to follow a normal distribution, hence this subset of select patients from our overall database is also expected to fall within the normal distribution. Statistical analyses were performed with SPSS® software (SPSS Inc, Chicago, IL).

Results

The knee flexion contracture improved ($p = 0.001$) from a mean of 25° preoperatively to 6° postoperatively. Knee flexion at initial contact improved ($p = 0.05$) from 38° preoperatively to 9° postoperatively. Knee flexion at minimum knee flexion in single-limb stance improved

($p = 0.002$) from 48° preoperatively to 16° postoperatively (Table 1).

Mean walking velocity was similar to that of age-matched normals: 72% versus 80% (preoperative: Fig. 1; postoperative: Fig. 2).

Discussion

Knee flexion contracture is a well-recognized deformity in patients with myelomeningocele. This knee flexion contracture is often accompanied by a crouch gait. Dynamic gait analysis is a tool frequently used to evaluate patients with myelomeningocele and crouch gait, as gait analysis offers the ability to obtain unique information that cannot be acquired from history, physical examination, or direct observation. We determined whether radical posterior knee capsulectomy in patients with myelomeningocele and a crouch gait improved sagittal knee kinematics using dynamic gait analysis.

Our study had shortcomings. First, we had a small number of patients. This was unavoidable because the number of patients potentially benefiting from this procedure is small. Nonetheless, we believe the data important. Second, a comparison between radical knee capsulectomy and other procedures to address knee flexion contracture would have

Table 1. Individual patient data including preoperative and postoperative clinical examination and gait parameters

Patient	MM level	KFC ($^\circ$) preop	KFC ($^\circ$) postop	IC ($^\circ$) preop	IC ($^\circ$) postop	MKFSLS ($^\circ$) preop	MKFSLS ($^\circ$) postop
1	Sacral	25	16	39	9	53	13
1	Sacral	35	12	49	14	63	12
2	Sacral	35	0	84	11	91	10
2	Sacral	37	5	80	10	96	18
3	Low lumbar	15	7	29	1	40	3
4	Low lumbar	26	18	31	28	46	40
4	Low lumbar	22	12	26	25	37	42
5	Low lumbar	26	0	20	-2	32	2
5	Low lumbar	24	0	20	8	34	5
6	Sacral	25	0	43	0	47	18
6	Sacral	26	0	44	0	48	18
7	Low lumbar	26	22	25	37	13	42
8	Sacral	22	8	37	13	27	10
8	Sacral	15	6	20	18	39	16
9	Sacral	10	0	15	9	27	10
9	Sacral	18	0	26	11	39	16
10	Sacral	30	0	26	11	30	14
10	Sacral	25	3	21	8	32	11
11	Sacral	20	5	16	10	28	15
11	Sacral	18	8	20	11	30	13

MM = myelomeningocele; KFC = knee flexion contracture; IC = knee flexion at initial contact; MKFSLS = minimum knee flexion during single-leg stance; preop = preoperative; postop = postoperative.

Fig. 1 A composite graph of knee flexion shows preoperative kinematic data from patients included in the study. Flex = flexion; Ext = extension.

Fig. 2 A composite graph of knee flexion shows postoperative kinematic data from patients included in the study. Flex = flexion; Ext = extension.

been a more powerful study design. However, given the size of the specific patient population and the number of patients necessary for this type of trial, this was not feasible. Third, our length of followup of 1 year is short. A longer duration of followup would have provided stronger conclusions; however, gait analysis at 1 year postoperatively is part of the senior surgeon's (LD) protocol, and performing further analysis is cost-prohibitive. Additionally, the senior surgeon (LD) has not noted any clinical recurrence of knee flexion contracture among this cohort of patients to date. Fourth, the effect of the postoperative physical therapy program on the final results achieved was not assessed separately from the surgical intervention.

Although there has been a study measuring the static knee flexion after selective hamstring lengthening with posterior knee capsulotomy for knee flexion contracture release for patients with myelomeningocele [13], this is the first study in the literature to use dynamic gait analysis to quantify knee kinematics for children with high-sacral-level and low-lumbar-level myelomeningocele undergoing radical posterior knee capsulectomy. Marshall et al. [13] reported improvements in static knee flexion contractures from an average of 39° to 5° in patients with myelomeningocele. However, it has been recognized there is a discrepancy between knee flexion contracture measured on clinical examination and knee flexion measured during

gait [14]. Our observations of decreases in clinical knee flexion contracture and, more importantly, dynamic knee flexion after knee flexion contracture release confirm and expand upon the earlier findings of Marshall et al. [13].

Finally, our study highlights the important difference between the surgical management of knee flexion contracture in patients with myelomeningocele and patients with cerebral palsy. The fundamental difference in surgical management of knee flexion contracture in patients with myelomeningocele, compared to patients with cerebral palsy, is the necessity of radical release of the posterior knee joint capsule. In patients with cerebral palsy, the etiology of knee flexion contracture is largely the natural history of the condition, as well as the result of therapeutic procedures that weaken the gastrocnemius-soleus [3, 11]. In patients with myelomeningocele, the etiology of knee flexion contracture depends on the level of the lesion. For patients with high-level lesions, contractures are believed to result from seated positioning, with long periods of time spent with the hips and knees flexed. For patients with low-lumbar-level and high-sacral-level lesions, it is believed increasing height and weight in association with weak gluteus maximus leads to an inability to resist dorsiflexion about the ankle even with the use of a solid AFO. This process is thought to ultimately cause a fixed deformity at the knee. For both high-level and low-level patients, the common result is a contracture of the knee capsule. Thus, to effectively correct knee flexion deformity in patients with myelomeningocele, a capsulectomy must be performed concomitantly with gastrocnemius release and selective hamstring lengthening.

We found radical posterior knee capsulectomy for knee flexion contracture in patients with myelomeningocele improved dynamic knee motion in the sagittal plane. This information can help surgeons in formulating the best treatment plan to help their patients maintain efficient, independent ambulation. We recommend radical posterior knee capsulectomy in patients with high-sacral-level or low-lumbar-level myelomeningocele who have knee flexion contracture of more than 15° interfering with gait.

Acknowledgments The authors thank Laura Johnson and Melissa Colthrust for their assistance in the preparation of this manuscript.

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