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Knee capsulotomy for fixed knee flexion contracture

Kalıcı diz fleksiyon kontraktüründe kapsülotomi

Patarawan WORATANARAT,[1] Kirk W. DABNEY,[2] Freeman MILLER[2]

[1]Department of Orthopaedics, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand;
[2]Department of Orthopaedics, Alfred I. duPont Hospital for Children, Nemours Children's Clinic, Wilmington, Delaware, USA

Objectives: This study aimed to assess the results of knee capsulotomy for correcting fixed knee flexion contracture in children with cerebral palsy (CP).

Methods: Thirty-five children (20 boys, 15 girls; mean age 13.5±2.5 years) with CP underwent posterior knee capsulotomy for 59 knees. Eleven patients had diplegia, one patient had hemiplegia, and 23 patients had quadriplegia. There were two community ambulators (3 knees), 19 household ambulators (33 knees), and 14 nonambulators (23 knees). Posterior knee capsulotomy was combined with hamstring lengthening (50 knees, 84.8%), rectus femoris transfer (10 knees, 17%), Achilles tendon lengthening (12 knees, 20.3%), and posterior cruciate ligament release (eight knees, 13.6%). The mean follow-up was 3.5±1.7 years.

Results: Fixed knee flexion contracture significantly improved from 26.5±15.4 degrees to 17.0±15.5 degrees after posterior knee capsulotomy ($p<0.0001$). The mean improvement was 9.5 degrees. Popliteal angle significantly improved from 70.6±18.7 degrees to 48.2±19.9 degrees ($p<0.0001$). Ankle dorsiflexion did not differ significantly. At the end of follow-up, 38 knees (64.4%) had improved knee flexion contracture and 21 knees (35.6%) had recurrent flexion contracture (failure). Age and male gender were significantly associated with failure rate (adjusted odds ratio 0.78, 95% CI: 0.62-0.99 and 12.1, 95% CI: 2.37-61.7, respectively). Complications included transient sciatic nerve palsy in seven knees (11.9%), and wound dehiscence in two knees (3.4%). Revision was required in two knees (3.4%), and posterolateral corner reconstruction in one knee (1.7%).

Conclusion: Posterior knee capsulotomy is another option for the treatment of knee contracture in CP, resulting in a significant decrease in knee contracture with acceptable complications. However, failure rate is higher in boys, patients who are marginal ambulators, and in younger age group.

Key words: Cerebral palsy; child; contracture/surgery; knee/surgery; knee joint/surgery; range of motion, articular; walking.

Amaç: Beyin felçli (BF) çocuklarda kalıcı diz fleksiyon kontraktürünün düzeltilmesinde kapsülotominin sonuçları değerlendirildi.

Çalışma planı: Beyin felçli 35 çocuğun (20 erkek, 15 kız; ort. yaş 13.5±2.5) 59 dizine posterior diz kapsülotomisi uygulandı. On bir hastada dipleji, bir hastada hemipleji, 23 hastada kuadripleji vardı. Yürüyebilme durumu açısından, iki hasta dışarda (3 diz), 19 hasta (33 diz) ev içi yardımcı araçla yürüyebiliyorken, 14 hastada (23 diz) yürüme yoktu. Posterior diz kapsülotomisi ile birlikte uygulanan işlemler şunlardı: Hamstring uzatma (50 diz, %84.8), rektus femoris transferi (10 diz, %17), Aşil tendon uzatma (12 diz, %20 .3) ve arka çapraz bağ gevşetme (8 diz, %13.6). Ortalama takip süresi 3.5±1.7 yıldı.

Sonuçlar: Posterior diz kapsülotomisinden sonra kalıcı diz fleksiyon kontraktürü 26.5±15.4 dereceden 17.0±15.5 dereceye geriledi ($p<0.0001$). Ortalama düzelme 9.5 derece idi. Popliteal açıda da anlamlı düşme görüldü (70.6±18.7 dereceden 48.2±19.9 dereceye; $p<0.0001$). Ayak bileği dorsifleksiyonu ise benzer kaldı. Takip dönemi sonunda, 38 dizde (%64.4) diz fleksiyon kontraktüründe iyileşme görülürken, 21 dizde (%35.6) kontraktür nüksü gelişti. Yaş ve erkek cinsiyeti başarısızlık oranıyla anlamlı derecede ilişkili bulundu (yaş için ayarlanmış odds oranı 0.78, %95 GA: 0.62-0.99; erkek cinsiyet için ayarlanmış odds oranı 12.1, %95 GA: 2.37-61.7). Komplikasyon olarak, yedi dizde (%11.9) geçici siyatik sinir felci, iki dizde (%3.4) yara açılması görüldü. İki dizde (%3.4) revizyon, bir dizde (%1.7) de posterolateral köşe rekonstrüksiyonu yapılması gerekti.

Çıkarımlar: Posterior diz kapsülotomisi BF'de diz kontraktürünün bir başka tedavi yöntemidir ve kabul edilebilir komplikasyonlarla anlamlı derecede azaltılabilir. Ancak, erkek çocuklarda, marjinal yürümesi olanlarda ve daha küçük yaştaki çocuklarda başarısızlık oranı daha yüksektir.

Anahtar sözcükler: Beyin felci; çocuk; kontraktür/cerrahi; diz/cerrahi; diz eklemi/cerrahi; hareket açıklığı, eklem; yürüme.

Correspondence / *Yazışma adresi:* Freeman Miller, MD. Department of Orthopaedics, Alfred I. duPont Hospital for Children, Nemours Children's Clinic, P.O. Box 269, Wilmington, DE 19899, USA. Tel: +1 302 651 5921 e-mail: fmiller@nemours.org

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Fixed knee flexion contracture is a common problem in patients with cerebral palsy (CP). Spasticity and decreased growth rate in the length of muscle fibers cause hamstring contracture. If the hamstring contracture progresses and is left untreated, the knee no longer comes to full extension during gait or sleep. Because the knee is never fully extended, the posterior knee capsule shortens and a fixed knee flexion contracture develops. The knee contracture may also be propagated by concurrent hip flexion contracture, gastrocnemius contracture, and remaining for prolonged times in the sitting position.[1] Generally, knee contracture involving the posterior knee capsule becomes worse in middle childhood and during adolescent growth.

The treatment of fixed knee flexion contracture depends on age of the patients and the severity of the contracture. Stretching with nighttime splinting or combined with botulinum toxin A injection are advocated in mild cases. With nighttime soft splint better results were obtained in younger patients who had less severe contracture and patients had to comply with this splint for at least 10 months.[2] Botulinum toxin A improved knee extension and ambulatory function after injection, but its effects lasted 4.5 months.[3,4] In severe contracture, usually more aggressive treatment is needed. Hamstring lengthening reduced fixed knee flexion contracture after four years of follow-up. However, this procedure cannot permanently correct severe contracture more than 10 degrees. The use of posterior knee capsulotomy is the other choice of treatment especially in severe contracture without the deformity of the femoral condyle. It has been reported in children with poliomyelitis, cerebral palsy, and chronic arthritis.[5-7] In cerebral palsy, Heydarian et. al.[6] reported only two cases without sufficient data about their improvement in flexion contracture. Another report combined this procedure with hamstring lengthening with or without quadriceps mechanism shortening.[5] It included non-fixed knee flexion contracture and did not demonstrate preoperative fixed knee flexion contracture in each surgical group. From these reports, we do not know whether or not knee capsulotomy improved flexion contracture in CP.

This study aimed to assess the results of knee capsulotomy for correcting fixed knee flexion contracture especially with regard to failure rate/recurrence after follow-up.

Patients and methods

This study retrospectively reviewed all the patients with CP, who underwent posterior knee capsulotomy for correction of fixed knee flexion contracture at our children's hospital between 1991 and 2002. Only the patients who had at least one-year follow-up were included. This study was approved by our Institutional Board Review.

Data were collected from medical records. The main study factors were age, sex, type of spastic CP (diplegia, hemiplegia, quadriplegia), preoperative ambulatory status (community, household, nonambulator), preoperative fixed knee flexion contracture, popliteal angle, ankle equinus, postoperative bracing, and compliance. Fixed knee flexion contracture was measured with the patients positioned supine with maximum passive knee extension and hip extension and ankle equinus. The popliteal angle and ankle dorsiflexion were assessed as the maximum passive range of motion. Compliance was defined as good if the patients were in the brace for most of the required time. It was defined as poor if the medical records showed that the child was not using the immobilization as recommended. The outcomes were postoperative fixed knee flexion contracture, popliteal angle, ankle equinus, ambulatory status at the last follow-up, and recurrence of flexion contracture. If in the last follow-up, flexion contracture was equal to or more than preoperative flexion contracture, it was categorized as recurrence. The patients who have severe preoperative fixed knee flexion contracture of more than 30 degrees may have a higher risk for failure. Therefore, we categorized preoperative fixed knee flexion contracture into two groups: 10 to 30 degrees and more than 30 degrees. Also, we categorized ambulatory status into ambulatory and nonambulatory because nonambulators may sit with the hip and knee flexed after surgery resulting in a bad outcome compared with household and community ambulators. Complications such as sciatic nerve palsy, wound complications, and knee instability were recorded from the retrospective chart review.

Surgical indication

The indication for knee capsulotomy was moderate knee flexion contracture equal to or more than 10 degrees, allowing at least standing transfers. All patients failed conservative treatment with stretching and nighttime splints and did not have the deformity

of the femoral condyle on the radiographs. If the progression of fixed knee flexion contracture was documented, hamstring lengthening was indicated. For ambulatory patients who could perform gait analysis, hamstring lengthening was indicated for the following conditions: *(i)* initial contact knee flexion more than 20 degrees; *(ii)* midstance knee flexion more than 20 degrees; *(iii)* popliteal angle more than 45 degrees, and *(iv)* electromyographically documented significant premature activation during initial swing.

Surgical technique

A posterior medial incision was used for posterior knee capsulotomy. The medial head of the gastrocnemius muscle was exposed and a proximal myofascial lengthening was performed. The posterior capsule was exposed and the incision in the capsule started just posterior to the medial collateral ligament above the meniscal insertion and was carried posterior to the intercondylar notch. In most children with the knee flexed, the soft tissue was freed from the capsule in the lateral compartment and the capsular incision was carried across to the posterolateral corner through the medial incision. For large patients (two patients, three knees), a separate incision was made at the posterolateral corner and the capsule from the lateral compartment was released through the lateral incision. After wound closure, the knee was held in maximum extension with a leg cylinder cast or Velcro fastened knee immobilizer. The splint or bivalved cast was recommended to be used for 18 to 20 hours per day for six weeks and for nighttime wear for six months. Other procedures concomitant with this surgery were detailed during the chart review. All procedures were performed by senior authors (FM and KWD).

Statistical analysis

Continuous data were expressed as mean±standard deviation and categorical data were expressed as percentages. For the comparison between preoperative and last follow-up data, paired t-test was used for continuous data and Fisher's exact test was used for categorical data. Factors associated with failure (defined by a final fixed knee flexion contracture of greater than that of preoperatively) were analyzed using univariate analysis and logistic regression analysis. Factors that had a p value equal to or less than 0.2 were considered a potential confounding factor and were included into the multivariate analysis. The final model was selected manually based on parsimonious consideration and Hosmer-Lemeshow goodness of fit test. Significance was set at $p<0.05$. All statistical analysis was performed by using the STATA 8.2 program (Stata Corp, Texas).

Sample size

The sample size was calculated by the PS program (Version 2.1.30 Vanderbilt University Medical Center, Nashville, Tennessee). Based on uncorrected chi-square test for independent retrospective analysis, the alpha error was set at 0.05, and the power of the study at 0.8. Estimated probabilities of having recurrence were 0.35 and 0.7 for patients whose preoperative fixed knee flexion contractures were 10 to 30 degrees and more than 30 degrees, respectively. The sample size in each group was 31 knees.

Results

Thirty-five patients (20 boys, 15 girls) with 59 knees had posterior knee capsulotomy (31 right, 28 left). Eleven patients (18 knees; 4 unilateral, 7 bilateral) had diplegia, one patient (1 knee) had hemiplegia, and 23

Table 1. Baseline characteristics of success and failure groups

	Success group (38 knees)			Failure group (21 knees)		
	n	%	Mean±SD	n	%	Mean±SD
Age at surgery (years)			14.1±2.3			12.9±2.8
Male	18	47.4		19	90.5	
Quadriplegic	25	65.8		15	71.4	
Nonambulators	14	36.8		9	42.9	
Preoperative FKFC (°)			27.0±17.8			25.8±10.1
Hamstring lengthening	32	84.2		18	85.7	
Rectus femoris transfer	5	13.2		5	23.8	
Bracing with good compliance	19	50.0		11	52.4	

FKFC: Fixed knee flexion contracture.

Table 2. Comparison between preoperative and final data of 59 knees

	Preoperative	Last follow-up	Difference	95% Confidence interval	p^*
Fixed knee flexion contracture (°)	26.5±15.4	17.0±15.5	9.5	5.2; 13.8	**<0.0001**
Popliteal angle (°)	70.6±18.7	48.2±19.9	22.4	15.4; 13.8	**<0.0001**
Ankle dorsiflexion (°)	6.3±14.7	9.0±10.4	-2.7	-7.7; -2.4	0.2876

*Paired t-test.

patients (40 knees; 6 unilateral, 17 bilateral) had quadriplegia. There were two community ambulators (3 knees), 19 household ambulators (33 knees), and 14 nonambulators (23 knees). All nonambulators were able to do standing transfers or were considered to have the potential for doing standing transfers. The average age at surgery was 13.5±2.5 years and the average duration of follow-up was 3.5±1.7 years. The procedures performed simultaneously with posterior knee capsulotomy were hamstring lengthening (50 knees, 84.8%), rectus femoris transfer (10 knees, 17%), Achilles tendon lengthening (12 knees, 20.3%), and posterior cruciate ligament release (8 knees, 13.6%) (Table 1).

Fixed knee flexion contracture significantly improved from 26.5±15.4 degrees to 17.0±15.5 degrees after posterior knee capsulotomy (p<0.0001; Table 2). The average improvement was 9.5 degrees (95% confidence interval (CI): 5.2-13.8). Popliteal angle significantly improved from 70.6±18.7 degrees to 48.2±19.9 degrees (p<0.0001). Ankle dorsiflexion did not show significant improvement. Regarding ambulatory status, one knee improved from a nonambulator to a household ambulator. Three knees deteriorated from household ambulator to nonambulator due to severe scoliosis (2 knees) and severe spastic quadriplegia (1 knee).

Based on the results of knee capsulotomy at a mean of 3.5 years of follow-up, 38 knees (64.4%) had improved knee flexion contracture and 21 knees (35.6%) had recurrent flexion contracture (failure). Factors suspected to be associated with recurrent flexion contracture are shown in Table 3. In univariate analysis, male gender was the only factor significantly associated with recurrent flexion contracture. Quadriplegic type, ambulatory status, age, severe fixed knee flexion contracture, and postoperative bracing were not significantly associated with recurrent contracture

Table 3. Univariate analysis of factors to predict failure following knee capsulotomy

	Odds ratio	95% Confidence interval	p
Age at surgery (years)	0.80	0.64; 1.01	0.070
Gender			
Male	10.56	2.15; 51.77	**0.004**
Female	1.00	–	
Diagnosis			
Quadriplegic	1.20	0.37; 3.87	0.760
Diplegic	1.00	–	
Preambulatory status			
Nonambulator	1.28	0.43; 3.81	0.650
Ambulator	1.00	–	
Preoperative FKFC	0.99	0.96; 1.00	0.772
Hamstring lengthening			
Yes	1.13	0.25; 5.05	0.878
No	1.00	–	
Rectus femoris transfer			
Yes	2.06	0.52; 8.16	0.302
No	1.00	–	
Bracing			
Yes with good compliance	1.10	0.38; 3.20	0.861
No/poor compliance	1.00	–	

FKFC: Fixed knee flexion contracture.

Table 4. Multivariate analysis of factors associated with failure following knee capsulotomy

	Adjusted odds ratio	95% Confidence interval	*p*
Age at surgery (years)	0.78	0.62; 0.99	**0.048**
Gender			
Male	12.10	2.37; 61.7	**0.003**
Female*	1.00	–	

*Reference group.

(Table 3). However, increasing age was considered a potential confounder since the *p* value from univariate analysis was less than 0.2. Table 4 shows the final model from the multivariate analysis containing age and male gender. After controlling for gender, each increasing year of age at surgery decreased the risk of having recurrent contracture by 22% (adjusted OR 0.78, 95% CI: 0.62-0.99). Males had 12 times greater risk of having recurrent contracture compared with females (adjusted OR 12.1, 95% CI: 2.37-61.70) after controlling for age (Table 4).

Complications included sciatic nerve palsy in seven knees (11.9%), and wound dehiscence in two knees (3.4%). Revision was required in two knees (3.4%), and posterolateral corner reconstruction in one knee (1.7%). For patients with sciatic nerve palsy, the knees were allowed to flex in a bivalved cast to the place where the child was comfortable, but the child was not allowed to sit with hip flexion and the knees extended. Gradually, as the child was able to tolerate, the knee was gently stretched into full extension over several months. The loss of sensation lasted two to six months and all patients recovered full sensory and motor function. Wound dehiscence occurred in only two patients. One patient had stitch abscess and was treated with oral antibiotics. The other had an infected knee capsulotomy wound that healed by secondary intention using only dressing changes.

From 21 knees with recurrent contractures, two knees were revised. In one case, the patient was a household ambulator who had poor compliance with the use of knee immobilizers. His first operation was knee capsulotomy with hamstring and gastrocnemius lengthening. Knee flexion contracture reduced from 15 degrees to 0 degrees postoperatively. Then, it increased to 30 degrees at three years of follow-up. After the revision to 20 degrees of knee flexion contracture combined with hamstring and gastrocnemius lengthening, it recurred to 45 degrees at six years of follow-up. The other child with a recurrent contracture was a nonambulator. He had 10 degrees of knee contracture. His knee flexion contracture decreased to 5 degrees postoperatively. Unfortunately, the wound was infected and a knee brace could not be used till healing of the wound. His knee flexion contracture increased to 25 degrees at three years of follow-up. With revision posterior knee capsulotomy, fixed knee flexion contracture reduced to 10 degrees. Without postoperative knee immobilization, it again recurred to 40 degrees with a severe crouched stance at six years of follow up.

Of eight patients who underwent posterior knee capsulotomy with posterior cruciate ligament release, one developed posterior knee subluxation with posterolateral instability. The instability was treated with a bivalved cast; however, the knee remained unstable and required a posterolateral corner reconstruction. Her knee had mild subluxation with anterior translation following the reconstruction. Since then, there has been no mechanical instability during ambulation.

Discussion

The release of posterior capsule of the knee was first reported as posterior capsular stripping in chronic arthritis. After that, posterior knee capsulotomy was performed in cerebral palsy. Heydarian et al.[6] reported two children with cerebral palsy and 28 children with poliomyelitis and other diseases using postoperative skin traction. They found that failure rate was higher in nonpoliomyelitis group. There was only one peroneal nerve palsy which was fully recovered a couple of months later. Beals[5] advocated quadriceps mechanism shortening with knee capsulotomy in patients who had knee flexion contracture and infrapatellar tendon elongation to improve knee extension. Five community ambulators (10 knees) had 20 degrees of mean preoperative knee flexion contracture. All of them underwent hamstring release and eight of them underwent quadriceps mechanism shortening. No patients in this group had poor results. Other 15 house-

hold or nonambulators (29 knees) with 30 degrees of preoperative knee flexion contracture underwent hamstring lengthening and/or quadriceps mechanism shortening. Four out of 29 knees had poor results. Recurrent contracture increased in individuals who did not walk or who spent a significant amount of time with the knee flexed. The author found that combined quadriceps mechanism shortening improved ambulatory skills. However, preoperative fixed knee flexion contracture was not compared between patients who did and did not undergo combined quadriceps mechanism shortening.[5]

The study is the first study to primarily evaluate knee capsulotomy in children with CP, although 85% also had hamstring lengthening. We did not perform quadriceps mechanism shortening because we do not feel this is a cause of the flexion contracture; however, there clearly was secondary lengthening of the extensor mechanism in some patients. At final assessments, the percentage of knees having a fixed knee flexion contracture equal to or less than 10 degrees was 52%.

The preoperative ambulatory status was significantly associated with the improvement in fixed knee flexion contracture in this study and the Beals'[5] study. The more severely affected patients usually spend a large amount of time in the sitting position and are more prone to have a fixed knee flexion contracture. However, for those individuals who can do standing transfers, there is a great advantage to try to prevent the formation of severe contractures. The outcome of hamstring lengthening to prevent progressive knee flexion contracture has not been well defined; however, one report found a significant positive effect four years after proximal hamstring lengthening with the mean knee flexion contracture having been reduced from 16 to 9 degrees.[6] Dhawlikar et al.[8] reported long-term results of distal hamstring lengthening in CP. They reported that the popliteal angle improved markedly at one year, but then regressed over time but was not significantly associated with the results of fixed knee flexion contracture. Based on the data of our study, hamstring lengthening will not impact the knee contracture if children are allowed to sit and lie with the knees flexed all the time. Bracing and brace compliance are not significantly associated with knee contracture probably because it was used in severe contracture rather than in mild cases (mean preoperative fixed knee flexion contracture was 23.7±11.6 degrees in the nonbracing group and 28.3±17.4 degrees in the bracing group). If bracing had been used in every case, we could have assessed its effect on maintaining the knee extension position.

From the results of this study, increased age decreases risk for failure in knee capsulotomy. One possible explanation is that surgery in young children at puberty will face muscle tightness resulting in recurrence of knee contracture. Even though preoperative fixed knee flexion contracture was not significantly associated with failure of knee capsulotomy, we still believe that more severe forms of preoperative fixed knee flexion contracture would produce a bad result because these patients had more severe neurologic impairment, which is harder to correct. Therefore, the optimal time for surgery depends on severity of contracture and functional limitation of the patients.

In this study, males exhibited an increased risk for failure. The average ages of males and females were the same (13.8±2.9 and 13.5±1.7 years, respectively). Boys probably were still more immature and had more remaining growth. In addition, hormonal factors in males may cause greater muscle strength and stiffness, leading to increased tendency for joint contractures.

The most common complication in this study was sciatic nerve stretching which occurred in 11.9% of knees but spontaneously resolved within six months. Sciatic nerve palsy appeared to be more common when the knee capsulotomy is combined with Achilles tendon lengthening. However, in this study it was not associated with the preoperative degree of knee flexion contracture, posterior cruciate ligament release, or Achilles tendon lengthening because the sample size was not adequate to detect a significant difference. Wound dehiscence and revision occurred in only 3.4% of procedures. Posterior cruciate instability was only a major problem in one patient (1.7%).

There are many potential methods to treat fixed knee flexion contracture in children with spastic cerebral palsy. In personal communication with other physicians, we are aware of the use of anterior epiphyseal stapling, extension osteotomies, and stretching with the use of external fixators; however, there are as yet no reports of the outcome and complications from any of these techniques. Investigations may show that these techniques have a higher success rate or a lower complication rate compared to posterior capsulotomy, or vice versa.

In conclusion, posterior knee capsulotomy seems to yield the best outcome in correction of fixed knee flexion contractures in CP when applied to functional ambulatory children who are girls and adolescents. It significantly improved fixed knee flexion contracture by about 9.5 degrees in this study, and can completely eliminate the contracture in many children. The results are less favorable with younger age and male gender. The main complication is sciatic nerve palsy, which resolves, and other complications are uncommon and can be treated well. Posterior knee capsulotomy is the other option for children with spasticity at adolescence.

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