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Research Study

Correction of Combined Flexed and Stiff Knee Gait in Spastic Diplegic Cerebral Palsy by Double Tendon Transfers Around the Knee as Part of Multilevel Surgery

通過雙膝肌腱轉移作為多級手術的一部分，應用在痙攣性下肢性腦癱中的同時屈曲和僵硬膝關節的矯正

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ABSTRACT

Background/Purpose: Flexed knee gait and stiff knee gait are common coexisting gait disturbances in children with cerebral palsy. We analyzed the effect of medial hamstring transfer and distal rectus transfer around the knee as part of multi-level surgery for this group of patient.
Methods: Eleven lower limbs of six patients who received double transfer were retrospectively studied. Instrumented gait analysis were carried out before and a minimum of 2 years after operation.
Results: Comparing the kinematic study before and after the operation, maximum knee extension in stance phase (MKES), total knee swing (TKS) and the time to maximum knee flexion in swing phase (TMKFS) showed statistically significant improvement ($p < 0.05$). Hip extension in swing phase and hip extension power were maintained. The oxygen consumption during walking also decreased after operation ($p < 0.05$).
Conclusion: Double transfer around the knee can improve both flexed knee gait and stiff knee gait, without causing significant hip extension weakness.

中 文 摘 要

背景/目的：彎曲膝蓋步態和僵硬膝蓋步態是腦癱兒童中常見的共存步態障礙。我們分析了用內側繩肌腱轉移和遠端股直肌腱轉移圍繞膝蓋作為這一組病人的多層手術的一部分的影響。
方法：回顧性分析6例接受雙轉移的患者，共有11例下肢接受手術。在手術之前和最少2年之後進行儀器化步態分析。
結果：比較手術前後的運動學研究，站立期最大膝伸展（Maximum knee extension in stance phase, MKES），全膝關節擺動（Total knee swing, TKS）和擺動期最大膝關節屈曲時間（Time to maximum knee flexion in swing phase, TMKFS）顯示術後有統計學上顯著的改善（$p < 0.05$）。擺動期中的髖關節延伸角度和髖關節延伸能力全都得到保持。步行期間的氧消耗也在手術後減少（$p < 0.05$）。
結論：圍繞膝蓋的雙重肌腱轉移可以同時改善彎曲的膝蓋步態和僵硬的膝蓋步態，而不引起顯著的髖關節延伸弱化。

Introduction

Cerebral palsy (CP) is a disorder of movement, muscle tone, or posture that is caused by an insult to the immature and developing brain. Spastic diplegic CP, now more appropriately and commonly

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known as bilateral CP, is one of the most common types of CP. Spastic diplegic CP is characterized by increased muscle tone and hyperreflexia involving both sides of the body, with lower limbs being more severely affected. Spasticity is caused by damage to the pyramidal system in the brain featuring periventricular leukomalacia.[1,2]

Functional status of patients with spastic diplegic CP differs greatly. One of the important aims of treatment of ambulatory spastic CP patients [gross motor functional classification system (GMFCS) levels I–III] is to improve their gait disturbance so as to facilitate their daily activities and participation of normal life.

Flexed knee gait is one of the commonest gait abnormalities in the sagittal plane in this group of patients. The aetiology of flexed-knee gait is multifactorial. It includes a combination of abnormal motor control, muscle weakness, spasticity, and contracture at hip, knee, and ankle. Torsional malalignment and foot deformities may also contribute to the abnormality.[3]

Treatment for CP patients with crouch gait disturbance should be preventive as weakness of gastrosoleus is often iatrogenic, especially after overzealous lengthening of tendo Achilles.[4,5] Once developed, a conservative approach, such as physiotherapy and bracing, is often ineffective.[4,6,7] Botox can be given to the hamstrings and psoas to prevent contracture. Multilevel surgery is often employed after exhausting the above treatment options.[7–9] The main surgical principles include release of tight and spastic muscle or lengthening of their tendon, augmentation of weak muscle by tendon transfer, and corrective osteotomy of fixed deformity. Special attention is paid to muscle groups that cross two or more joint levels. Lengthening of their tendon may unintentionally weaken the uninvolved joint.

Hamstrings are one such example. It has been popular to lengthen hamstrings to increase knee extension in flexed knee gait. However, there are concerns that this procedure weakens hip extension.[10] Transfer of the semitendinosus to the adductor tubercle has been considered by some authors, which helps preserve hip extension power.[10–12]

In patients with flexed knee gait, there is a subgroup with rectus femoris spasticity, in which the effect of the resultant stiff knee pattern is masked.[4] Peak knee flexion in swing phase is apparently normal. After effective release of hamstring tightness, such stiff knee pattern becomes apparent with diminished and delayed maximum knee flexion during swing phase, which results in a clearance problem.[13] With preoperative instrumented gait analysis, other features of stiff knee gait can be more effectively scrutinized. This problem can be tackled by distal rectus femoris transfer (DRFT). While the results of individual procedures have been studied, the combined effect of semitendinosus transfer and DRFT ("double tendon transfer around the knee") is not well documented in this subgroup.

The aim of this study is to analyse the efficacy of the double transfer as part of multilevel surgery for individuals with combined flexed knee and stiff knee problem during walking.

Methods

A retrospective review was conducted at Tuen Mun Hospital for the consecutive cases of spastic diplegic CP with flexed knee gait operated for multilevel surgery between January 2009 and July 2011 by, or under the supervision of, the same senior surgeon (Dr A.K.Y. Choi). Inclusion criteria include (1) independent ambulatory with or without assistive device (GMFCS levels II–III), (2) normal or near-normal intelligence, (3) presence of hidden stiff knee gait, (4) no or minimal fixed knee contracture, and (5) minimal 2 years of follow-up. Institutional Research and Ethics Review Board approval was obtained. Informed consent from patients and/or their parents were obtained to use their data for research purpose.

The strategy for correction involved detailed clinical examination by both the surgeons and physiotherapists, and preoperative three-dimensional instrumented gait analysis within 2 months of the surgical correction. Gait analysis was repeated at least 2 years after the double transfer and compared with the preoperative analysis.

Stiff knee gait is considered present with positive Ely–Duncan test in physical examination, diminished and/or delayed peak knee flexion during swing phase in gait analysis, and out-of-phase firing of rectus femoris muscle in surface electromyogram during gait analysis.

A double tendon transfer at knee level was employed for all lower limbs with flexed knee gait in stance phase and stiff knee in swing. The first transfer involves a medial hamstring release and transfer (MHRT). A longitudinal posteromedial incision was made over the distal thigh. The semitendinosus tendon was released at the far distal end of the wound with the proximal end tacked with suture. The semimembranosus was released with two aponeurotic cuts over the muscle. The semitendinosus tendon was transferred to the adductor magnus at its insertion at the adductor tubercle of medial femoral condyle after being tunnelled underneath the semimembranosus and sartorius. Care was taken to protect the saphenous nerve. The two tendons were sutured with the Pulvertaft technique at neutral hip and knee extension.

For DRFT, the gracilis tendon was identified, tacked, and released at the proximal end of the wound. Another midline incision was made over the anterior thigh starting at the proximal pole of patella and extending proximally. The rectus femoris tendon was harvested, tunnelling through the medial intermuscular septum. It was sutured with the distal gracilis tendon stump using the Pulvertaft technique with neutral knee and hip extension. This was combined with other soft tissue surgery (Table 1).

Postoperatively, the patient was started on mobilization exercises and allowed full weight-bearing walking if no osteotomy was performed. The patient was put on short leg walking cast if gastrocnemius recession was performed. Otherwise, no cast was given. A nocturnal knee extension brace was used if there was a mild degree of knee flexion contracture.

Assessment of gait pattern was carried out with computerized gait analysis, using Vicon MXF40 (Vicon Motion System Ltd, Oxford, UK) equipped with eight cameras and four force plates at a capture frequency of 100 Hz. Markers were placed according to the Helen Hayes marker set. Kinematic data were collected as patients walked barefoot on a 9-m walkway five times with an interval of approximately 30 seconds. Consistency was checked, and three representative trials were averaged to determine the values of the index variables. Metabolic energy analysis was represented by oxygen consumption (COSMED K4b2; COSMED Srl., Rome, Italy). In

Table 1
Preoperative functional status (GMFCS) and previous treatments

Patient	GMFCS	Previous treatment		
		Botox	SDR	PETA
A	II	✓	✓	
B	III		✓	
C	III			✓ (left only)
D	II		✓	✓
E	II	✓		✓
F	II	✓		

Botox = botulinum toxin injection; GMFCS = gross motor functional classification system; PETA = percutaneous elongation of tendo Achilles; SDR = selective dorsal rhizotomy.