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Spasticity





Spasticity - Orthopaedic Perspectives

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This article has been selected by the Editorial Board of the Hong Kong Medical Diary for participants in the CME programme of the Medical Council of Hong Kong (MCHK) to complete the following self-assessment questions in order to be awarded CME credit under the programme upon returning the completed answer sheet to the Federation Secretariat on or before 31 July 2011. The CME accreditation is in application. The number of CME credit is subject to the final decision of the organisations.

Background

Children who suffer from spastic cerebral palsy will have increased muscle tone due to hyperexcitability of the myotonic reflex arc. Together with the poor selective motor control, these primary abnormalities will drive the development of secondary deformities in the muscle (e.g. hamstring and gastrocnemius contracture) and in the skeleton (e.g. excessive femoral anteversion and external tibial torsion)¹. It is not uncommon to see patients with spastic cerebral palsy developing scoliosis, hip adduction contracture, windswept deformity, knee flexion contracture, and rocker bottom foot deformity. The patients will have problems with mobility and posture as a result of these deformities.

The magnitude of spasticity changes as the patients mature. Usually, the spasticity is most severe at 4 years of age and gradually decreases up to the age of 12². Therefore, it is very crucial to monitor the effects of the spasticity on the development of the affected children. Various treatments have been used to reduce the spasticity in patients with spastic cerebral palsy. Botulinum (Botox) and baclofen are commonly used medical therapies and selective dorsal rhizotomy is a very effective surgical method in reducing spasticity. Despite all these, orthopaedic surgical interventions are quite often needed for the management of gait abnormality, hip instability, joint contractures and ankle deformities³⁻⁵.

Orthopaedic Surgery for Spastic Cerebral Palsy Patients – Multidisciplinary Approach

The role of orthopaedic surgeries in spastic cerebral palsy patients is to (1) reduce the effect of the spasticity of the muscles and (2) correct secondary bony deformities. The surgery should help to improve the walking ability for the potential walkers and sitting posture for the sitters. The indications of the surgeries have to be set clearly with the parents and caretakers before the surgeries in order to avoid any unrealistic expectations and misunderstanding. The keys to success in managing spastic cerebral palsy patients are (1) proper patient selection, (2) identification of

the underlying problems, (3) selection and execution of surgery, and (4) rehabilitation. Different bony and soft tissue surgeries have been described in managing spastic cerebral palsy. The choice of the surgery depends on the severity of the spasticity, selective motor control, age, pattern of the paralysis and types of deformities. Thorough and detailed assessment is very important since the patients' condition may fluctuate from time to time. In order to make the assessment more objective and comprehensive, a multidisciplinary approach, including the orthopaedic surgeons, physiotherapists and occupational therapists, is adopted in the pre-operative assessment. The assessment is often supplemented by modern gait analysis whenever possible. The team should be aware of the limitations of the patients and set reachable goals for them when deciding on the choice of treatment. The post-operative rehabilitation provided by nurses, physiotherapists, occupational therapists, and orthotists also play a very important role in helping these children to reach their full potential.

Gross Motor Function Classification

The Gross Motor Function Classification System (GMFCS) is a commonly used classification to help classify the disabilities of children with cerebral palsy. It was first used for children from age 12 months to 12 years based on the observation of a child's self movements and need for assistive technology and/ or wheeled mobility⁶. The GMFCS was revised, expanded and further validated to include children up to the age of 18⁷. The GMFCS has five levels in which level I children can walk and run independently; whereas, level V children have very limited voluntary movements. GMFCS is a very useful treatment and prognostic guide for managing cerebral palsy children⁸⁻¹⁰. In general, orthopaedic surgery aims for gait modification for level I-III children and postural improvement for level IV and V children.

Modern Gait Analysis and Surgery

For GMFCS I-III, the aim of the orthopaedic surgery is for gait improvement. Careful analysis of the abnormal gait pattern is very important. Apart from careful

clinical examinations, more detailed quantitative information can be acquired using computer-based gait analysis. Such motion analysis consists of 3-dimensional measurements of motion (kinematics), measurements of moments and power in the articulations of the lower limbs (kinetics), electromyography, dynamic foot pressure (pedobarography) and oxygen consumption measurement. It helps the clinicians to understand the interaction of the selective motor control, balance and spasticity of the patients during walking. More importantly, the effects of the secondary changes such as the lever-arm dysfunction of the lower limbs as well as the tertiary changes e.g. compensatory or coping mechanism for the primary and secondary abnormalities can be clearly delineated. The records can also be used for monitoring the progress of the disease as well as the outcome of the surgery.

Timing of Surgery

In the past, CP children were commonly treated surgically every year until they reached skeletal maturity. Tendon lengthening was one of the most commonly performed surgeries on these children. Due to repeated hospitalisation and prolonged immobilisation, such "birthday surgeries" are no longer welcome. Today, single-event multilevel surgery (SEMLS), addressing all concomitant joint contractures in a single surgery, is advocated. Since the abnormality of one joint also affects the position of other joints, SEMLS corrects all the related deformities in one surgery and helps shorten the rehabilitation period. This also avoids repeated hospitalisation and overcorrection of the abnormalities. Since the skeleton continues to model as the child grows, it is advisable to defer any gait modification surgery until the child is relatively more skeletally mature e.g. after the age of 7. However, in situations like progressive hip subluxation^{11,12} or severe joint contracture limiting the original walking potential in some children, early soft tissue release should be considered before the deformity progresses further.

Gait Modification Surgery

The parents should be aware that gait modification surgery can change the gait pattern of their children but not to make it normal. Identifying common gait abnormalities, recognising their causes and understanding the interaction between the soft tissue and bony abnormalities are the keys to success in gait modification surgery. The biarticular muscles are more commonly affected in spastic cerebral palsy patients e.g. rectus femoris, hamstrings and gastrocnemius. Due to the biarticular involvement, they can result in very complex gait abnormalities¹³. There are four common gait abnormalities of the knees in cerebral palsy patients - jump knee, crouch knee, stiff knee, and recurvatum knee patterns¹⁴. Jump knee gait is quite frequently seen in spastic diplegic patients due to overactive hamstrings in the presence of tight or spastic gastrosoleus complex. Crouch knee gait can be related to the weakness or overlengthened triceps surae, external tibial torsion and or rocker bottom feet that disrupt the normal ankle plantarflexion knee extension couple. Stiff knee gait is caused by inappropriate phasic activity of the

rectus femoris resulting in excessive knee extension throughout the swing phase. Lastly, recurvatum knee gait is caused by spastic and contracted triceps surae with weakened hamstrings leading to hyperextension of the knee during the middle and late stance phase. Therefore, understanding the interaction of different muscles during walking is essential in the decision-making of gait improvement surgery.

Lever-arm Dysfunction

Normal movement of a joint relies on the normal moment (M) of a muscle joint complex, which is the product of muscle force (F) multiplied by the lever arm (d). Lever-arm dysfunction in cerebral palsy refers to the disruption of this moment generation because of abnormal development of the skeleton despite normal muscle force. In cerebral palsy, the skeleton develops differently because of the abnormal forces acting onto it and very often results in shortened lever arm. Since the moment (M) = F x d, the already weakened muscle force and shortened lever arm will produce ineffective moments. Depending on the site of the abnormal lever arm, the gait pattern will be affected accordingly e.g. coxa valga and excessive femoral anteversion will bring about ineffective lever arm at the hip leading to Trendelenburg gait. Five types of lever-arm dysfunction were described¹: (1) short lever-arm (coxa valga), (2) flexible lever-arm (pes valgus), (3) malrotated lever-arm (external tibial torsion), (4) an abnormal pivot or action point (hip subluxation or dislocation), and/or (5) positional lever-arm dysfunction (crouch gait).

Abnormal moment of a joint can also affect the action of the neighbouring joints. This can be illustrated by the plantar flexion / knee extension (PF-KE) couple at the knee and ankle. With a competent soleus muscle to slow down the forward momentum of the tibia in the stance phase, the ground reaction force is maintained in front of the knee. This generates an extension moment at the knee without any additional action of the quadriceps. However, such PF-KE couple is disturbed in many spastic diplegic cerebral palsy patients because of the weakened triceps surae and lever-arm dysfunction. The malrotated lever arm of the foot (external tibial torsion) and flexible level arm (breakage of midfoot and planovalgus foot) will cause the ground reaction force (GRF) to shift more laterally and posteriorly to the normal position. The already weakened or overlengthened triceps surae fails to control the progression of the tibia over the planted foot during the stance phase leading to excessive ankle dorsiflexion. The resulting GRF therefore shifts to the posterior aspect of the knee and brings about flexion moment of the knee.

Proper bracing can compensate some of these deformities. But the severe lever-arm dysfunction will require bony surgeries to correct them. Some of the procedures include varus derotational osteotomy of the femur for coxa valga; derotation osteotomy of the tibia in patients with external tibial torsion; and foot stabilisation surgeries for severe planovalgus foot and lever-arm dysfunction to improve the function of the patients.



Case Illustration

A 14 years old boy suffers from spastic diplegic cerebral palsy. He walked with significant crouch knee gait because of weakness in the triceps surae, bilateral knee flexion contracture, hamstring contracture and planovalgus foot deformity (Fig. 1). X-rays of the feet showed severe rocker bottom deformities with breakage in the midfoot (Fig. 2). The gait analysis showed persistent knee flexion and increased ankle dorsiflexion during stance phase (Fig. 3). He subsequently received posterior capsular release of both knees, bilateral hamstring lengthening and bilateral calcaneal lengthening to correct the lever arm dysfunction. Post-operatively, he could walk upright with significant improvement in the gait pattern (Fig. 4).

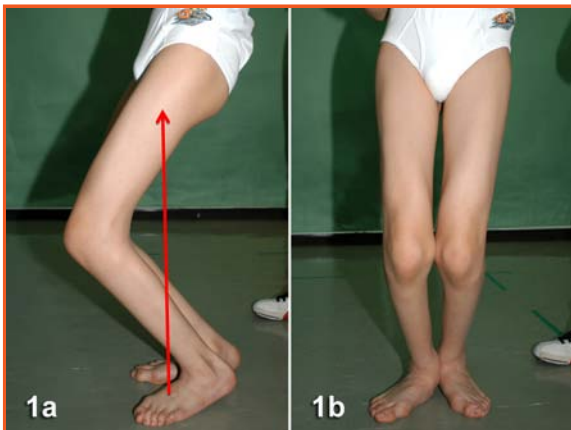


Fig. 1a Weakness of the triceps surae resulted in increase ankle dorsiflexion and shifted the ground reaction force posteriorly (red arrow). Both knees developed secondary fixed flexion contracture because of the loss of PF-KE couple and hamstring spasticity.

Fig. 1b. The patient had bilateral rocker bottom foot deformities, breakage in midfoot and forefoot abduction leading to an inefficient moment arm



Fig. 1c Patient walked with significant crouching with persistent knee flexion and ankle dorsiflexion during stance phase. Note the severe rocker bottom foot deformity (red arrow)

Fig. 1d The lever-arm dysfunction of the feet resulted in excessive out-toeing on both sides

Conclusion

Spasticity affects the normal action of the muscles and also the development of the skeleton in cerebral palsy patients. Orthopaedic surgery aims to correct these abnormalities e.g. muscle contracture and lever-arm dysfunction to improve the mobility and daily activities for these children. A multidisciplinary approach together with modern assessment tools such as gait analysis should be adopted in the decision-making when treating these patients. With a holistic approach, we aim to provide the best care to our patients and maximise their full potential.

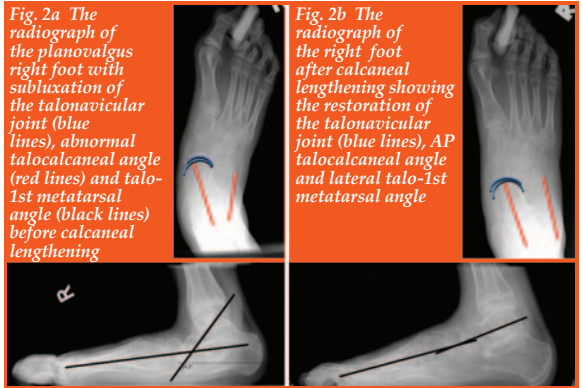


Fig. 2a The radiograph of the planovalgus right foot with subluxation of the talonavicular joint (blue lines), abnormal talocalcaneal angle (red lines) and talo-1st metatarsal angle (black lines) before calcaneal lengthening

Fig. 2b The radiograph of the right foot after calcaneal lengthening showing the restoration of the talonavicular joint (blue lines), AP talocalcaneal angle and lateral talo-1st metatarsal angle

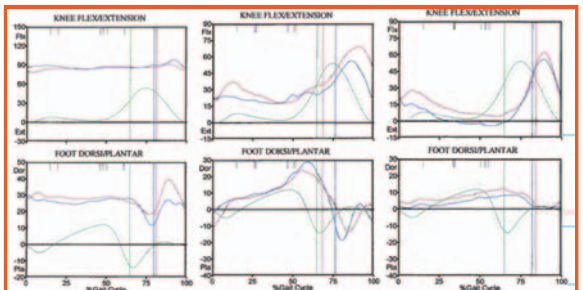


Fig. 3a Pre-operative gait analysis showed that the knees were held in flexion and the ankles in dorsiflexion throughout the stance phase (red line - left; blue line - right; green line - normal)

Fig. 3b Post-operative gait analysis without ground reaction orthosis showed significant improvement in the kinematics of the knees and ankles in the stance phase; but weakness in the triceps surae leading to residual ankle dorsiflexion and therefore weakening the PF-KE couple resulting in residual knee flexion during the stance phase

Fig. 3c Post-operative gait analysis with ground reaction orthosis to the ankles showed near normal kinematics in the knees



Fig. 4a The patient could walk upright with restoration of near normal PF-KE couple

Fig 4b. The planovalgus feet were corrected and the foot progression angles were relatively normal on both sides

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MCHK CME Programme Self-assessment Questions

Please read the article entitled "Spasticity - Orthopaedic Perspectives" by Dr. Michael KT TO and Dr. W CHOW and complete the following self-assessment questions. Participants in the MCHK CME Programme will be awarded CME credit under the Programme for returning completed answer sheets via fax (2865 0345) or by mail to the Federation Secretariat on or before 31 July 2011. Answers to questions will be provided in the next issue of The Hong Kong Medical Diary. The CME accreditation is in application. The number of CME credit is subject to the final decision of the organisations.

Questions 1-10: Please answer T (true) or F (false)

1. In the Gross Motor Function Classification System (GMFCS), cerebral palsy patients are classified into five levels based on the patients' intellectual levels.
2. In general, orthopaedic surgeries aim for gait modification for GMFCS level I-III children and postural improvement for level IV and V children.
3. Modern gait analysis utilizes a computer-based system to study brain activity through the 3-dimensional measurement of motion (kinematics), measurements of moments and power in the articulations of the lower limbs (kinetics), electromyography, dynamic foot pressure (pedobarography) and oxygen consumption measurement.
4. In spastic cerebral palsy patients, hip subluxation is caused by spasticity of the lower limb muscle including the hip adductors and hip flexors.
5. In spastic cerebral palsy patients, muscles spasticity usually increases after the age of 4 and continues to increase until skeletally mature.
6. Gait modification surgery should be performed at older age when the patient is more skeletally mature e.g. after age 7.
7. According to Sutherland, the gait abnormalities of the knees in cerebral palsy patients can be classified into jump knee, crouch knee, stiff knee, and recurvatum knee patterns.
8. Gait analysis helps the clinicians to understand the interaction of the selective motor control, balance and spasticity of the cerebral palsy patients during walking.
9. When progressive hip subluxation is observed in a young spastic cerebral palsy patient despite adequate preventive measures e.g. hip abduction splints and physiotherapy, early surgical intervention should be considered despite he/she is skeletally immature.
10. Crouch knee gait can be caused by overlengthening of the triceps surae in spastic cerebral palsy patients.

ANSWER SHEET FOR JULY 2011

Please return the completed answer sheet to the Federation Secretariat on or before 31 July 2011 for documentation. The CME accreditation is in application. The number of CME credit is subject to the final decision of the organisations.

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Answers to June 2011 Issue

Pathology and Medical Therapy of Benign Prostatic Hyperplasia

1. F 2. T 3. T 4. T 5. F 6. F 7. F 8. T 9. T 10. F