CHANGES IN TREATMENT OF PATIENTS WITH CEREBRAL PALSY DUE TO MOTION ANALYSIS RESEARCH

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GENERAL

Children with cerebral palsy (CP) often have complex walking patterns which are difficult to assess with the naked eye. In addition, problems at one level (pelvis, hip, knee and ankle) affect other joints in both the ipsilateral and contralateral lower extremity. Problems in the different planes (sagittal, coronal and transverse) impact the other planes. Computerized motion analysis allows the objective assessment of multiple levels and multiple planes simultaneously.

The information gleaned from studies using pre- and post-operative computerized motion analysis has shaped the practices of physicians caring for children with CP.

BOTULINUM TOXIN A (BOTOX®) AS AN ADJUNCT TO SERIAL CASTING

Botulinum toxin A has become a common intervention in young children with CP. As is widely known, botulinum toxin injections can delay the need for surgery and may also decrease the extent of surgery needed in children with CP. 1-2

Though botulinum toxin is known to decrease muscle tone, it has no direct impact on muscle contracture. The combination of botulinum toxin injection and the application of short leg stretching casts became a common combination treatment as botulinum toxin A use became widespread.

A prospective randomized controlled trial was performed to compare the outcomes of serial casting with and without gastrocnemius botulinum toxin injection in ambulatory children with CP. 3 This study used gait analysis and clearly demonstrated that the use of botulinum toxin as an adjunct to serial casting in these patients was not beneficial. As a result, many practitioners have ceased using this combination treatment in children with CP.
SINGLE EVENT MUTILEVEL SURGERY (SEMLS)

Prior to the widespread use of computerized motion analysis, the standard surgical care of children with CP entailed a series of single level surgeries. Mercer Rang referred to this as “birthday syndrome,” as children would often be hospitalized on an annual basis for orthopaedic surgery. The inability to objectively evaluate and quantify multilevel and multiplane abnormalities simultaneously resulted in frequent surgeries with suboptimal outcomes.

Computerized motion analysis allows the objective assessment of multiple levels and planes during gait. CMA has been shown in numerous previous studies to alter decision-making in the treatment of children with CP, with some previous authors reporting changes in surgical plans in 89% of patients. Wren et al. have also reported that pre-operative gait analysis decreased the reoperation rate in ambulatory children with cerebral palsy from 40% to 20% by 5 years post-op, without any increase in overall cost.

With the use of computerized motion analysis, surgeons have increased ability to accurately assess their patients’ multilevel needs. As a result, SEMLS has largely replaced single level surgery in children with CP. Numerous studies using pre- and post-operative gait analysis confirm the successful outcomes following SEMLS. Thomason et al. have shown that improvements in gait and function are maintained at 5 years following SEMLS in a prospective randomized control trial.

SPECIFIC PROBLEMS AND SURGERIES

ANKLE EQUINUS AND ACHILLES TENDON LENGTHENING

Gait analysis has proven useful in both determining which patients are candidates for triceps surae lengthening and which type of lengthening (Achilles tendon lengthening versus gastrocnemius recession) should be considered.

Ankle equinus is seen frequently in children with CP, and has been reported in 61% of children with CP who present to a gait lab. Unfortunately, observers tend to overestimate the amount of equinus when watching a child walk. Many observers attribute toe walking to equinus in children with normal dorsiflexion but increased knee flexion during gait. The motion analysis data clarify such issues readily. In addition, it is common for static “contractures” as measured on physical examination to “stretch” during gait, resulting in normal (or sometimes excessive) ankle dorsiflexion in stance phase as seen on computerized motion analysis. As such, computerized motion analysis can prevent unneeded heelcord lengthening surgery in many children.

Even in the presence of true equinus during gait which is recalcitrant to nonsurgical means, the surgeon is faced with the decision of whether to perform an Achilles tendon lengthening or a gastrocnemius recession. Both have been reported to have favorable results, though gait analysis has not uniformly been used in previous studies.
Unfortunatley, excessive laxity in the triceps surae with calcaneal gait is common after Achilles tendon lengthening. When using gait analysis, previous authors have reported calcaneal gait in up to 30-36% of children with CP following Achilles tendon lengthening.\textsuperscript{13-14} Borton et al. reported the highest rate of calcaneal gait in bilaterally-involved children who had undergone percutaneous Achilles lengthening.\textsuperscript{13-14} As such, Borton et al. recommended that percutaneous Achilles tendon lengthening should be avoided in children with CP.\textsuperscript{13} Dietz et al. reported overlengthening of the heelcord frequently in children with bilateral CP, resulting in the need for floor reaction AFO braces in 44% of their bilaterally-involved children with CP.\textsuperscript{15}

Gastrocnemius recession has been increasingly advocated in children with CP and equinus gait since the advent of gait analysis. In contrast to the high rates noted following Achilles tendon lengthening, Firth et al. recently reported no cases of crouch gait, with only a 2.5% rate of overcorrection (calcaneus) at more than 7 years post-op in children with gastrocnemius recession as part of SEMLS.\textsuperscript{10} Firth et al. did report recurrent equinus in 35%, though noted that mild recurrent equinus was well-tolerated and helped avoid crouch.

These data provide further evidence of the avoidance of Achilles tendon lengthening whenever possible in children with CP.

**STIFF KNEE GAIT AND DISTAL RECTUS FEMORIS TRANSFER**

Distal rectus femoris transfer (DRFT) is a surgery whose advent relied on data from motion analysis studies. Further, such data have also helped help narrow surgical indications.

Stiff-knee gait has long been recognized as a difficult problem in those with CP. Stiff-knee gait causes difficulty with foot clearance and can result in falls. It was not until the advent of gait analysis that a viable solution to this problem, distal rectus femoris transfer (DRFT) became widely available to treat this malady.\textsuperscript{16-18} Computerized motion analysis, including the use of dynamic electromyography (EMG), form the basis in the objective assessment of the need for DRFT. A good candidate should have both sagittal kinematic data (decreased magnitude and/or delayed timing of peak knee flexion in swing phase) in conjunction with EMG evidence of overactivity of the rectus femoris in swing phase.

Numerous studies over the years have shown good results following DRFT surgery. More recent studies using gait analysis have also helped develop somewhat more selective criteria to enhance patient selection for DRFT in order to enhance patient outcome.\textsuperscript{19-22} Based on these studies, the results of DRFT are best in GMFCS I and II patients and in those without significant crouch gait pre-op.

**VARUS FOOT DEFORMITY**
Pes varus is seen frequently in children with CP, particularly in those with unilateral involvement. Varus foot deformity commonly compromises stability in stance phase and contributes to intoeing gait.

Classic teaching was that the posterior tibialis was the primary cause of pes varus deformity. Many physicians have traditionally lengthened or transferred the posterior tibial tendon in order to correct pes varus in those with CP. However, the two largest series studying the cause of varus feet in children with CP used computerized gait data (including dynamic EMG) showed that the varus was due to the anterior tibialis in one-third of patients, the posterior tibialis in one-third, and both the anterior and posterior tibialis in the remaining third. Dynamic EMG is necessary to best determine the muscular contribution(s) to varus foot deformity in a child with CP.

Though pes varus often results in intoeing gait in children with CP, most children with intoeing gait do not have pes varus. Despite this, some physicians commonly assume that intoeing gait is primarily due to varus foot deformity. Consequently, many children undergo posterior tibial tendon surgery for intoeing which is actually due to bony torsion rather than pes varus. Using gait analysis in approximately 400 Rethlefsen et al. previously reported that long bone torsion (femur and tibia) are the most common cause of intoeing in children with CP, and that about one-third of these children had at least 2 or more causes of intoeing in the affected limb. In the same study, it was noted that varus foot contributed to intoeing in 43% of the hemiplegic children with intoeing in the study, compared to 8% of bilaterally involved (di- or quadriplegic) who were noted to intoe. By using the gait graphs of the transverse plane kinematics, the cause(s) of intoeing can be accurately determined in each child. In addition, since the gait data quantitate the amount of rotation, the surgeon can more accurately determine the amount of derotation needed to optimize correction of the child’s gait.

**CROUCH GAIT AND DISTAL FEMORAL EXTENSION OSTEOTOMY**

Crouch gait is one of the most common gait deviations in children with CP, and increases as children age. Patella baja is often seen in conjunction with crouch gait in CP. Hamstring lengthening has been a traditional technique for decreasing crouch gait in children with CP.

Recent authors have reported mixed results following repeat hamstring lengthening in children with recurrent crouch after previous hamstring lengthening. In an attempt to address recurrent crouch in children with cerebral palsy, other surgical interventions were developed. These include surgeries such as anterior femoral hemiepiphysiosis, patellar tendon advancement and distal femoral extension osteotomy. Using pre- and post-operative gait analysis data, Stout et al. reported favorable results following distal femoral extension osteotomy (DFEO) and patellar tendon advancement (PTA), both in isolation and combination. The best results were shown when the two procedures (DFEO and PTA) were combined.
DFEO and PTA now provide an effective treatment for children with significant crouch gait recalcitrant to other interventions.

INTERNAL HIP ROTATION AND FEMORAL DEROTATIONAL OSTEOTOMY

Femoral anteversion (with resultant in-toeing gait and lever arm dysfunction) remains a common gait deviation impacting function in children with CP. Previously, femoral derotational osteotomy (FDRO) were done almost exclusively in the proximal femur, with good outcomes reported in children with CP. Some authors performed FDRO distally and two “camps” emerged regarding whether or not FDRO needed to be performed proximally.

This question was answered by two previous studies which used pre- and post-operative gait studies to compare proximal and distal femoral derotational osteotomies in children with CP and in-toeing gait. Both studies showed comparable results after proximal and distal FDRO.

Another important result of these gait lab data was in helping to determine the amount of derotation needed to be achieved intra-operatively for a favorable outcome. Both of these studies showed that the correction seen on post-operative gait analysis was $\frac{1}{2} - \frac{2}{3}$ of the amount of correction obtained intra-operatively (indicating that for 20° of desired correction on post-operative gait analysis, the surgeon should rotate the femur 30-40° at surgery.)

Since the results of proximal and distal femoral rotational osteotomies are comparable, the surgeon may perform FDRO at either level when addressing femoral anteversion and in-toeing gait. In children in whom there is also coxa valga and hip subluxation, proximal femoral osteotomy is indicated to address the deformity.

REFERENCES


Changes in treatment based upon motion analysis, AACPDM 2013


