

Single event multilevel orthopedic surgery for crouch gait in cerebral palsy

A thesis submitted for partial fulfillment of M.D. degree in Orthopaedic
Surgery

By

John Fathy Haleem Amen

M.B.B.Ch

M.Sc. of Orthopaedic Surgery

Faculty of Medicine - Ain Shams University

Supervised by

Prof. Dr. Tamer Ahmed El-Sobky

Professor of Orthopaedic Surgery

Ain Shams University

Dr. Ahmed Hassan Yosry

Assistant Professor of Orthopaedic Surgery

Ain Shams University

Dr. Mohamed Abdel-Monem ElGebely

Assistant professor of Orthopaedic Surgery

Ain Shams University

Dr. Dalia Mohamed Ezz-Eldin

Assistant professor of Physical Medicine

Ain Shams University

Dr. Mostafa Hassan Aboulfotoh ElSherbini

Assistant Professor of Orthopaedic Surgery

National Institute of Neuromotor System

Faculty of Medicine -Ain Shams University

2018

List of contents

• Acknowledgement.....	ii
• List of abbreviations.....	iii
• List of figures.....	v
• List of tables.....	vii
• Introduction.....	1
• Aim of the Work.....	4
• Review of Literature:	
✓ Introduction to Cerebral Palsy.....	5
✓ Pathomechanics of crouch.....	15
✓ Patient evaluation.....	31
✓ Surgical management of crouch gait.....	68
• Patients and methods.....	93
• Results.....	116
• Case presentation.....	121
• Discussion.....	127
• Conclusion.....	133
• Summary.....	135
• References.....	136
• Arabic summary.....	146

Acknowledgement

First of all thanks to **ALLAH** to whom I relate any success in achieving any work in my life.

I would like to express my sincere gratitude to **Prof. Dr. Tamer Ahmed El-Sobky**, for his kind supervision, valuable advice and unlimited help in providing all the facilities for this work.

I am heartily thankful to my supervisors **Dr. Ahmed Hassan Yosry** and **Dr. Mohamed Abdel-Monem ElGebely**, for their continuous support and encouragement throughout this work.

Special and great thanks to **Dr. Dalia Mohamed Ezz-Eldin**, for her help and great effort in rehabilitation of the thesis cases.

I would like to express my great appreciation to **Dr. Mostafa Hassan Aboulfotoh El-Sherbini**, for his kind supervision, continuous help and the great hard work that helped to finalize this work.

Thanks a million to **Dr. Mai Abdelmohsen Ahmed**, the gait operator and analyst at MAC gait laboratory, for her patience and effort in providing accurate report for every patient individually.

I am also very grateful to my professors and colleagues at Ain Shams University. Last but not least, I extend a special thanks to my family for all the sleepless nights and unwavering support.

Thank you

List of abbreviations

CP	Cerebral Palsy
IGA	Instrumented Gait Analysis
SEMLS	Single-Event Multilevel Surgery
TORCHES	Toxoplasmosis, Rubella, Cytomegalovirus, Herpes, and Syphilis.
AFO	Ankle Foot Orthosis
GRF	Ground Reaction Force
MMT	Manual Muscle Testing
ROM	Range Of Motion
ASIS	Anterior Superior Iliac Spine
PSIS	Posterior Superior Iliac Spine
FA	Femoral Anteversion
TPAT	Trochanteric Prominence Angle Test
TFA	Thigh-Foot Angle
TMA	Transmaleolar Axis
CT	Computed Tomography
PCI	Physiological Cost Index
FMS	Functional Mobility Scale
QOL	Quality Of Life
CP QOL-Child	The Cerebral Palsy Quality of Life Questionnaire for Children
WHODAS 2.0	The World Health Organization Disability Assessment Schedule

List of abbreviations

EMG	Electromyography
FDROs	Femoral Derotation Osteotomies
IHR	Internal Hip Rotation
TDRO	Tibial Derotation Osteotomy
DFEO/PTA	Distal Femoral Extension Osteotomy and Patellar Tendon Advancement
RF	Rectus Femoris
VL	Vastus Lateralis
VI	Vastus Intermedius
VM	Vastus Medialis
GMFCSE&R	Expanded and Revised Gross Motor Function Classification System
EUA	Examination Under Anesthesia
IQR	Intequartile Range
P-value	Probability value
NICU	Neonatal Intensive Care Unit
MLS	Multilevel Surgery

List of figures

Figure	Page	legend
1	17	Diagrams showing each gait pattern, with the affected muscle groups and appropriate orthotic prescription.
2	22	The ground-reaction force in crouch gait and after correction with ground reaction AFO.
3	36	Instrumented spasticity assessment
4	40	Measurement of hip abduction
5	43	Unilateral (A) and bilateral (B) popliteal angles.
6	44	The Silverskiöld test.
7	46	Clinical photograph of the trochanteric prominence angle test.
8	48	Measurement of the TFA
9	48	Measurement of the TMA
10 A–C	48	Measurement of tibial torsion using the second toe test.
11	50	Knee extensor lag measurement.
12	56	Functional Mobility Scale (FMS).
13	61	Anteroposterior radiograph of the pelvis
14	62	Koshino index.
15	64	Kinematic data of the knee in the sagittal plane.
16	66	Kinematic curve showing ankle planter flexion with no corresponding muscle activity on EMG data due to gastrocnemius contracture.
17	67	A pedobarograph
18	74	Diagrams showing sites and effects of proximal and distal FDRO.
19	75	Technique for distal tibial derotational osteotomy
20	81	Surgical technique of RF transfer

21	84	supracondylar extension osteotomy with removal of triangular wedge
22	85	Three slip technique for patellar tendon advancement
23	86	A T-shaped periosteal incision just distal to the tibial tubercle apophysis allows the elevation of medial and lateral periosteal flaps.
24	86	The patellar tendon is advanced under the periosteal flaps, and the flaps are repaired over the tendon.
25	87	supracondylar extension osteotomy and patellar tendon shortening
26	88	more proximal wedge locations increase translation of distal fragment
27	92	Lateral view of foot showing mobilization of calcaneal tuberosity fragment.
28	92	lateral aspect of foot showing cuboid opening wedge osteotomy with peroneal tendons retracted inferiorly
29	104	Lateral knee X-ray of case 6 illustrating Koshino index.
30	114	6 weeks postoperative X-ray of case 16 after derotation osteotomy distal femur.
31	121	Preoperative (left) and 1 year postoperative (right) clinical photograph of case no 2.
32	122	Preoperative (left) and 1 year postoperative (right) clinical photograph of case no 3.
33	123	Improvement in hip rotation in case no 3 before (left) and after (right) SEMLS.
34	124	Preoperative (left) and 1 year postoperative (right) clinical photograph of case no 4.
35	125	Preoperative (left) and postoperative (right) knee kinematics of case no 4.

List of tables

Table	Page	Legend
1	96	Previous interventions.
2	102	WHODAS 2.0 12-item interviewer administered version.
3	108	Index surgical procedures.
4	115	Preoperative and postoperative clinical examination parameters
5	116	Percentage of patients showing improvement in FMS
6	117	Values of FMS.
7	117	Values of walking speed, PCI and WHO DAS 0.2
8	118	Preoperative and postoperative values of three IGA parameters.

Introduction

Ambulatory children with cerebral palsy (CP) present with different gait patterns caused by spasticity and contractures with subsequent limited range of motion leading to loss of functional abilities. Crouch gait is one of the most common gait patterns in ambulatory children with CP and is contributed to several factors. Erect posture during gait is accomplished by concentric contraction of hip extensors, knee extensors and ankle plantar flexors. The mechanical effect is to keep the ground reaction force in front of the knee joint during the stance phase. Continuous knee flexion during gait is commonly described as crouch gait regardless of ankle joint status during stance.¹

Rodda et al. described five patterns of gait in spastic diplegic patients based on pelvis, hip, knee, and ankle position during stance. With a definition of crouch gait as, knee flexion throughout stance larger than 20° . The ankle is excessively dorsiflexed and the hip is excessively flexed during stance. The pelvis is in the normal range or tilted posteriorly.²

The ground-reaction force is maintained close to the centers of the hip, knee, and ankle joints, reducing the demands on the antigravity support muscles. Failure of the total body extensor moment as a result of diminished

ability of the hip, knee, or ankle plantar flexor moments may result in collapse of the extension posture into a flexion posture, described as crouch gait. This often occurs as part of the natural history of gait in patients with CP but may be precipitated by any intervention that weakens the gastrocnemius-soleus muscle. Such interventions may include injection of Botulinum toxin A (Botox), selective dorsal rhizotomy, and surgical lengthening of the triceps surae as treatment for equinus deformity.³

Crouch gait may progress rapidly around puberty due to increased body mass. The inherent weakness in lower limb muscles will not be able to support the increased body weight. Musculoskeletal deformities are important factor in the pathogenesis of crouch. These deformities are termed lever arm dysfunction and include excessive femoral anteversion, hip subluxation, patella alta, excessive external tibial torsion and pes valgus.³

Given that the cause of crouch gait is usually multifactorial and difficult to characterize precisely, treatment is controversial. Options include muscle-strengthening, external support with orthoses, and orthopaedic operations to correct fixed musculoskeletal deformities at single or multiple levels. The choice of orthopaedic procedures may be based on clinical evaluation

alone, but instrumented gait analysis (IGA) is increasingly recommended to aid decision-making. Recently, it is recommended to correct all musculoskeletal deformities in one surgical session followed by single long rehabilitation period. This trend is termed single-event multilevel surgery (SEMLS).³SEMLS is considered to be the standard of care to improve gait and function in children with CP. SEMLS improves the likelihood of achieving sagittal plane balance and reduces the need for repeated anesthetics, reduces episodes of hospitalization and requires only one major period of rehabilitation.⁴

Aim of the work

The aim of this prospective clinical study is three fold:

- The first aim is to evaluate the effectiveness of single event multilevel orthopaedic surgery (SEMLS) on the functional mobility of cerebral palsied patients' with crouch gait at one year or more with the help of validated scales and scores.
- Secondly the study aims to assess the effect of SEMLS on energy consumption during gait.
- The third aim is to assess the responsiveness of the patients mental, attitudinal and lifestyle status to orthopaedic correction by SEMLS.

Definition of CP

It has always been a challenge to define ‘Cerebral Palsy’, as documented by the number of attempts that have been made over the years. For example, **Bax** reported and annotated a definition of CP suggested by an international working group that has become classic and is still used. It stated that CP is ‘a disorder of movement and posture due to a defect or lesion of the immature brain.’ For practical purposes **Bax** excluded from CP those disorders of posture and movement which are (1) of short duration, (2) due to progressive disease, or (3) due solely to mental deficiency.⁵

Although the term ‘Cerebral Palsy’ is inaccurate, it became widely used and recognized among clinicians and cannot be changed. ‘*Cerebral*’ does not strictly include all parts of the brain that may be affected in the condition, however most people would accept this extension of its meaning. ‘*Palsy*’ is expected to mean the same as ‘paralysis’ and by ‘paralysis’ understand what others would term ‘complete paralysis. The term ‘paresis’, where power is present but impaired, is more accurate.⁵

Mutch et al. modified the definition of CP in 1992 as follows: ‘an umbrella term covering a group of non-progressive, but often changing, motor impairment

syndromes secondary to lesions or anomalies of the brain arising in the early stages of development.’⁶ The drawback of this definition is that it has focused on motor aspects of CP without taking into consideration sensory, cognitive, behavioral and other associated impairments very prevalent in patients with CP.⁷

Rosenbaum P et al. held an international workshop to evaluate the status of information about cerebral palsy definition and classification and revisit the language presently used to describe it. This was driven by a host of factors:

- ✓ Changes in delivery of care to children with disabilities.
- ✓ Recognition that children with slowly progressive inborn errors of metabolism can present with motor difficulties at times indistinguishable from those of children with nonprogressive disease.
- ✓ Increased availability of high-quality brain imaging.
- ✓ Developmental motor impairment is almost invariably associated with a range of other disabilities.
- ✓ Increased understanding about associated antecedents and correlates of CP.⁷

ANNOTATION

*Cerebral Palsy (CP) describes a group of permanent disorders of the development of movement and posture causing activity limitation that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behavior, by epilepsy, and by secondary musculoskeletal problems.*⁷

Epidemiology

The incidence of CP is increasing slightly. In recent reports the incidence has been estimated to be between 2.4 and 2.7 per 1000 live births. The prevalence of CP appears to be increasing secondary to an increase in the number of infants with very low birth weight being born and the increased survival of these tiny neonates, whereas the rate of CP in infants of a given birth weight has remained stable.⁸

The incidence of CP has been correlated with both:

- Gestational age: The risk for CP in a child born full-term is approximately 1 in 2000. CP was diagnosed in