Surgical Treatment of Spastic Cerebral Palsy

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Cerebral Palsy

- Fixed, nonprogressive brain lesion(s)
  - No active disease at present

- Disorders
  - Primary
    - Musculoskeletal system
      - Lack of motor control
  - Others
    - MR, convulsion, sensory dist., speech impediments, defect of hearing eyesight, etc
Cerebral Palsy: Etiology

- Prenatal
- Natal
  - Prematurity
- Postnatal
Cerebral palsy: Etiology

- Vulnerability of the **preterm** cerebral vasculature
Geographic classification

- Hemiplegia
  - One side of body
  - PVHI
- Diplegia
  - L/E >> U/E
  - PVL
- Quadriplegia
  - Both U/E, L/E, Trunk
- Others
  - Paraplegia
  - Triplesgia
  - Monoplegia

Preterm baby
Physiological Classification:

- Spastic type (50-75%)
- Corticospinal tract lesion
Physiological Classification:

- Dystonic type (25%)
  - Extrapyramidal tract lesion
    (Basal ganglia thalamic injury)
    - Hypertonic or choreoathetoid
    - Athetoid
    - Rigidity
    - Tremor
Physiological Classification:

- Ataxic type
  - Cerebellar level lesion

- Other type:
  - Mixed type
Muscle growth

- Satellite cell: M-T junction
- Pre-requisite
  - Muscle stretching
Abnormalities Due to CNS Damage

- **Primary abnormalities**
  - Spasticity
  - Muscle imbalance

- **Secondary abnormalities**
  - Muscle contracture
  - Joint deformity
  - Bony deformity

- **Tertiary abnormalities**
  - Coping response
  - Spontaneous correction
SURGICAL TREATMENT OF CEREBRAL PALSY

THE PAST

Where were we then?
Causes of Poor Results

- Poor Understanding of the pathophysiology
- Poor understanding of normal gait
- Little understanding of pathologic gait
- Surgery by eye observation & static P/E
The Diving Syndrome

Staged correction of one muscle group at a time
Dr. Rang’s Birthday Syndrome

Childhood is a series of surgeries & recoveries.

Usually not smiling or walking by this time
Results

- Not treated dynamic deformity, but treated static deformity.
- CP is a dynamic disease
Surgical Evaluation

- Physical examination
- Gait analysis
  - Video
  - Kinematics & Kinetics
  - Dynamic EMG
  - Energy consumption
  - Muscle length
  - Various indices
  - Foot pressure
- Other evaluation
  - X-ray and CT
- EUA (exam under anesth.)
Gait analysis benefits:

- Allow study of multiple interlink joint levels
- Differentiate primary deformities from secondary compensation
- Safely perform MLEP (multiple lower extremity procedure)
Surgical Treatment

- Spastic type >> Athetoid type
- Rarely indicated for ataxic type
- Athetoid type
  - Fixed bony deformity
  - Joint subluxation or dislocation
  - Scoliosis
- Non-remedible problem
  - Selective motor control
  - Balance
Surgical Treatment of Foot & Ankle Deformities
Equinus

- Ambulator
  - Stance phase instability
  - Forefoot callosities
  - Ankle sprain
  - Knee flexion contracture
  - Knee hyperextension

- Non-Ambulator
  - Shoeing problems
  - Wheelchair footrest
Equinus

- **Kinematics**
  - Persistent PF
  - Loss of 1\textsuperscript{st} rocker
  - Inversion of 2\textsuperscript{nd} rocker
  - Knee extension in stance

- **Kinetics**
  - Double bump pattern
  - Loss of ankle dorsiflexion moment in initial stance
  - Knee flexion moment in stance
  - Decreased A2 power generation
Operative Methods

- **Technique**
  - Z-plasty
  - Strayer
    - Save soleus
    - Siverskiold
  - Baker’s Tongue in groove
  - Triple hemisection
  - Heel cord advancement

- **Goal**
  - Ankle DF 10° with knee extension
Iatrogenic Problem

- Over-lengthened Soleus
- Ignore Knee and Hip flexion contracture
- Ignore Lever arm dysfunction

Crouch gait
Varus

- Weight bearing instability
- Diminished stride length
- Inversion during swing
  - interfere foot clearance
- Pain
- Lever arm dysfunction
- Others
  - Shoe fitting
  - Shoe wear
  - Cosmesis
Muscle Actions

- Dorsiflexor
  - TA
  - EHL
  - EDL
  - PT
  - PB
  - PL
- Invertor
  - TP
  - FDL
  - FHL
  - SOL
  - GAS
- Plantarflexor
  - TP
  - FDL
  - FHL
  - SOL
  - GAS
Varus

- **TP spasticity**- hindfoot varus, stance phase
- **TA spasticity**- forefoot varus, swing phase
- **Peroneal underactivity** (weakness)
- **Transverse Plane Abnormalities**
  - Severe femoral anteversion or internal tibial torsion
    - Cause roll over of the foot
    - Pseudovarus
Operative Methods

- **Forefoot varus**
  - Split transfer of TA
  - 1st metatarsal osteotomy
    - metatarsus primus equinus
- **Hindfoot varus**
  - Split transfer of TP
  - Split transfer of TP & TA
  - Dwyer osteotomy
  - 1st metatarsal osteotomy
- **Severe equinovarus**
  - Triple osteotomy
  - Triple arthrodesis

Split transfer of TP

Triple osteotomy
Iatrogenic Problem

- Total transfer: reverse deformity
  - PB transfer – hindfoot varus
  - TP transfer – hindfoot valgus
  - PL transfer – dorsal bunion and forefoot supination
- TP to dorsum: should not be done

Split transfers are better
Planovalgus

- Stance phase instability
- Medial callosities
- Hallux valgus
- Shoe wear
- Pain
- Lever arm disease
Muscle Actions

Dorsiflexor

- TA
- EHL
- EDL
- PL
- PT
- FDL
- FHL
- SOL
- GAS

Invertor

- TP

Evertor

- PB

Plantarflexor
Planovalgus

- Valgus
  - PB spasticity
  - Achilles spasticity
  - TP weakness

- Transverse Plane Abnormality
  - External tibial torsion
Pathomechanism

- Equinus contracture + Peroneal spasticity
- Restriction of 2nd rocker -- Midfoot break
  -- Dorsolateral sublux. of navicular
  -- Lateral rotation of calcaneus
  -- Talar head falling plantar-medially
- Relative or actual shortening of lateral column (calcaneus)
Gait Disturbance

- Lever arm dysfunction
- Diminished plantarflexion-knee extension couple
- Pain in talonavicular joint
Operative Methods

- Primary problems
  - TAL
  - PB lengthening
- Poor clearance of foot
  - Rectus femoris transfer
- Extra-articular subtalar arthrodesis
  - Green-Grice subtalar arthrodesis
  - Dennyson and Fulford method
- Calcaneal slinding osteotomy
- Calcaneal lengthening
Calcaneal lengthening

- Modified Evans’ CL
  - TAL
  - PB lengthening
  - Save PL and CC joint

- Postop management
  - SL cast : 6 wks
  - Wt bearing : 7 wks
Calcaneal lengthening

Preop

Postop
Surgical Treatment
Around the Knee
Crouch Gait

- Weak triceps
- Hip flexion contracture
- Hip extensor weakness
- Dynamic hamstring spasticity
- Hamstring tightness
- Extension moment of knee
Jump Gait

- Knee flexion
- Equinus(?)
- No evidence of extension moment
Hamstring Contracture

- Crouch/Jump gait
  - Increased knee flexion at initial contact & terminal swing
  - Inadequate knee extension at terminal stance
- Pelvis tilted posteriorly
Hamstring Lengthening

- **Indications**
  - Excessive knee flexion at initial contact and during stance
  - Increased popliteal angle (true angle)

- **Procedure**
  - Gracilis: intramuscular or Z-plasty
  - Semitendinosus: intramuscular, Z-plasty, transfer to add. mag.
  - Semimembranosus: fascial lengthening
  - Biceps: fascial lengthening
Hamstring Lengthening:

- **Goal**
  - Politeal angle 15°

- **Hamstring shift**
  - Bilat. PA vs Uni. PA

- **Outcome**
  - Improved step length
  - Improved knee extension
Iatrogenic Problem

- Over-lengthened hamstring
  - Need crutch
  - Intractable lordosis and back pain

- Remedy
  - No real remedy
  - Intramuscular psoas lengthening
  - Abdominal strengthening
  - Rectus femoris transfer
Stiff Knee Gait

- Co-spasticity of rectus femoris and hamstrings
- Hamstring weakness in stance
- Knee muscular tightness
Stiff Knee Gait

- Kinematics
  - Inadequate knee flexion in swing
  - Delayed amount and rate of flexion

- Dynamic EMG
  - Abnormal firing of rectus femoris in swing phase
Rectus femoris transfer

- **Indications**
  - Decreased and/or delayed peak knee flexion in swing
  - EMG activity in swing phase
  - Duncan Ely test (+)
  - Associated hamstring lengthen.

- **Transfer site**
  - Gracilis
  - Sartorius

- **Outcome**
  - Improved knee motion in swing
  - Improved foot clearance
  - No rotation effect
  - Transfer >> Release
Surgical Treatment
Around The Hip
Hip Flexion Contracture

- Hip flexor tightness
- Hip flexor spasticity
- Anterior pelvic tilt
- Crouch
Hip Flexion Contracture

- **Cause**
  - Psoas: major
  - Iliacus
  - Rectus femoris
  - Other anterior muscles

- **P/E:** lack of 15 - 20° full extension
  - Thomas test
  - Staheli's test
Hip Flexion Contracture

- Kinematics
  - Inadequate hip extension
  - Anterior pelvic tilt
Operative Methods

■ Nonambulator
  ■ Anterior release
    ■ TFL, RF, Psoas
    ■ Caution: hip extension contracture

■ Ambulator
  ■ Iliopsoas Z-lengthening or Recession (Bleck)
    ■ weakness
    ■ Require protection
  ■ Intramuscular psoas lengthening over the pelvic brim
    ■ Preserve strength
    ■ No protection
  ■ Botox injection and stretching
    ■ Patient with significant weak flexor
Scissoring

- **Cause**
  - Adductor spasticity / contracture
  - Weak abductors
  - Pelvic obliquity
  - LLD
Operative Methods

- Adductor transfer to ischium
- Obturator nerve ant. br. neurectomy
  - Only for nonamulator
  - Abduction contracture
  - Wide abduction & E/R gait
- Adductor tenotomy
  - Percutaneous or Open, desired abduction > 40°
- Indications
  - limited abduction in hip flexion
  - Hip subluxation
  - Loss of abduction following varus osteotomy
- Proximal adductor longus tenotomy and distal gracilis tenotomy are sufficient for ambulator
Iatrogenic Problem

- **Cause**
  - Obturator neurectomy
  - Hip I/R mistaken for adductor contracture

- **Remedy**
  - SemiT to add. Mag.
  - RF to biceps
  - Correct femoral retroversion
Iatrogenic Problem

- **Primum Non Nocere!**
  (First Do No Harm)
  *(Hippocrates)*

- If you don’t know the gait pathology, don’t try to treat!

"It's time we face reality, my friends...we're not exactly rocket scientists."
Hip Instability: Paralytic Subluxation & Dislocation

**Etiology**

- Muscle imbalance around the hip
  - Adduc, Flx>>Abduc, Ext
- Poor Posture
- Lack of standing & walking
- Primitive reflex pattern
Operative Methods

- **Subluxation**
  - FVDO
  - FVDO + PO

- **Dislocation**
  - FVDO + PO
  - OR + FVDO + PO

- **Pelvic osteotomy**
  - Post. Defect
  - Dega type osteotomy

OR(Capsulorrhaphy) + FO + PO
Dega Pelvic Osteotomy

- Cover all anterior, superior and posterior wall
- Increase Volume

Post-op 1 yr
Pathologic Gaits due to Torsional Problems
In-Toeing Gait

- Internal hip rotation (increased. f. antever.)
- Internal tibial torsion
- Posterior/anterior tibialis spasticity
- Foot drag
Torsional Problems

- Physical exam
  - Rotational Profile (Staheli 1985)
    - Foot progression angle
    - Medial rotation
    - Lateral rotation
    - Thigh-foot angle
    - Transmalleolar angle
  - Foot evaluation

- Image
Femoral anteversion

- G. Trochanter Palpation Method *(Ryder 1953, Ruwe 1992)*

- Procedure
  - Prone position
  - Palpate G. trochanter
  - External rotate limb until G. T. reaches most lateral
Thigh-Foot Angle

- Internal tibial torsion: “-”
- External tibial torsion: ”+”
- Normal range
  - 0° ~ 20° (av. 10°)
- Caution!
  - Equinovarus
  - Planovalgus
Transmalleolar Angle

- Normal range
  - 0º ~ 40º (av. 20 º)
- TMA = TFA + 10º
- More practical
  - Foot deformity
Computed Tomography

- Relatively accurate
- Need secure immob.
- Problem
  - Severe coxa valga
  - Cutting level
3D reconstruction CT

- Accurate
- Any position
- Problem
  - Radiation
Increased Femoral Anteversion

- Unilateral
  - Compensatory pelvic rotation
  - Hemiplegia

- Bilateral
  - Bilat. Intoeing
  - Diplegia, Quadriplegia
Femoral derotation osteotomy

- **Indication**
  - 20-30°: never
  - 30-40°: rarely
  - 40-50°: usually
  - 50-60°: almost always

- **Hemiplegia**
  - Do not overderotate

- **Diplegia and quadriplegia**
  - Do not underderotate
  - Goal 5-10° - controversy

- **Weight bearing**
  - 3 wks vs imme. POP
Tibial Torsion in CP

- **Causes**
  - Generally result from poor clearance

- **Problem**
  - Abnormal foot progression angle
  - Lever arm disease
    - Impaired plantar flexor moment arm
      - PF/KE couple
      - Push off

- External > Internal in diplegia, quadriplegia

- Correction for small tibial torsion (>15°)- controversy
Operative Methods

Supramalleolar osteotomy
Quandary

- Functional outcome assessment
  - Score
    - NCMRR, PODCI, PEDI, WeeFIM, GMFCS, AAQ, GMFM, COPM, FAQ.
  - 3D gait analysis
    - Univariate: Oxygen consumption, Walking speed.
    - Multivariate: Normalcy index (GGS), HFI.
Case
HISTORY

- F/5+6
- CP, spastic diplegia (essen. hemi, Rt.)
- Product of 32 wks GA., B.W.: 2.1kg.
- Incubator for 1 month
- Independent community ambulator
## Physical Examination

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<th>Right</th>
<th>Left</th>
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<tr>
<td>Anteversion</td>
<td>60</td>
<td>60</td>
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<tr>
<td>Ely test</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Popliteal Angle</td>
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<td>T. P.</td>
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<td>normal</td>
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<tr>
<td>Heel</td>
<td>Varus</td>
<td>neutral</td>
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Pre-operative Gait
Gait lab
Surgeries

- **Right side**
  - Intertrochanteric FDO
  - Distal hamstring lengthening
  - Z-plastic lengthening of Tendo-Achilles
  - TP split transfer to PB
  - Plantar fasciotomy
  - Foot medial release

- **Left side**
  - Intertrochanteric FDO
  - Distal hamstring lengthening
  - Foot medial release
Post-operative Gait
Thank you!

Invite the Fellowship to SNUBH
- Pediatric & Neuromuscular
- Spine
- Knee
- Hip
- Hand & Upper Extremity
- Tumor & Shoulder
Thank you!
Level of affection

- Corticospinal (Pyramidal) level (UMN)
- Extra-pyramidal level (UMN)
- Cerebellar level (UMN)
- Spinomuscular level (LMN)
  - Spinal level
  - Neural level
  - Neuromuscular junctional level
  - Muscular level
Physiologic classification

- Spastic type (50-75%)
- Dystonic type (25%)
  - Basal ganglia thalamic injury
    - Hypertonic or choreoathetoid
    - Athetoid
    - Rigidity
    - Tremor
- Ataxic type
- Mixed type

Term baby