DEFICIENCE MOTRICE CEREBRALE: INTERVENTIONS EN ORTHOPEDIE PEDIATRIQUE

CAROLINE FORSYTHE
MD, FRCSC

RESUME

• SURVEILLANCE DES HANCHES
• TRAITEMENTS NONCHIRURGICALES
  – BOTOX
  – PLATRES D’INHIBITION
• APPROCHE CHIRURGICALE
CEREBRAL PALSY

• NON PROGRESSIVE INJURY TO BRAIN OCCURING PRIOR TO AGE 2 YEARS
• PROGRESSIVE MUSCULOSKELETAL PATHOLOGY
• PREVALENCE 2-3/1000

Gross Motor Function Classification System
Gold Standard

GMFCS Levels
Ambulatory Cerebral Palsy : 65%
  • Level I: Walks and runs
  • Level II: Walks; no aids
  • Level III: Walks with aids
Non-Ambulatory Cerebral Palsy : 35%
  • Level IV: Stands; wheelchair
  • Level V: Wheelchair; dependant
GMFCS Level III

GMFCS IV
GMFCS Level V

PROGRESSIVE MUSCULOSKELETAL DEFORMITY
Progressive Musculoskeletal Pathology

Primary Abnormalities
- Abnormal muscle tone
- Muscle imbalance
- Weakness

Dynamic Contracture

Developmental Delay

Static Contracture

Bony Deformity

Joint Instability

Effect of Bone Growth

Longitudinal Muscle Growth

• Functional Impairment/ Disability
• Degenerative Arthritis
• Pain

Static Physical Examination

Hip Flexors (Ilio-Psoas)
- Thomas test: for hip flexion contracture
- Flex contralateral hip to neutralize lumbar lordosis
Static Physical Examination
Hip Adductors

- Hip Abduction
  - Hips & knees flexed
  - Add longus, brevis, magnus

- Hip Abduction:
  - Hips & knees extended
  - Tests for Gracilis tightness

Static Physical Examination
Knee: Hamstring Length

- Straight leg raise (hamstring tightness)

- Knee extension: to measure flexion contracture
**Popliteal angle: Unilateral**
(Test of Hamstrings)

- Amount of knee extension with hip flexed at 90°
- “Functional HS contracture”
- Normal Range
  - 0° to 30° (< 6 yrs)
  - 15° to 40° (7-12 yrs)
  - 20° to 50° (13-18 yrs)

**Popliteal angle: Bilateral**
(Hamstring Shift Test)

- Popliteal angle with contralateral hip & knee flexed so that pelvis is neutralized (tipped posteriorly)
- “True hamstring contracture”
- Difference between uni- and bilateral popliteal angle: Hamstring Shift
Popliteal angle: Bilateral (Hamstring Shift Test)

- Hamstring shift > 20º indicates excessive anterior pelvic tilt
  - Tight hip flexors
  - Weak abdominals
  - Weak hip extensors

- In presence of increased lordosis: Apparent HS contracture with normal HS length

Static Physical Examination
Rectus Femoris

- Duncan Ely test (Grade 0 – 3)
  - Rectus femoris tightness is assessed prone
Static Physical Examination
Dorsiflexion of Ankle

- Dorsiflexion with knee flexed
tests tightness of soleus & gastroc

- Dorsiflexion with knee extended
  (Silverskjold test) tests tightness of gastrocnemius

Foot must be supinated to lock subtalar joint prior to
dorsiflexion to prevent midfoot break (valgus escape)

---

Static Physical Examination: Foot & Ankle

- **Hindfoot varus**
  - Tibialis posterior tightness
  - Weak peroneals

- **Hindfoot valgus**
  - Tight peroneals
  - Equinus

- **Supination**
  - Tight tibialis anterior

- **Tibialis anterior**
  - Strength
  - Voluntary (selective) control
  - Confusion test

- **Hallux valgus**
Tibial Torsional Profile

Thigh foot angle
- Normal: 10º
- (0º - 20º external)

Trans (bi)malleolar axis
- Measures tibial torsion
- Normal: 20º (0º to 35º external)
Measuring Femoral Anteversion

Palpate lateral prominence of greater trochanter

Femoral Anteversion + External Tibial Torsion
Abnormal Muscle Tone

• Spasticity
  – Velocity dependent hypertonia: Clasp knife
  – Tardieu: R1 & R2 catch
  – Hyperreflexia: increased deep tendon reflexes
  – Clonus
  – Quantified by modified Ashworth scale

• Dystonia
  – Abnormal and distorted postures (trunk)
  – Variable muscle tone induced by movement
  – Low tone in supine position
  – May “shake loose”
  – No hyper reflexia

• Choreoathetosis
  – When patient initiates a movement
  – Massive involuntary movements
  – Motor overflow to other muscle groups
  – Posturing of fingers or limbs

• Mixed tone
• Hypotonia

Muscle Strength & Control

• Standard Manual Testing
  – Graded 0 – 5
  – All relevant muscle groups
  – Tested if adequate selective control is present

• Selectivity
  0 = Patterned movement only
  1 = Partially isolated movements (reactions/substitutions)
  2 = Completely isolated movement

• Confusion test (mass flexion pattern)
  – Sitting: antigravity hip flexion associated with ankle dorsiflexion

• Sitting balance/Trunk balance
IGA
INSTRUMENTED GAIT ANALYSIS

Spastic diplegia –pre-op gait lab
CINEMATIQUE

CINEMATIQUE, MOMENT, PUISSANCE
EMG

TREATMENT
TREATMENT PRINCIPLES

- Prevention of contractures, hip subluxation
- Strengthening
- Optimizing biomechanics
- Correction of contractures & deformities
CP – Hip Surveillance – Australian Consensus

• GMFCS 1 – AP Pelvis at 12 – 24 months age
• Review at 3 yo
• Review at 5 yo

• GMFCS II AP PELVIS AT 12 – 24 MONTHS AGE
• Repeat assessment q 12 months until MP stable
• Review age 4-5, then age 8-10

CP – Hip Surveillance – Australian Consensus

• GMFCS III, IV, V – AP PELVIS AT 12-24 MONTHS
  – SURVEILLANCE Q 6 MONTHS
  – REVIEW AT 7 YEARS
  – IF MP STABLE AND LESS THAN 30%, DISCONTINUE
    UNTIL PRE-PUBERTY. RESUME Q 12MONTH AP PELVIS
    AT PRE-PUBERTY UNTIL SKELETAL MATURITY
Cerebral Palsy: Hip

- SOFT TISSUE CONTRACTURE
- PROGRESSIVE BONY DEFORMITY

Cerebral Palsy: Hip

- SPASTIC CP:
  - DYSPLASIA ~ 35%
  - >85% QUADRIPLEGIA
  - ~ 50% PAINFUL
CP Hip: Evaluation

- Clinical:
  - ROM
  - tone/spasticity
- Radiographic:
  - Migration percentage
  - change vs. magnitude

CP Hip: Management

- Adductor stretching
- Seating systems
- Standing frames
- Abduction splinting
  - Static
  - Dynamic
**CP Hip: Management**

- Medical tone management
  - Baclofen
- Parenteral therapy
  - Phenol to obturator nerve
  - Botox to adductors
    - associated stretching/splinting/etc.

**CP Hip: Surgery**

- Soft tissue releases:
  - <30% subluxation/<4 y.o.
  - Adductor longus
  - Iliopsoas: medial approach vs. over-the-brim
    - Anterior Obturator nervectomy in non-ambulators
  - Early release may prevent subluxation in up to 60%
CP Hip: Surgery

- Bony: 30 - 50% subluxation
  - Varus Derotation Osteotomy
    - Unilateral vs. Bilateral
    - Associated soft-tissue releases

Management Summary

- <4 yo with abduction < 30 degrees and > 30% Reimer Migration index: Soft tissue release
- <8 yo with >50% Reimer migration index – VDRO +/- DEGA
- > 8 yo with > 40% Reimer migration index – VDRO +/- DEGA
AUSTRALIE

- 8 YO MALE WITH BILATERAL CP
CHIRURGIE BILATERALE SANS PLATRE

CANADA

FILLE 6 ANS
GMFCS 4
BILATERAL DYSPLASIE
AVEC DYSPLASIE DU BASSIN
CP Hip: Surgery

- Acetabular reconstruction
  - Degree of dysplasia
    - Must evaluate area of deficiency
      - 3D CT reconstruction
    - Avoid posterior uncovering
    - Redirection vs. Reshaping
  - Age dependent
HIP SURVEILLANCE

• REGISTRY OF CEREBRAL PALSY
• ORGANIZE MEETING OF STAKEHOLDERS TO DEVELOP SURVEILLANCE PLAN

BOTOX
BOTOX

• INHIBITS THE RELEASE OF ACETYLCHOLINE AT NEUROMUSCULAR JUNCTION

• RESULTS IN TEMPORARY REVERSIBLE MUSCLE WEAKNESS

BOTOX IN CP

• LOWER EXTREMITIES
  – USED FOR MORE THAN 15 YEARS
  – EFFECTIVE FOR TREATMENT OF SPASTICITY (LARGE R1>R2)
  – MAX DOSE 12-16 UNITS/KG, NO MORE THAN 300-400 UNITS
  – Q.3 MONTHS OR MORE
  – NO MAXIMAL NUMBER OF INTERVENTIONS
POST BOTOX SPLINTING

• ADDUCTORS – ABDUCTOR PILLOW AT NIGHT
• HAMSTRINGS – SPLINTS AT NIGHT
• GASTROC – SERIAL CASTING UNTIL 10 DEGREES DORSIFLEXION THEN FULL TIME AFOS

EUROPEAN JOURNAL OF NEUROLOGY CONSENSUS STATEMENT

• BOTOX EFFECTIVE IN MANAGEMENT OF SPASTIC EQUINUS (LEVEL A)
• SIMILAR TO SERIAL CASTING IN MANAGEMENT OF EQUINUS
• INJECTION IN ADDUCTOR AND HAMSTRINGS MAY DELAY HIP DISPLACEMENT, BUT DOES NOT AFFECT LONG TERM OUTCOME
CONSENSUS STATEMENT – EXPERT OPINION

- SERIAL CASTING SHOULD FOLLOW BOTOX
- AFOS ARE EFFECTIVE ADJUNCT
- PROLONGED STRETCHING IS AN ADJUNCT INTERVENTION
- STRENGTHENING IS AN ESSENTIAL ADJUNCT INTERVENTION

DELAYED VERSUS IMMEDIATE SERIAL CASTING AFTER BOTOX

- CAST REPLACED WEEKLY FOR THREE WEEKS
- BENEFIT TO DELAY CASTS FOR 4 WEEKS VERSUS PLACING SAME DAY
SERIAL CASTING

- KAY ET AL, JBJS 2004 BOTOX + SERIAL CASTING VERSUS SERIAL CASTING ALONE
- CASTS CHANGED Q 2 WEEKS UNTIL >5 DEGREES DORSIFLEXION
- ADDITION OF BOTOX LED TO EARLIER RECURRENCE SPASTICITY AND EQUINUS CONTRACTURE

BOTOX UPPER EXTREMITIY

- 2U/KG FOREARM
- 4 U/KG UPPER ARM
- UP TO Q 3 MONTHS
- SPLINTING/EXERCISE POST BOTOX BASED ON GOALS
BOTOX + SWASH FOR HIP DISPLACEMENT
JBJS 2008

- BOTOX Q 6 MONTHS FOR 3 YEARS + SWASH 6 HOURS PER DAY
- SMALL BENEFIT IN PREVENTING PROGRESSION OF CONTRACTURES
- HIP DYSPLASIA CONTINUED TO PROGRESS.
- NO CHANGE IN GMFCS

CONSERVATIVE TREATMENT
**Management: Therapy & Orthotics**

**Physical Therapy**
- Developmental
- Range of motion
- Stretching
- Strengthening

**Orthotic Management**
- Goals
  - Prevent deformity
  - Protect a part
  - Improve function
- Dynamic bracing
  - AFOs
- Resting splints
  - Maintain stretch
  - Hip abduction
  - Knee immobilizers
  - Night time use
- Serial casting

**Spasticity Management**
- Multi-disciplinary approach
- Pharmacologic agents
  - Local (injection)
    - Botulinum toxin
    - Phenol
  - Systemic (oral)
    - Baclofen
- Adjuncts
  - Casting
  - Orthotics
- Surgical (neurosurgical)
  - Selective dorsal rhizotomy
  - Intra-thecal baclofen
- Optimal management of spasticity to avoid or delay orthopaedic surgery
Orthopaedic Management
Ambulatory Cerebral Palsy

- Goals: Maintain or improve
  - Gait efficiency / Gait appearance
  - Function: activities & participation
  - Quality of life

- Soft tissue Procedures
  - Muscle/Tendon lengthening
  - Tendon transfers

- Bony procedures
  - Corrective osteotomies

- Joint procedures
  - Correction of joint deformities
Mercer Rang’s “Birthday Syndrome”

PROGRESSIVE MS PATHOLOGY CAUSES DECLINE IN GMFCS AND GAIT
**Single Event Multiple Lower Extremity Procedures**

- **Muscle/tendon lengthening**
  - Psoas
  - Adductors
  - Hamstrings (medial)
  - Gastrocnemius
  - Tibialis posterior

- **Tendon transfers**
  - Rectus Femoris
  - Split tibialis posterior
  - Split tibialis anterior

- **Bony surgery**
  - Femoral derotation for excessive anteversion (> 45 degrees)
  - Tibial derotation for abnormal torsion
  - Extension osteotomy distal femur for knee flexion contracture & crouch gait
  - Calcaneal lengthening for Pes Equinovalgus

- **Joint Instability**
  - Hip subluxation
  - Midfoot break
  - Hallux valgus

---

**SEMLS**

50% improvement in gait (GGI) at 12 months and 24 months post SEMLS
A 4.9% improvement in Gross Motor Function (GMFM66) at 24 months.
An 11% improvement in QoL (CHQ) at 24 months
All FMS domains improved, at 24 months
Soft Tissue Surgery
Intra-muscular Lengthening

- Psoas-over-the-brim IM tenotomy
- (Medial) Hamstring lengthening
  - Semitendinosus (IM tenotomy)
  - Gracilis (IM tenotomy)
  - Semimembranosus (aponeurosis)
- Rectus femoris transfer to semitendinosis
- Gastrocnemius lengthening
  - Strayer recession
  - Vulpius
  - Baker
- Tibialis posterior intramuscular tenotomy

Psoas Release at the Pelvic Brim in Ambulatory Patients with Cerebral Palsy:
Operative Technique and Functional Outcome
Lengthening and transfer of hamstrings for a flexion deformity of the knee in children with bilateral cerebral palsy

Ma et al, JBJS (Br) VOL. 88-B, No. 2, FEBRUARY 2006

**Bony Surgery: Lever Arm Disease**

Derotational Osteotomies for excessive femoral anteversion

Derotational Osteotomies for excessive tibial torsional deformity
### TYPE I: EQUINUS GAIT – TOE WALKER

- Ankle equinus: Calf dominance
- Knee and hip extended
- Knee sometimes recurvatum
- Other levels are usually tight
- Over active Planter Flexion-Knee Extension (PF-KE) couple

#### Management

- **Bilateral CP**
  - Selective gastroc lengthening
- **Unilateral CP**
  - Tendoachilles lengthening
- **Hinged or Posterior leaf spring AFO**

---

### TYPE I: EQUINUS GAIT – TOE WALKER

- Avoid TAL in bilateral CP to avoid crouch gait
**TYPE II: JUMP GAIT**

- Ankle equinus
- Knee/hip flexion
- Contracture at each level
- Strong PF-KE couple

**Management**
- Balance all levels as needed
  - Selective gastroc (soleus)
  - Medial hamstrings lengthening
  - Rectus femoris transfer for stiff knee gait
  - IM Psoas lengthening

---

**Type III: APPARENT EQUINUS**

- No heel contact: toe-toe or toe-heel gait
- Ankle neutral: No fixed equinus
- Hip and knee flexed
  - Proximal contractures
- PF-KE couple neutral

**Management**
- Lengthen at knee/hip
- Rectus transfer for stiff knee gait
- No botox or surgery to calf
- Ground Reaction AFO or solid AFO
TYPE IV: CROUCH GAIT

- Ankle dorsiflexed
- Knee/hip flexed
- Patella alta: inferior pole avulsion fx

Causes
- Tight Psoas & Hamstrings
- Weak quads
- Weak soleus
- Natural history
- Iatrogenic from (over) TAL in bilateral CP

Management
- Lengthen at hip and knee
- HS length may be normal with increased ant pelvic tilt
- Extension osteotomy of distal femur +/- patellar tendon advancement or shortening
- May need lateral column lengthening to correct planovalgus & forefoot abduction
- Ground Reaction AFO

FOOT & ANKLE PATHOLOGY IN CP

- Equinus
- Equinovarus
- Equinovalgus
- Hallux Valgus
- Tibial Torsion
**EQUINOVALGUS DEFORMITY IN CP**

- Common in spastic diplegia
- Tight gastrocnemius & weak tibialis posterior
- Peroneals may become secondarily short
- Midfoot break to accommodate plantarflexion while keeping foot flat on the ground
- Forefoot abducted/externally rotated

**EQUINOVALGUS DEFORMITY IN CP**

- Incompetent subtalar joint cannot “lock” (mid-foot break)
- Lever arm disease: weak push off
- Ground reaction force passes posterior and lateral to knee
  - Genu valgum
- Callosity/pain over prominence of talar head medially
- Shoe fitting and shoe wear problems
Spastic Diplegia
Equino/Plano Valgus Deformity

- Rigid AFO: if flexible
- Lateral column (calcaneal) lengthening, medial tightening
- Subtalar fusion

EQUINOVARUS IN CP

- Common in hemiplegia
- Imbalance between inverters and everters
  - Overactive tibialis posterior (varus in stance & swing)
  - Overactive tibialis anterior (varus in swing phase)
  - Weak peroneals
- Intoed gait
- Inverted heel (tib post)
- Supinated forefoot (tib ant)
CONSEQUENCES OF EQUINOVARUS

- Impaired stability in stance phase
- Poor foot clearance
- Callosity along lateral border and pain
- Shoe fitting/shoe wear
- Lever arm disease

ASSESSMENT OF EQUINOVARUS

- Static range of motion
- Gait assessment
  - Video of foot & ankle
  - Kinematics & kinetics
  - Pedobarograph
- Dynamic EMG
  - Surface: gastroc, tib ant
  - Fine wire: tib post
- Radiographs
Spastic Hemiplegia
Equino-varus deformity

- Split tibialis posterior tendon transfer (SPOTT)
  - Younger child
  - Flexible deformity
  - Stance phase varus
  - No significant supination

- Split tibialis anterior tendon transfer (SPLATT)
  - Swing phase varus
  - Dropfoot
  - Forefoot supination

- Split tibialis anterior tendon transfer + intra-muscular lengthening of tibialis posterior and gastrocsoleus lengthening (as needed)
  - Older child
  - Stiffer deformity
  - When both tendons are involved in varus

SPLATT
Equinovarus Deformity
**Equinovarus Deformity**

- Common in diplegics with planovalgus feet
- Painful bunion/callosity over 1st MT head
- Associated foot malalignment
  - Equinovarus
  - External tibial torsion

**Management**
- 1st MTP fusion
- Corrected ass. malalignment

---

**Hallux Valgus**

- Common in diplegics with planovalgus feet
- Painful bunion/callosity over 1st MT head
- Associated foot malalignment
  - Equinovarus
  - External tibial torsion

**Management**
- 1st MTP fusion
- Corrected ass. malalignment
1. What type of cerebral palsy?
2. What surgery for equinus?
3. What is a common complication of surgery for equinus in this type of CP?

1. What type of cerebral palsy? Unilateral or R Hemiplegia
2. What surgery for equinus? R TAL
3. What is a common complication of surgery for equinus in this type of CP? Recurrent equinus
1. What type of cerebral palsy?
   - Bilateral Spastic Diplegia

2. What surgery did this child have?
   - Bil TAL’s

3. What is the outcome?
   - Calcaneus/crouch
• FEMORAL SHORTENING +/- HAMSTRINGS LENGTHENING + PATELLAR TENDON PLICATION
PATELLAR TENDON PLICATION

Patellar tendon split into three & the lateral slips detached from tibial attachment (central slip left intact)

Patella pulled distally

Flaps of periosteum raised

Central slip pulled up & sutured to patella

Lateral slips pulled down & buried under periosteal flaps

Koala in tree