Hypertonia management for ambulatory cerebral palsy

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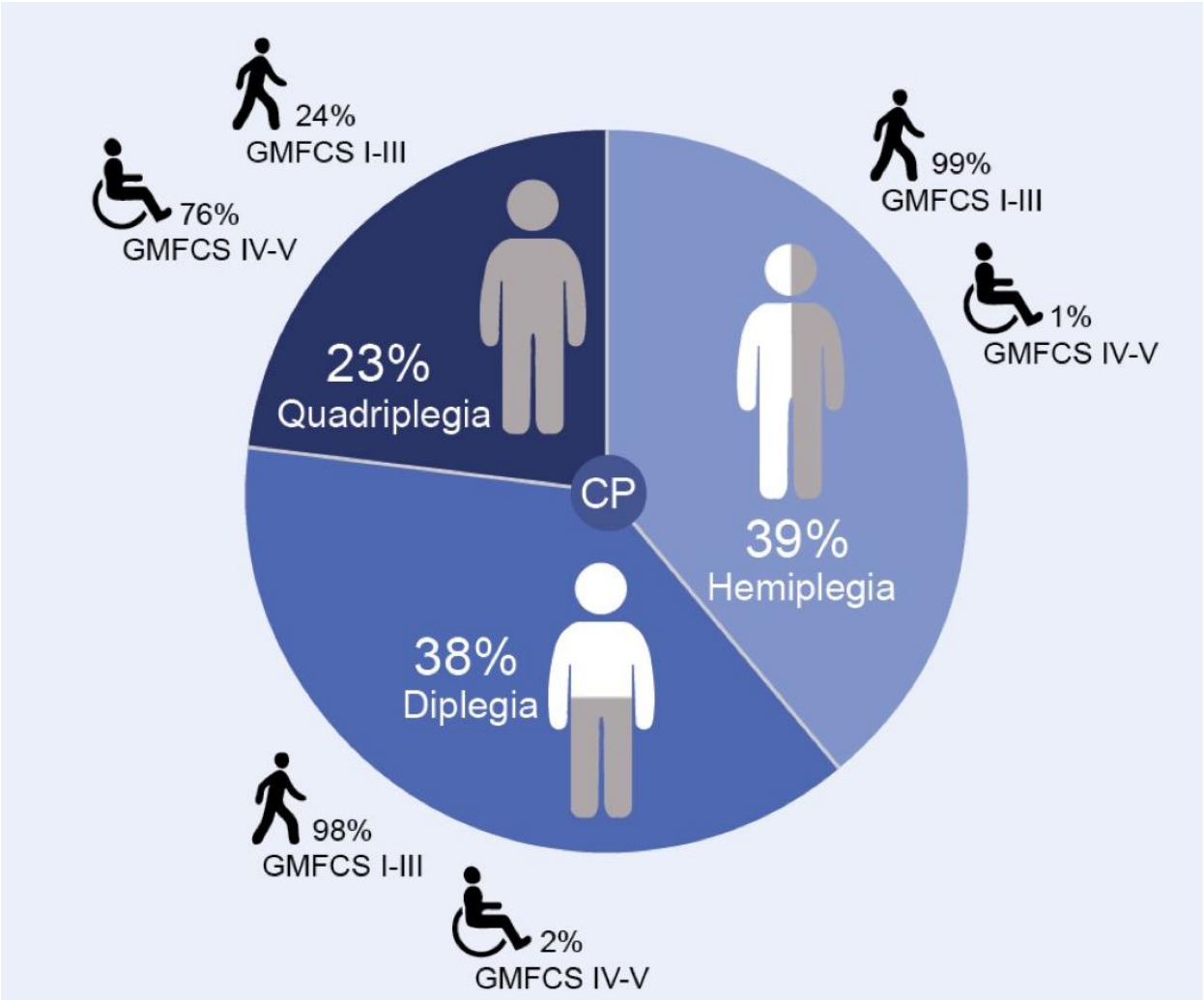
Ambulatory Function in CP



- *The incidence and severity of cerebral palsy has changed dramatically in the last 40 years.*

- ***80% of children are GMFCS Level I to III***
- ***60% walk independently***

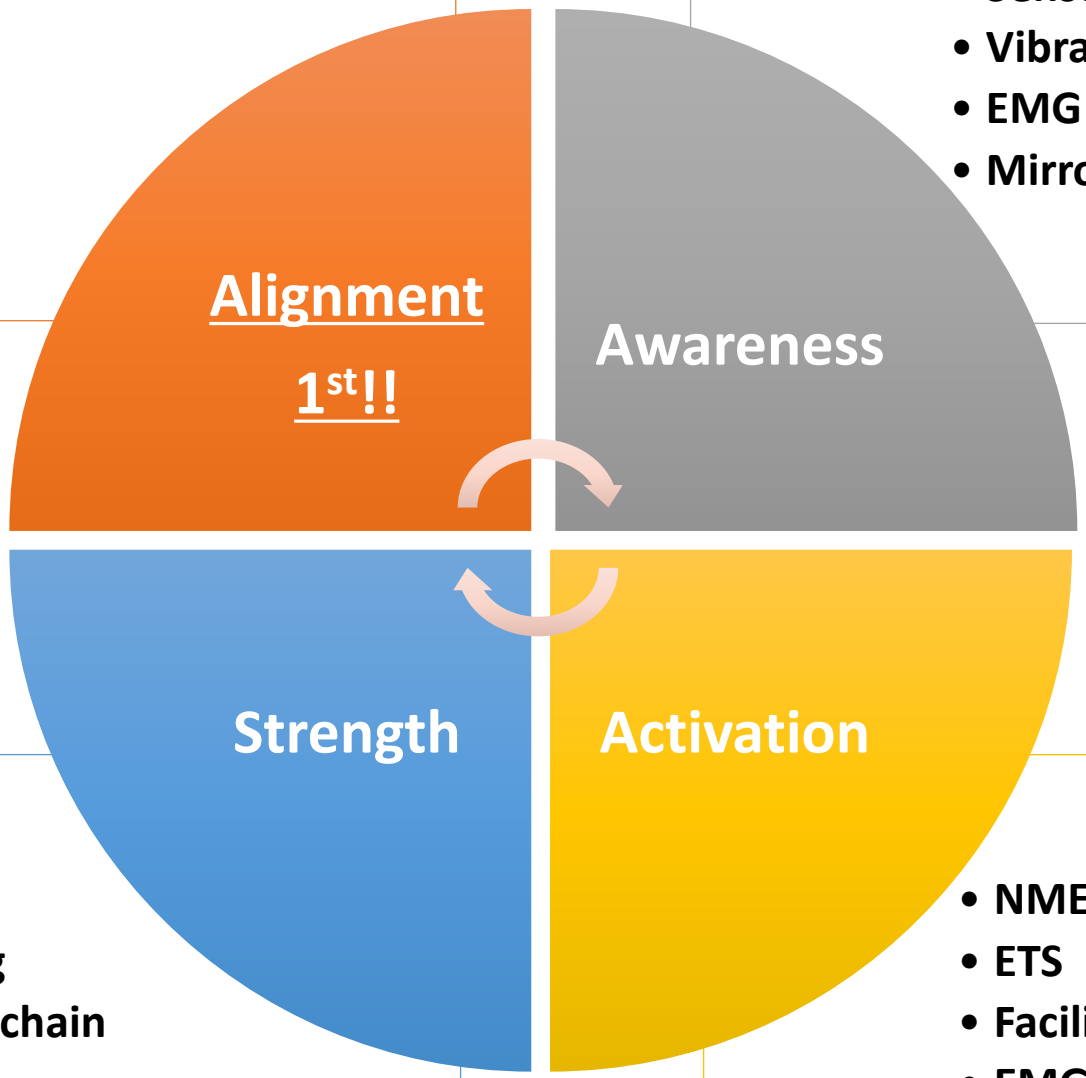
Most children with cerebral palsy walk
The question is not if they will walk, but how well will they walk?

Novak, I: Evidence-Based Diagnosis, Health Care, and Rehabilitation for Children With Cerebral Palsy.
***Journal of Child Neurology 2014**; 29: p1141-1156*

Principles for Changing the outcome for children with CP

- Stretching
- Orthosis
- Hypertonia management
- Surgery

- Sensory
- Vibration
- EMG biofeedback
- Mirror therapy



- Treadmill
- Circuit training
- Closed kinetic chain exercise

- NMES
- ETS
- Facilitation Techniques
- EMG biofeedback

Pediatric Hypertonia

1st Question: Nature of hypertonia

whether the increased tone relates to spasticity, dystonia, or both, and what is the relative contribution of each to the overall hypertonia

Hypertonia Assessment Tool : Spasticity, Dystonia, Rigidity

HAT ITEM	SCORING GUIDELINES (0=negative or 1=positive)	SCORE 0=negative 1=positive *(circle score)*	TYPE OF HYPERTONIA
1. Increased involuntary movements/postures of the designated limb with tactile stimulus of a distal body part	0= No involuntary movements or postures observed	0	DYSTONIA
	1= Involuntary movements or postures observed	1	
2. Increased involuntary movements/postures with purposeful movements of a distal body part	0= No involuntary movements or postures observed	0	DYSTONIA
	1= Involuntary movements or postures observed	1	
3. Velocity dependent resistance to stretch	0= No increased resistance noticed during fast stretch compared to slow stretch	0	SPASTICITY
	1= Increased resistance noticed during fast stretch compared to slow stretch	1	
4. Presence of a spastic catch	0= No spastic catch noted	0	SPASTICITY
	1= Spastic catch noted	1	
5. Equal resistance to passive stretch during bi-directional movement of a joint	0= Equal resistance not noted with bi-directional movement	0	RIGIDITY
	1= Equal resistance noted with bi-directional movement	1	
6. Increased tone with movement of a distal body part	0= No increased tone noted with purposeful movement	0	DYSTONIA
	1= Greater tone noted with purposeful movement	1	
7. Maintenance of limb position after passive movement	0= Limb returns (partially or fully) to original position	0	RIGIDITY
	1= Limb remains in final position of stretch	1	

SUMMARY SCORE – HAT DIAGNOSIS

		Check box:	
DYSTONIA →	Positive score (1) on at least one of the Items #1, 2, or 6	☐ Yes	☐ No
SPASTICITY →	Positive score (1) on either one or both of the Items #3 or 4	☐ Yes	☐ No
RIGIDITY →	Positive score (1) on either one or both of the Items #5 or 7	☐ Yes	☐ No
MIXED TONE →	Presence of 1 or more subgroups (e.g. dystonia, spasticity, rigidity)	☐ Yes	☐ No

Spasticity you feel, Dystonia you see
- Barry Russman, MD

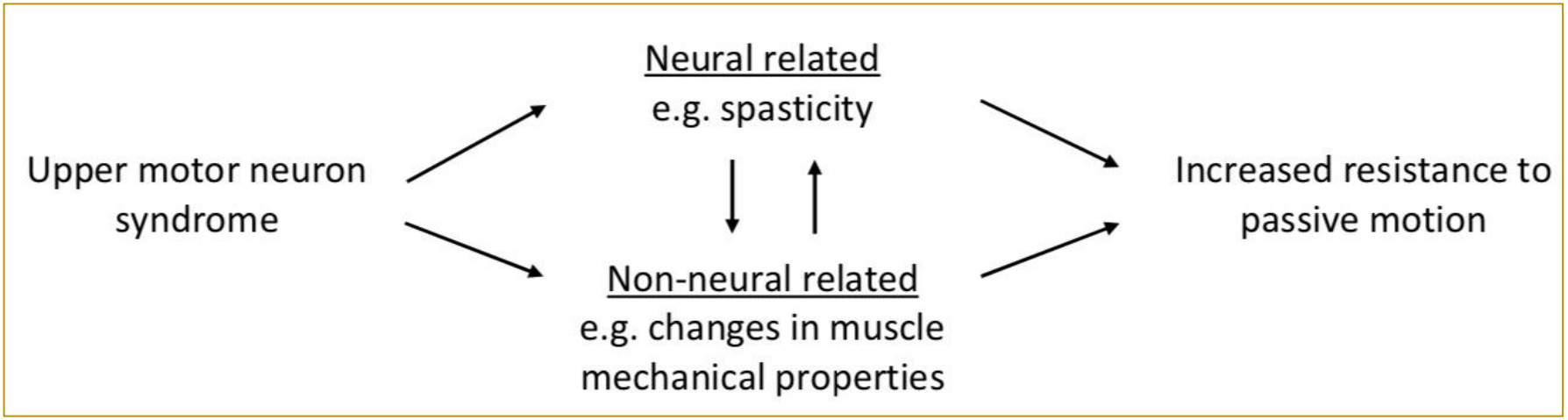
Spasticity and dystonia **frequently coexist**

- whether in fact recognition of some dyskinesias are "masked" by the presence of spasticity, according to conventional clinical descriptors

- 247 CP children, 5-year-old, in the South Australian CP population
- 19.4% on re-evaluation: have abnormal movements, dyskinesia
- This increased with motor severity by GMFCS from 7% (level I) - 45% (level V)

Pediatric Hypertonia

2nd Question: Neural vs Non-neural components



Neural and non-neural mechanisms contributing to increased resistance to passive motion in an upper motor neuron syndrome

Altered muscle length (elasticity): muscle fibers shorten (hypo-extensible)
Altered muscle structure (viscosity): filaments become sticky affecting muscle glide (stiffness)
Abnormal co-contraction (reciprocal innervation) : due to biomechanical effects of abnormal position (too much stability & not enough mobility)

Changes in visco-elastic properties leads to stiffness, tightness & contracture
+ Incoordination, Weakness, Reduced selective motor control, etc

Pediatric Hypertonia

3rd Question: Adverse and beneficial effects

Disabling

- Abnormal posture
- Difficulty in hygiene and dressing
- Difficulty in movements, sitting, transfers
- Inhibits muscle growth
- Joint subluxation/dislocation, contractures
- Masks Contraction in the antagonist
- Muscle pain, Pressure sores
- Shortening & Stiffness of the soft tissues

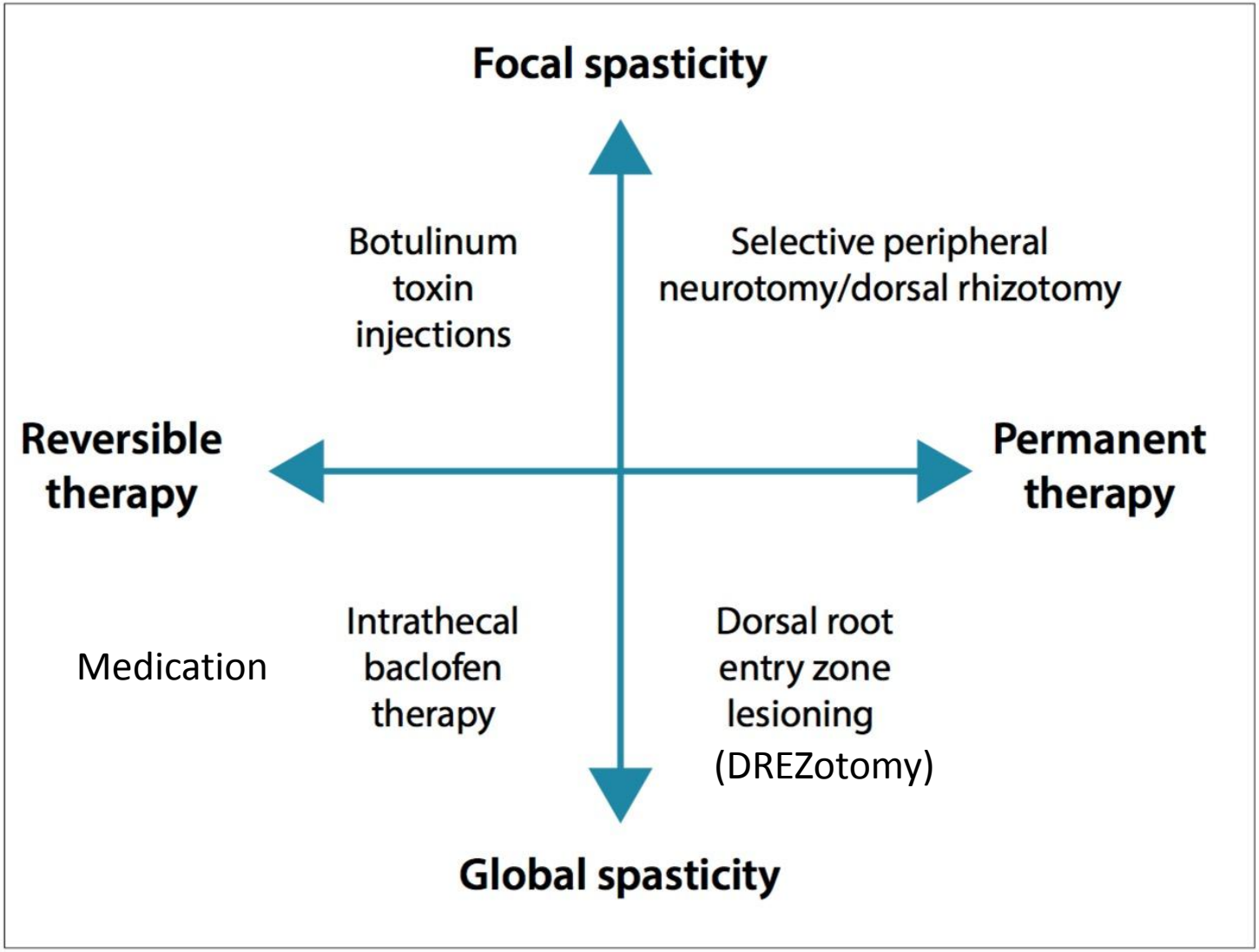
Beneficial

- Extensor tone in the limbs help standing
- Preserve bone density
- Preserve muscle bulk

- Alleviation of spasticity may not always be desirable; some patients may experience a decline in function with spasticity reduction
- Physicians often focus on treating impairment (spasticity) but not activity/participation

Pediatric Hypertonia

4th Question: Generalized vs Localized



Spasticity management diagram, JM Enslin et al, 2016

Therapeutic Modalities for CP

Therapeutic exercise

Chemo-denervation

Oral Medication

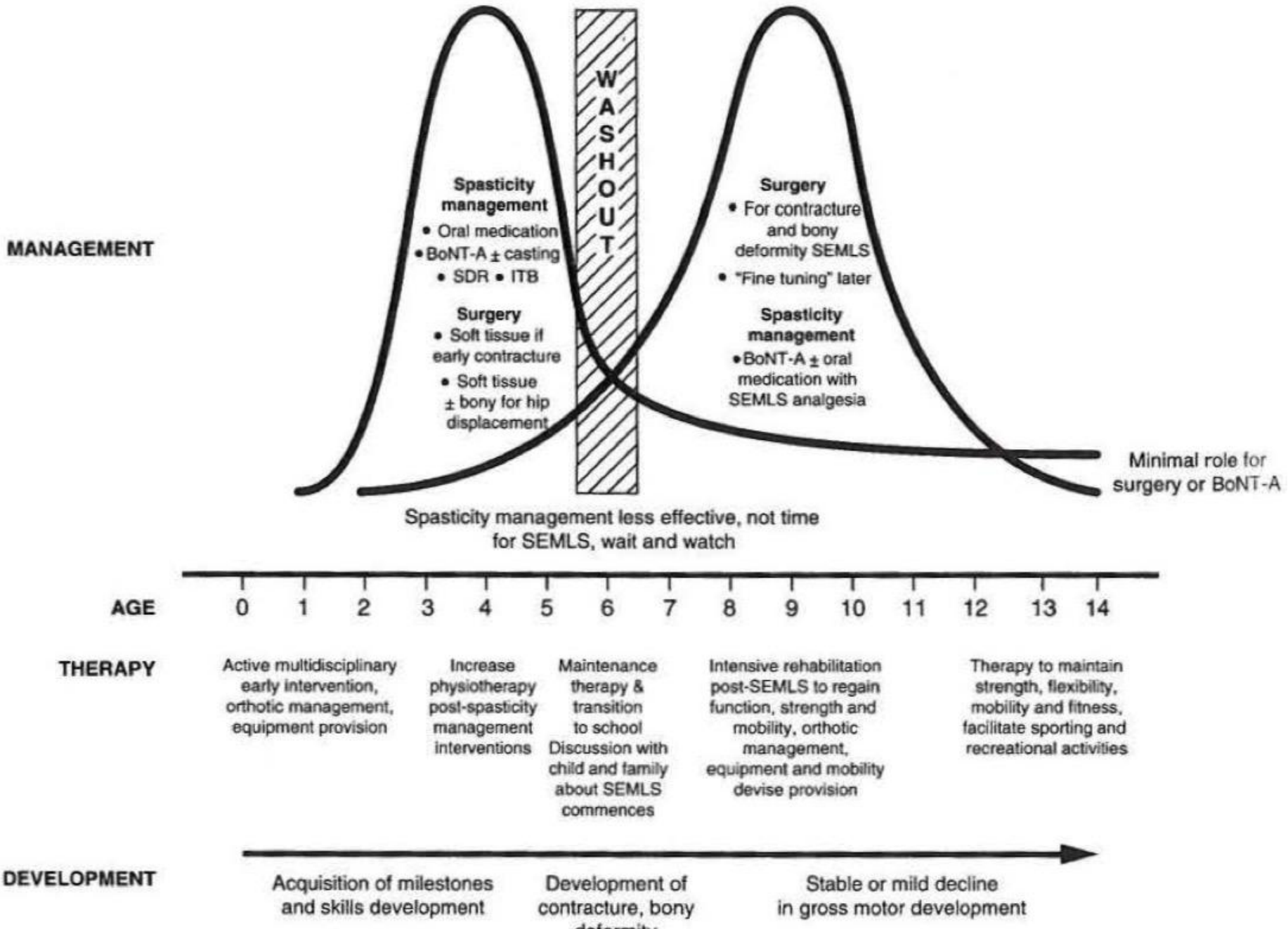
Electrical Stimulation

Cast, splint, orthoses

SDR, ITB

Orthopedic surgery

CP Musculoskeletal Management Algorithm



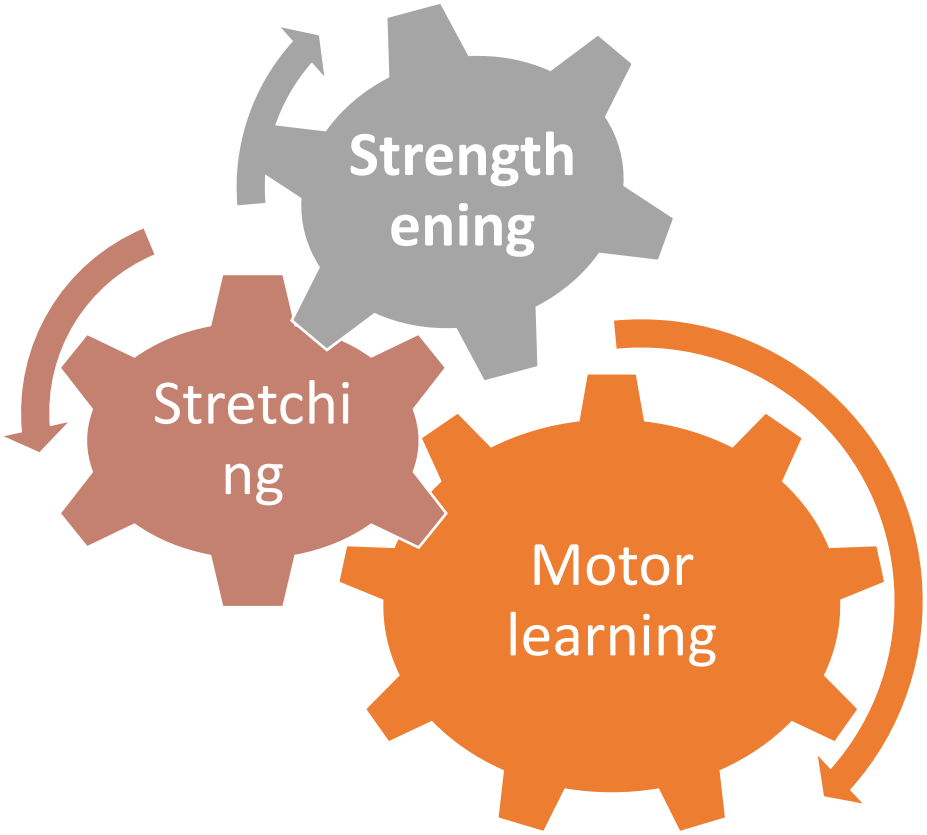
Nonsurgical Management

Therapeutic exercise
Medication
Chemodenervation
Cast, Splint, Orthosis

Therapeutic exercise

❖ Providing more normal sensorimotor experience

→ Reduction of abnormal Movement, Tone & Posture



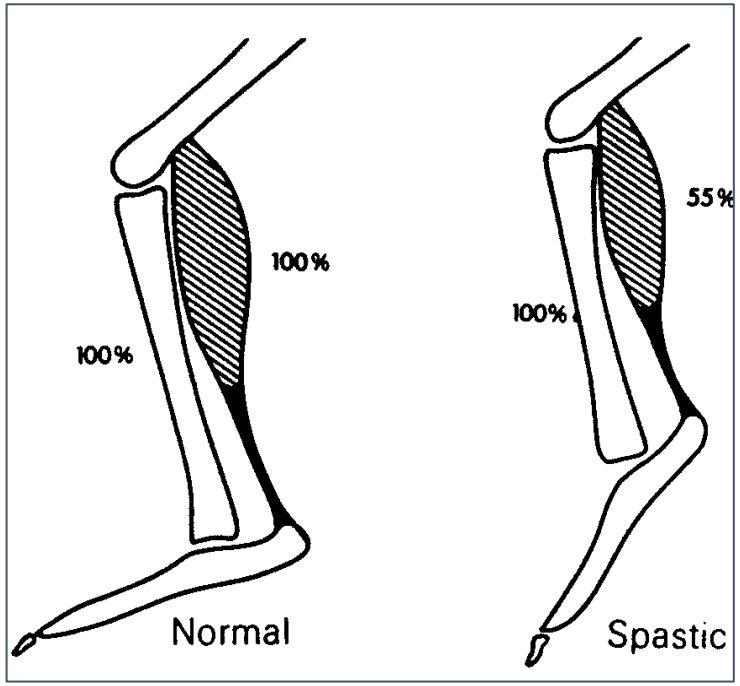
❖ Encouraging motor learning

❖ Minimizing 2ndary MS problems

Stretching

Risk for contracture

- Muscle imbalance
- Static positioning
- Muscle growth < bone growth



Dev Med Child Neruol 1984; 26; 94-9

Method of Stretching

Manual

Sustained

Cast, Orthosis, positioning

Strengthening

- distal muscle – more weak
- Hemiplegia: uninvolved side: also weak

Cause

- Deficit in voluntary muscle contraction
- CNS motor recruitment↓, co-contraction, muscle fiber atrophy, fat and connective tissue ↑

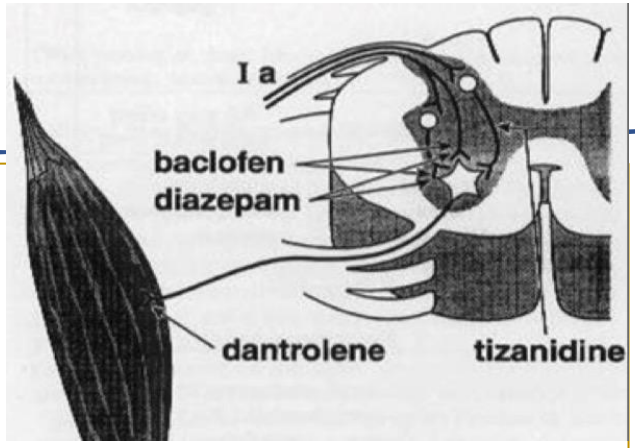
❖ Strengthening -> does not increase spasticity

❖ Progressive resisted exercise improves muscle performance & functional outcomes in CP children

❖ Research had supported effectiveness on increasing force production in CP

Dodd et.al. systematic review of strengthening for individuals with cerebral palsy . Arch Phys Med Reh,83:1157-1164, 2002

Oral Medication: Generalized



Baclofen (Baclofen® , Lioresal®) GABA-B agonist

- titrate up slowly, start with
- 2.5 mg TID for younger children
- **5 mg TID** for older children
- max 30-60mg/day
- (Milla et al) spasticity ↓, PROM/AROM ↑
- (Scheinberg et al) no effect on spasticity

Benzodiazepine (Diazepam® , Valium®)

- GABA-A agonist, 0.12- 0.8 mg/kg, divided into 3-4 doses
- at bedtime may aid sleep without carry-over daytime sedation
- (Mathew et al) muscle overactivity ↓

Tizanidine (Sirdalud®)

- 0.1-0.3mg/kg/day, alpha-2 adrenergic stimulant
- Improved initiation of sleep and reduced tone/ SE. dry mouth, hepato-

Dantrolene sodium (Anorex ®)

- 0.5mg/kg/day -> 2mg/kg tid/day
- SE. hepatotoxicity

For Dystonia

Trihexyphenidyl: Titrate up slowly to 0.5 - 1 mg/kg/day divided TID. Watch for constipation

Levodopa-carbidopa (Sinemet): titrate up slowly to 10 mg/kg/day divided TID

Chemo-denervation: Selective

Injectable therapy to prevent nerve-muscle transmission

- Perineural injection of **phenol or ethyl alcohol**
- Intramuscular injection of **botulinum toxin (BoNT)**

All 3 are appropriate for focal spasticity or for targeting specific problem muscles

Botulinum toxin (BoNT) Injection

- Lack of sensory disturbance, Good in tolerability of children, Ease of administration
- Adverse effect : High cost, Short duration of action, Distant unwanted m. weakness (diffusion & systemic spread)
- Diffusion of the toxin into adjacent area: Depend on injection volume, dose, injection method

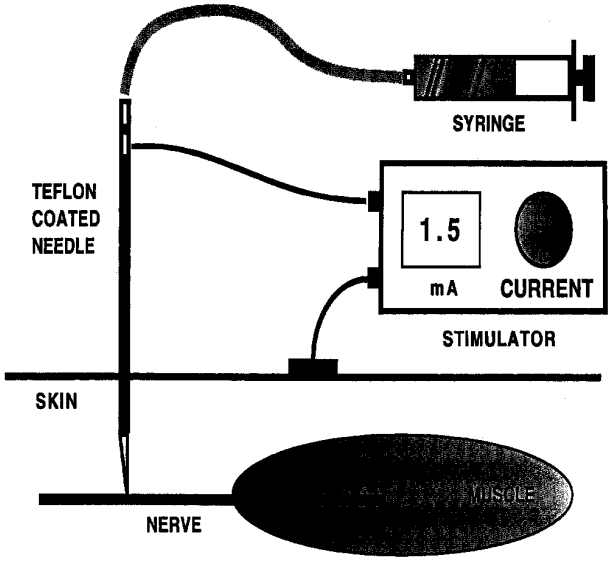
Ethyl Alcohol / Phenol injection

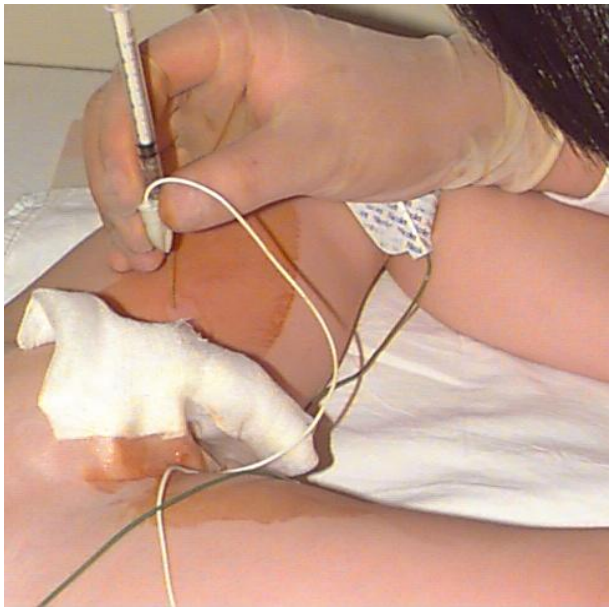
- Perineural injection -> promotes denervation via axonal degeneration
- 35-60% (50%) ethyl alcohol
- 5 % phenol (total <20 ml (1g))
- not permanent, with functional reinnervation occurring over months to years (few wks to 2 years: no factors conclusively identified in the literature as determining the duration
- Adverse effects: significant risk of pain or paresthesia when targeting a mixed nerve, which may persist

Nerve block for Lower limb spasticity

- Obturator nerve block
  - for hip adductor spasticity

- Motor nerve branch or motor point block
  - To hamstring : medial hamstring or lateral hams
  - To Gastrocnemius muscle or soleus
  - To Tibialis posterior



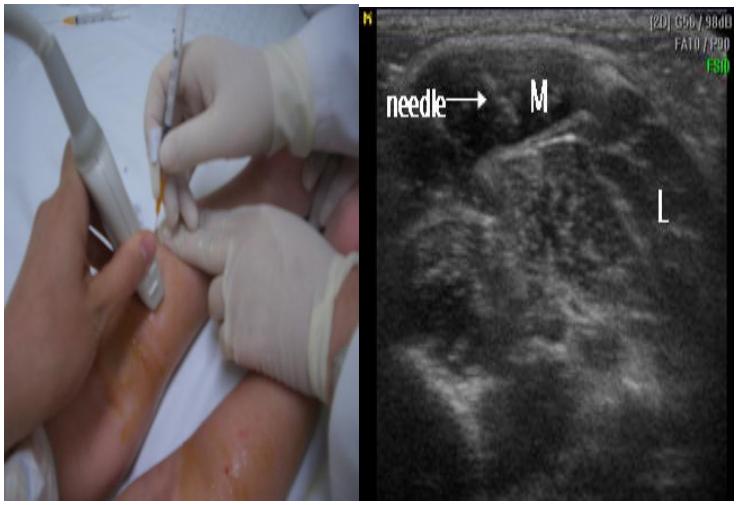


Electrical stimulation
Accurate, Painful,
Need for sedation

Accurate injection technique

Comparison of Injection Techniques

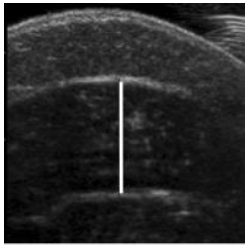
	Palpation	EMG	Stimulation	Sonography
Accuracy	+/-	+/-	+	+++
Practicability	+	-	+/-	++
Availability	+/-	+/-	+/-	+
Pain	+	-	+/-	+++
Speed	+/-	-	+/-	++
Evaluation	+/-	-	+/-	+++
Future research	-	-	-	+++

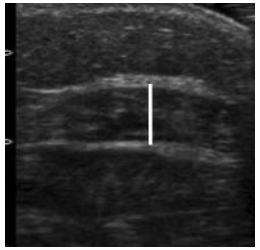


US guided injection

- Provides direct assessment of target: Depth, Location, Structures to be avoided
- Visualize/isolate target muscles: Quickly, Easily, Accurately during procedure
- Less painful: Smaller needles

*** Muscle size: Inversely related to impairment level
→ Importance of accurate injection


GMFCS I


GMFCS III

Spasticity Assessment for Muscle selection

- **Evaluation Scales**

I Ashworth-like Scales:

Ashworth scale	AS	Ashworth, 1964
Modified Ashworth scale-Bohannon	MAS-B	Bohannon and Smith, 1987
Modified Ashworth scale-Peackok	MAS-P	Peackok and Staudt, 1991
New York University tone scale	NYU	Johann and Murphy, 1990

II Tardieu-like Scales:

Tardieu scale	TS	Held and Pierrot-Deseilligny, 1969
Modified Tardieu scale	MTS	Boyd and Graham, 1999

– **R1** is first catch on rapid movement, **R2** is last point of ROM
– R1 & R2 **difference** : dynamic component
– If R1-R2 gap is **>10 °** (more at some joints) expected benefit from BTX-A

Fixed contractures with no dynamic component ▶ Not an BTX indication

- **Additional Tests**

- Thomas Test, Duncan Ely Test, Silfverskjöld Test
- Pendulum Test, Selective motor control of the foot

Muscle Selection in Pathologic Gait

Differentiating Between Primary, Secondary, and Compensatory Mechanisms in Gait

- Differentiate between primary deviations that need to be treated and other gait deviations that will resolve if the primary problem is addressed
- Understand common multi-level gait patterns in CP

Primary Deviation

- kinematic abnormality related to the **impairment at the joint**

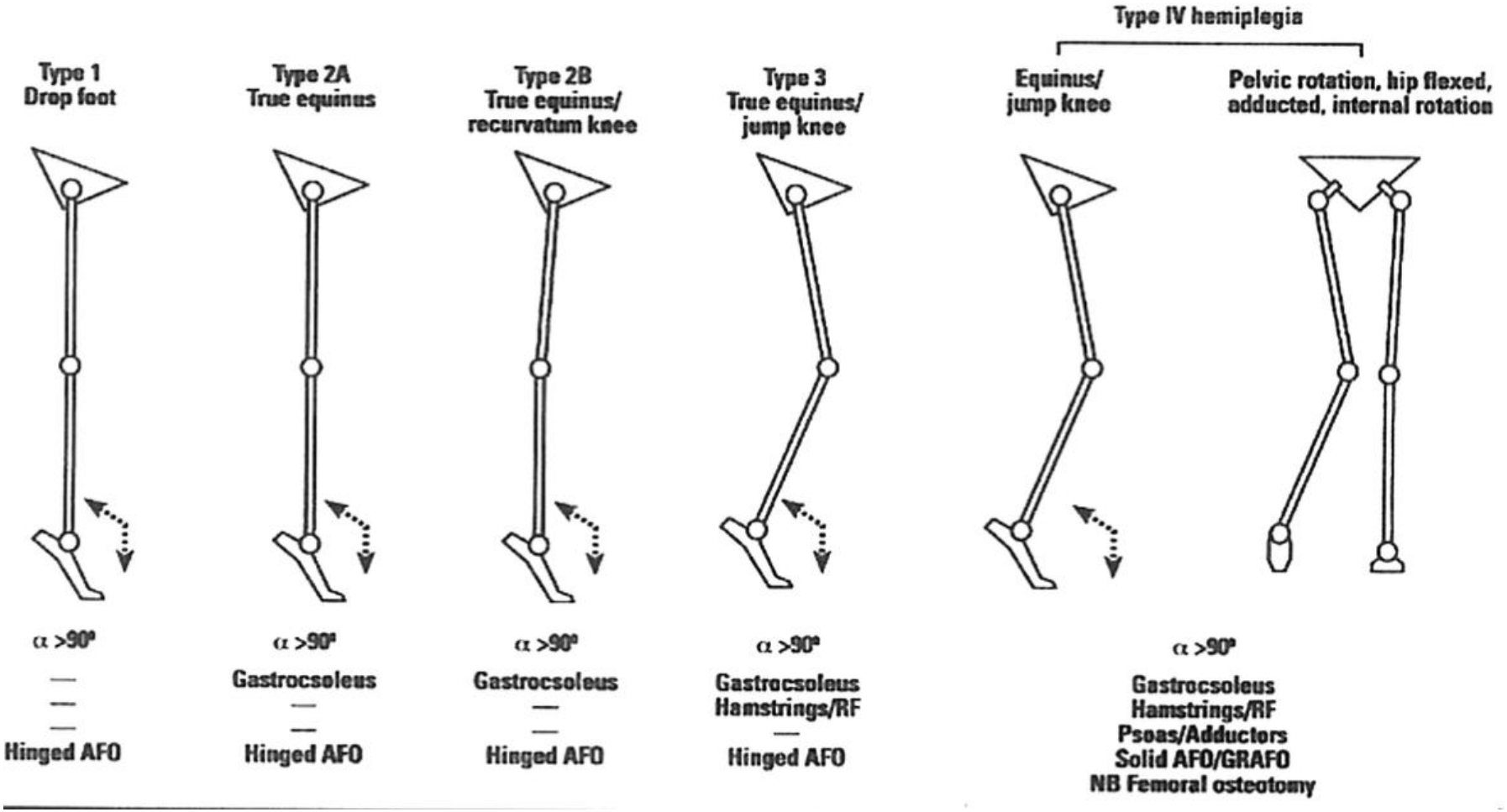
Secondary Deviation

- kinematic abnormality at **another joint that is a direct result of a primary** deviation

Compensatory Mechanism

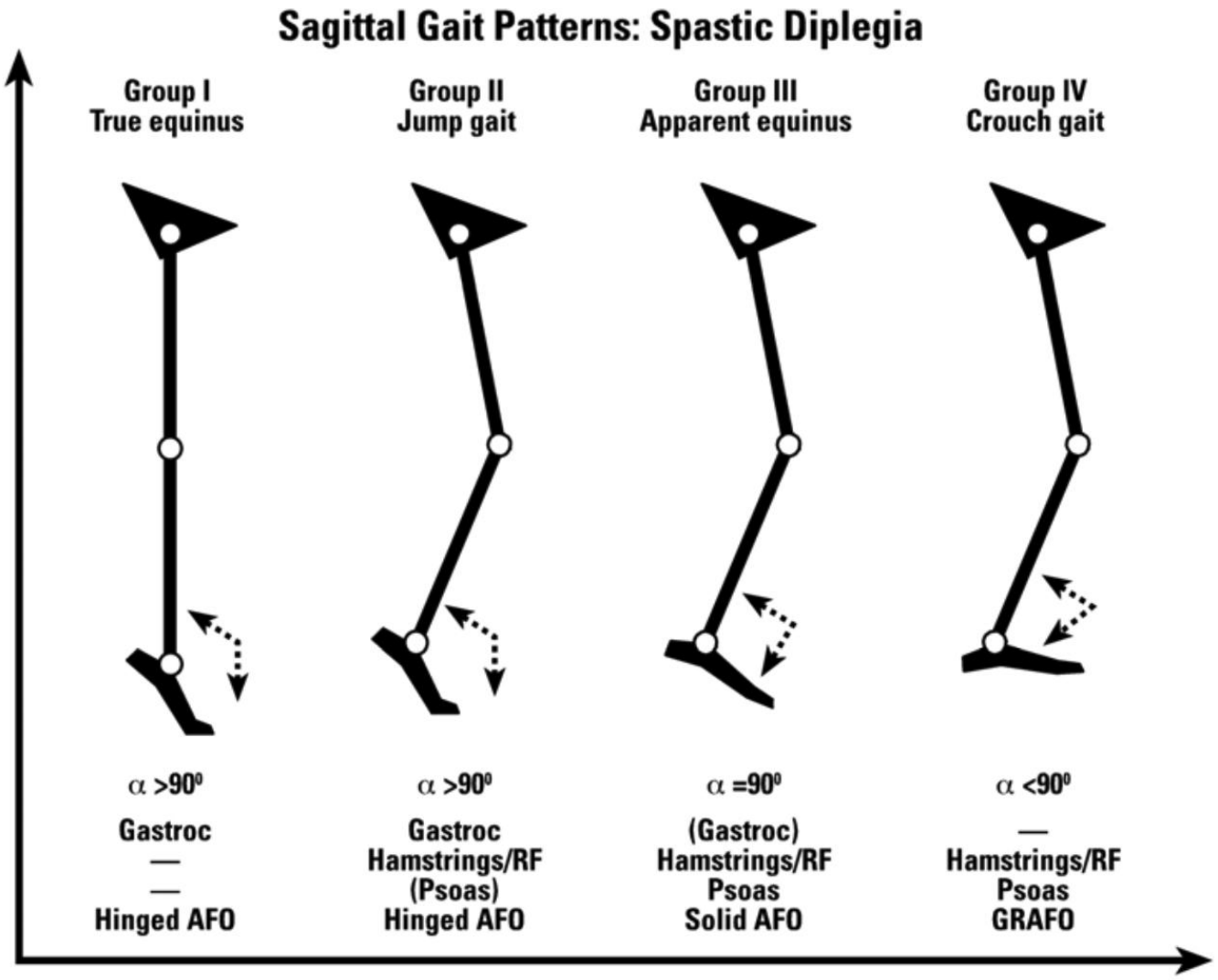
- kinematic abnormality that **is voluntary** that helps **reduce impact of primary** deviation

Common Gait Pattern – Unilateral CP



J. Rodda and H.K. Graham, Euro J Neurol, 2

Common Gait Pattern – Bilateral CP



J. Rodda and H.K. Graham, Euro J Neurol, 2

Muscle Selection

- Maximum dose per injection site : 50 U
- Maximum dose per child per session : 300 U
- Maximum total dosage : 20 U/kg (16~18)

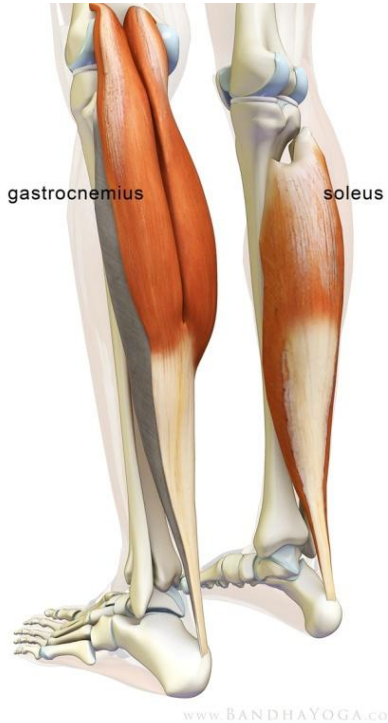
Suggesting toxin dosing (Botox)

Clinical pattern	Muscles	U/kg	site
Flexed hip	**Iliopsoas** Rectus femoris	1-2 3-4	1 2
Flexed knee	**Medial hamstring (SM/ST)** Lateral hamstring	3-6 2-3	3-4 1-2
Equinus Equinovarus Eqinovalgus	**Gastrocnemius (Med/Lat)** **Soelus** **Tibialis posterior** Peronues	3-6 1-2 1.5-2 1-2	2-4 1-2 1-2 1
Scissoring	**Hip adductor (AL/ Gr)**	3-6	1-2

Type A: **BOTOX** (100 Unit/ 1 ample) : Dilution with **2cc of normal saline for L/Ex (5 unit/0.1cc)**
: Meditoxin, Botulex, Xeomin : similar potency with Botox
Type A: **Dysport** (500 Unit/ 1 ample) : conversion rate **1 : 3 ~4 (if, 2.5cc NS mix, 20 unit/ 0.1cc)**

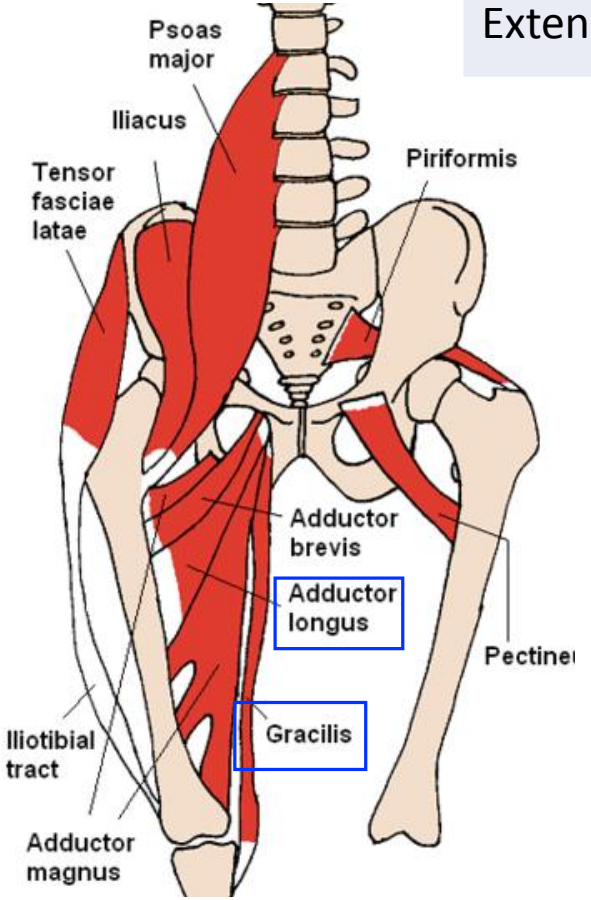
Muscle selection: Silfverskiold Test

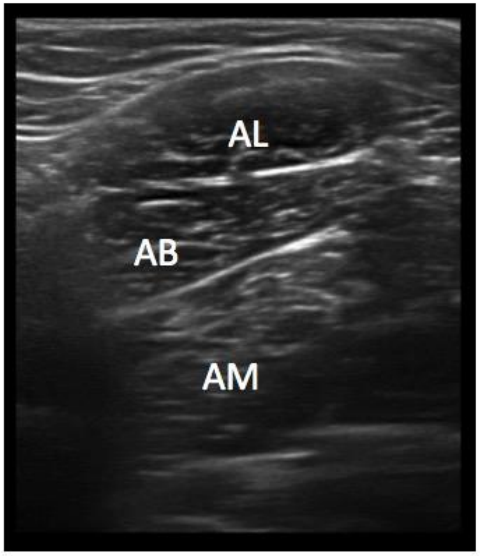
Gastrocnemius	Soleus
2-joint muscle	1-joint muscle
Test: Ankle DF with knee extension-> GCM + Soleus	Test: Ankle DF with knee flexion-> only Soleus

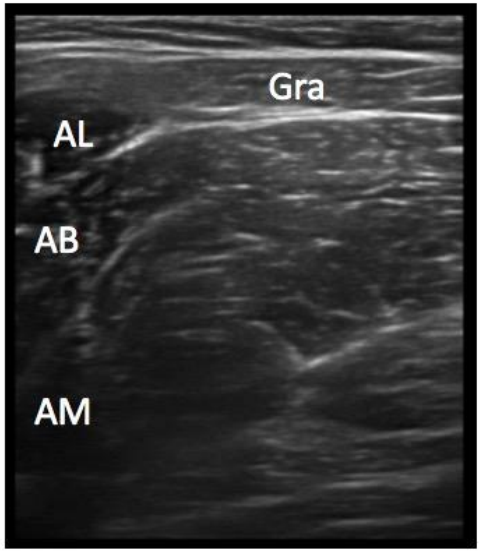


Muscle selection: Biarticulate Muscle : Hip Ad

Gracilis	Adductor Longus
2-joint muscle	1-joint muscle
Test: Hip Abduction with knee Extension -> Gr + AL	Test: Hip Abduction with knee Flexion -> only AL







Multilevel BoNT-A

+ Comprehensive Rehabilitation

- GMFCS level I to III
- Outcome measures at pre &1 mo and 3 mon after injection
  - Walking distance
  - Walking speed
  - Observational gait scale
  - Selective motor control
- BTX injection into
  - Iliopsoas, mediolateral hamstring , hip adductors, rectus femoris, gastrocnemius, soleus, and tibialis posterior m. with varying combination
- + Comprehensive rehabilitation

⇒ **<u>Significantly improvement in functional ability</u>** (Balbaloglu O et al , 2 011)

Combined therapy

Serial cast

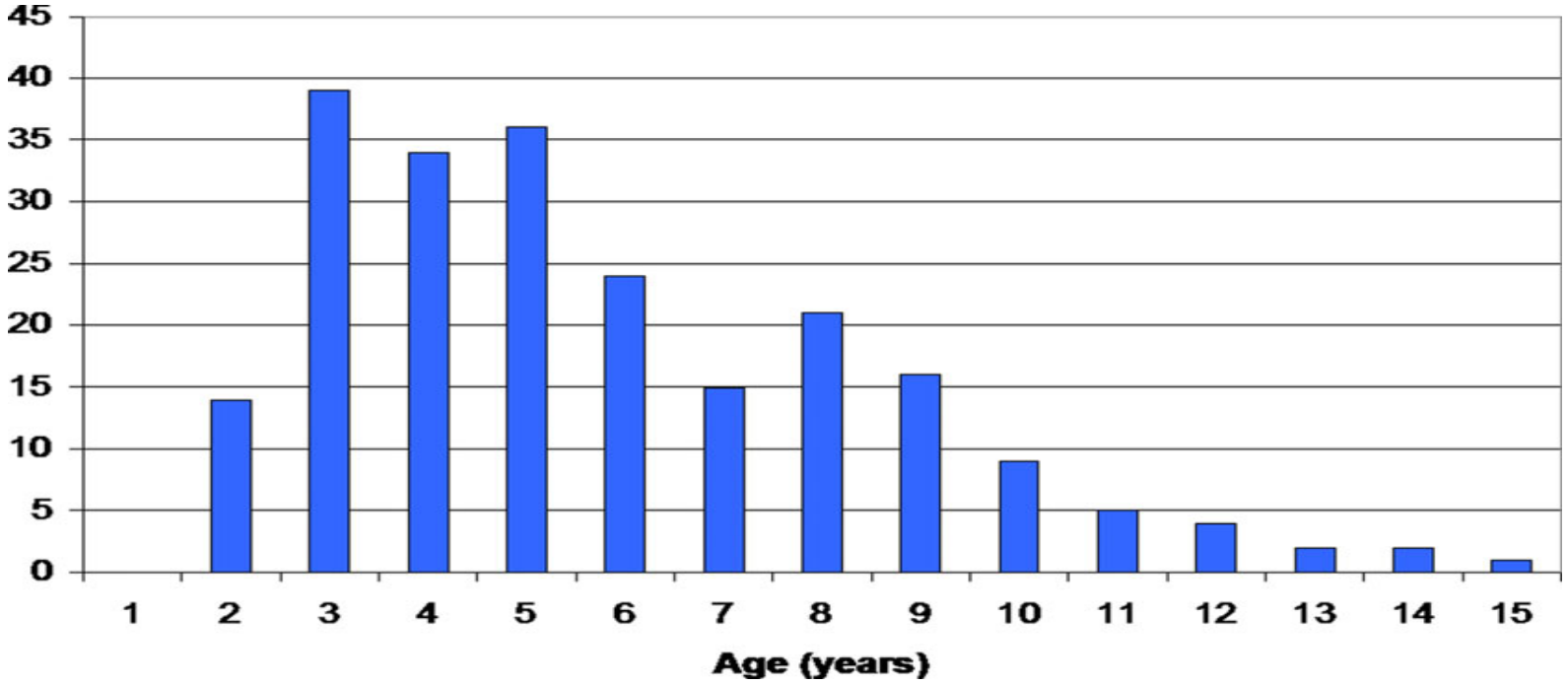
- Spasticity + LOM, Long leg vs Short leg
- reduce spasticity in muscles(Bertoli 1996)
- provides stability&prolonged stretch (Mosley 1997)
- improve muscle length and passive ROM (Kay 2004)
- Casting is usually delayed until the peak effect of the toxin, about 2-4 weeks after injection, which produces superior results to immediate casting (J Pediatr Orthop, 2007)

NMES

- Reduce spasticity, Increase ROM & strength, Increase force production, Promote initial learning of selective motor control
- Short term NMES To muscles injected with BTX-A (-7days)
- Enhances the rate of uptake the toxin
- EST over the antagonist muscles ⇒ enhance function

Development of spasticity with age

No of BTX injections in CP : 547 children during 15 years



Number of treatments with BxA related to age at time of treatment in the total sample of children with CP

- Gunnar Hägglund and Philippe Wagner (2008)-

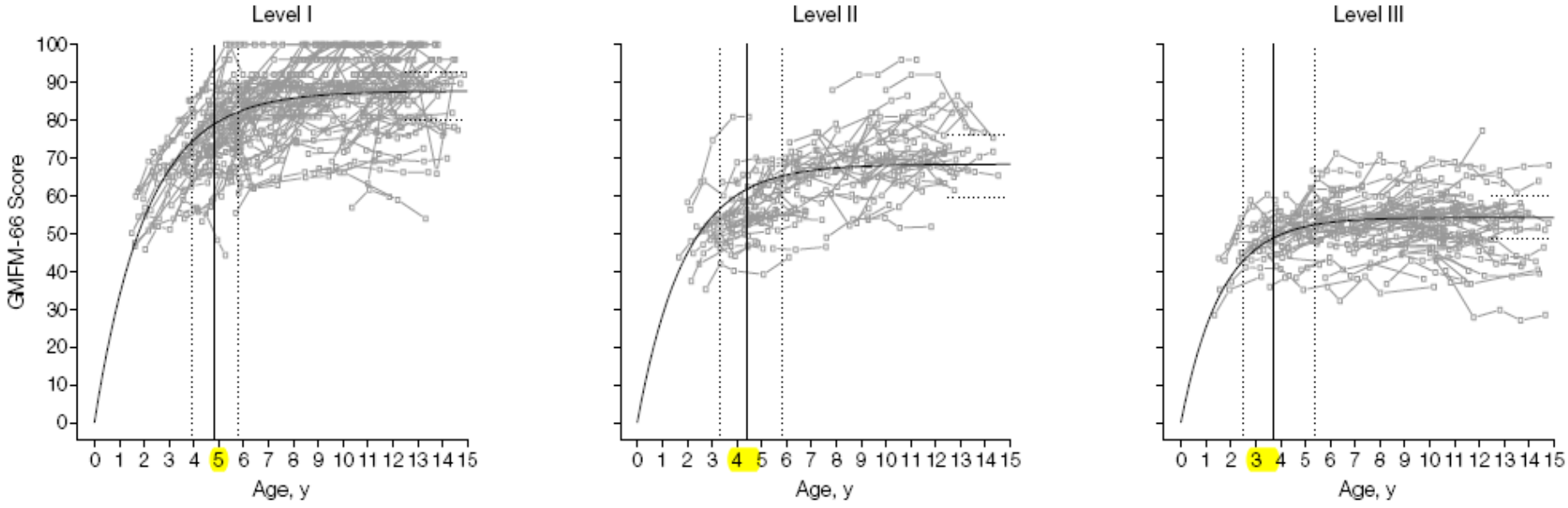
- Treatment Goal

i. Maximize function

ii. Delay/avoid surgery when possible

Orthopedic Surgery

Indications for Operative interventions



Average age of child attaining 90% of expected motor ability	
GMFCS Level	Age
I	5y 2mo
II	4y 11mo
III	3y 2mo

Typical Indications

1. Age: 7 – 10 years or after
2. Wait until child has plateaued for ~ 6 months, after gait maturation
3. Non-operative interventions will not suffice (ex. PT, BoTN, Bracing…)

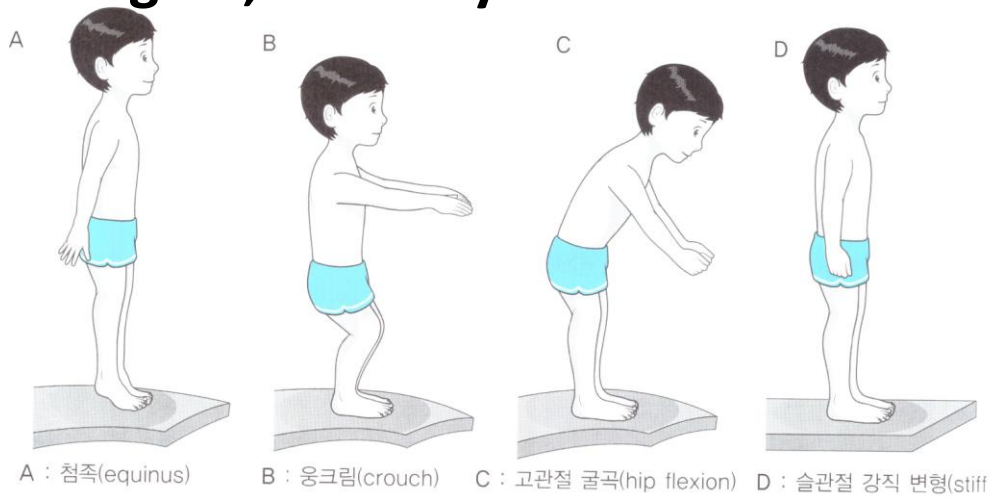
* If hip dislocation -> before age 6 years (uncommon in ambulatory CP in this early phase)

Aims of Orthopedic Surgery in Ambulatory CP

GMFCS I	GMFCS II	GMFCS III
• Improve Gait pattern • Mainly cosmetic reason • Energy and gait speed – no significant change	• Gait speed & energy consumption : improved	• Gait correction surgery and hip management

Orthopedic Surgery

❖ **Diving SD, Birthday SD**



❖ **SEMLS: Single event multi-level surgical procedure**

❖ **SMILE: Staged multi-level interventions in the LEx** (Sussman et al)

- Timing of surgery is determined by functional need
- Proper orthopedic surgery-> facilitates the development of functional motor skills
- Scissoring: adductor tenotomy in 1~2 yr-old
- But, equinus deformity, knee flexion contracture
  -> over-correction, recurrence risk -> wait until 6~7 yr-old

Orthopedic Surgery

Bony procedure

- Derotational Osteotomy: Femoral, Tibial
- Pelvic Osteotomies
- Distal Femoral Extension Osteotomy
- Calcaneal Lengthening Osteotomy, Other Various Foot Procedures
- Arthrodesis (severe case, fusing bones together)

Soft tissue procedure

- Muscle Lengthening: Psoas, Hamstring, Adductor, Gastrocnemius
- Tenotomy, Tendon lengthening
- Tendon Transfer: TP, TA, RF
- Patellar Tendon advancements

Hip problems

Hip flexion contractures

Static and dynamic measures are not well-correlated

- 50% with HFC > 10°, do not walk with excessive hip flexion (Rethlefsenet al. J Pediatr Orthop 2010)
- Main problem is crouch, though crouch is often seen in the absence of hip flexion contracture

Consider surgery (**psoas recession**) if HFC >10° and significant hip flexion in stance

Hip adduction contractures

Problem: Scissoring

- **Adductor longus** is typically tightest
- **Gracilis** often needs lengthening
- Brevis and magnus rarely need lengthening (esp. in GMFCS I-III)

Obturator neurectomy should be avoided (to avoid “frog” positioning of hips)

Knee problems

Stiff knee gait

Problem: swing phase peak knee flexion ↓, interferes with foot clearance in swing phase

Rectus femoris spasticity? **RF transfer** (peak knee Fl <50◦, EMG overactivity during swing, GMFCS I-II)

Knee flexion contractures

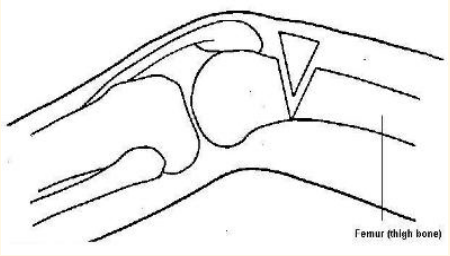
Problem: Crouch gait

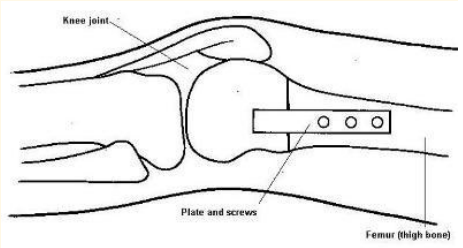
Hamstring lengthening (HSL)

- Avoid overlengthening (results in recurvatum and oftenin stiff knee gait)
- Recurvatum much more common with medial/lateral lengthening than isolated medial lengthening => minimal acute lengthening (Δ Popliteal angle 30 degrees)

Distal femoral extension osteotomy / FESO

- for more severe deformities
- Better results when combined with **PTA**





Ankle/Foot problems

Equinus

Avoid surgery whenever possible (by using stretching, braces, serial casting...)

- Heelcords are better a little tight than a little loose
- Calcaneus gait more common with age (even without previous surgery)
- Calcaneus reported in up to 30-40% of patients following heelcord surgery

  -> Rate much lower with **gastroc-soleus recession (GSR) than TAL**

Strayer technique

- Cut in the GCM is transverse and more proximal
- Not lengthen soleus

FIGURE 35-21 Distal recession of the gastrocnemius, Strayer technique.

Vulpius procedure

- Aponeurosis of the Gastroc-soleus is divided

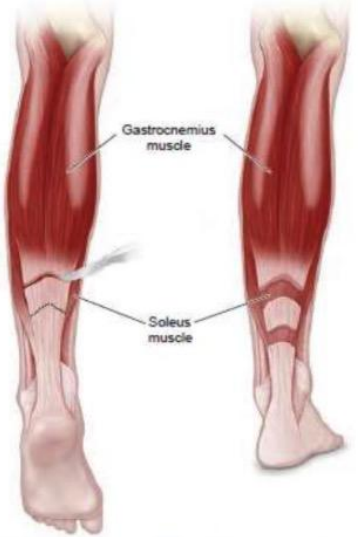


FIGURE 35-20 Lengthening of the gastrocnemius by the Vulpius technique.

Ankle/Foot problems

Varus

- Contributors: TA/ TP
  - ✓ **Anterior tibialis** ~ 1/3 of cases
  - ✓ **Posterior tibialis** ~ 1/3
  - ✓ **Anterior & Posterior tibialis** ~ 1/3
- Differentiate between flexible and rigid deformities
- Surgery: Balance soft tissues (Split TA transfer, Split TP transfer to PB, Tenotomy of TP)
  Bony surgery needed for rigid deformity (Dwyer osteotomy, triple arthrodesis –last choice)

Valgus

- Often associated with tight gastrocnemius and peroneals
- **Calcaneal osteotomies** help preserve hindfoot motion -> remained midfoot/forefoot supination: perform **medial column** plantarflexion osteotomy
- **Talonavicular fusion** may be needed for severe midfoot break

Lever arm Dysfunction

Femoral Derotational Osteotomy

- Comparable results for proximal and distal osteotomies
- Proximal osteotomy indicated if
  - Coxa valga, and/or
  - Hip subluxation

Tibial Derotational Osteotomy

- **Distal osteotomy** is much safer than proximal osteotomy
- Fibular osteotomy is **not** needed for rotational correction

Hip Subluxation, dislocation

- Soft tissue surgery + femoral varus osteotomy, pelvic osteotomy, Dega osteoomy, pericapsular acetabuloplasty
- Recession arthroplasty

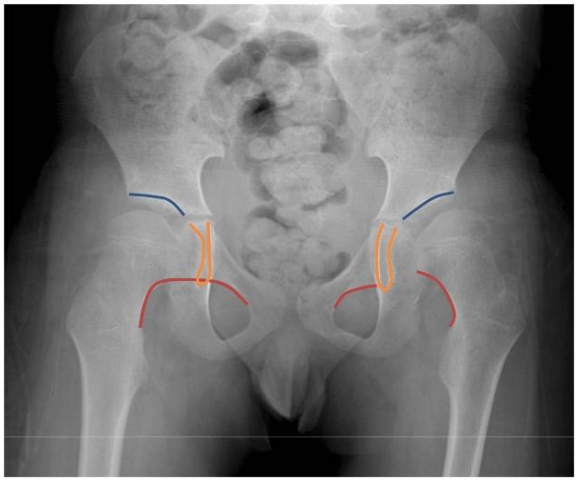
Hip Surveillance in Ambulatory CP

Clinical Assessment	Radiologic Assessment
• Hip pain • Hip Abduction ROM	• Pelvis AP • Migration Index

Hip Surveillance: When to Refer

- MI > 30% : increased risk of progressive displacement
- Hip pain, functional decline
- Hip abduction range < 30 degree

* MI: most reliable & quantitative



- Break in Shenton's Line
- Increased slope of acetabular roof
- Widened teardrop

Hip Surveillance in Ambulatory CP

Migration Index

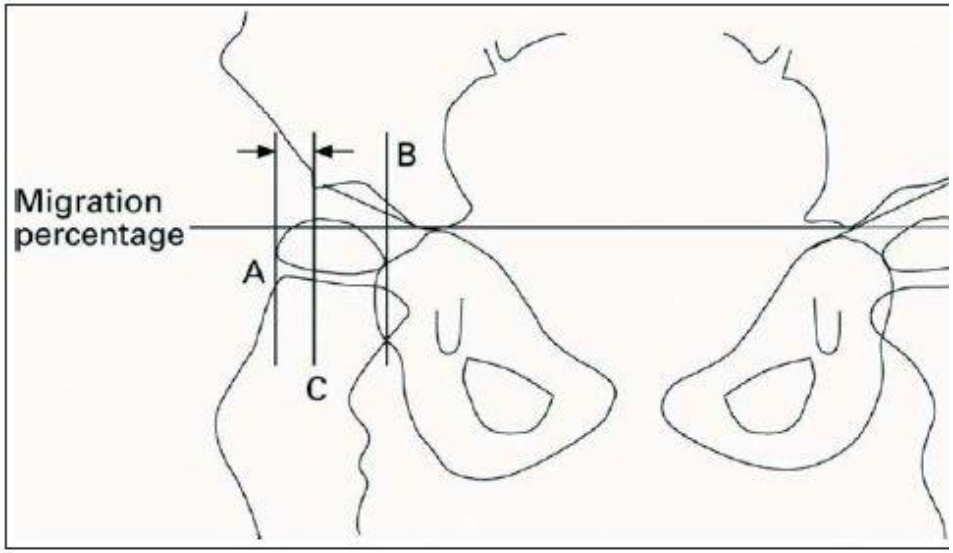


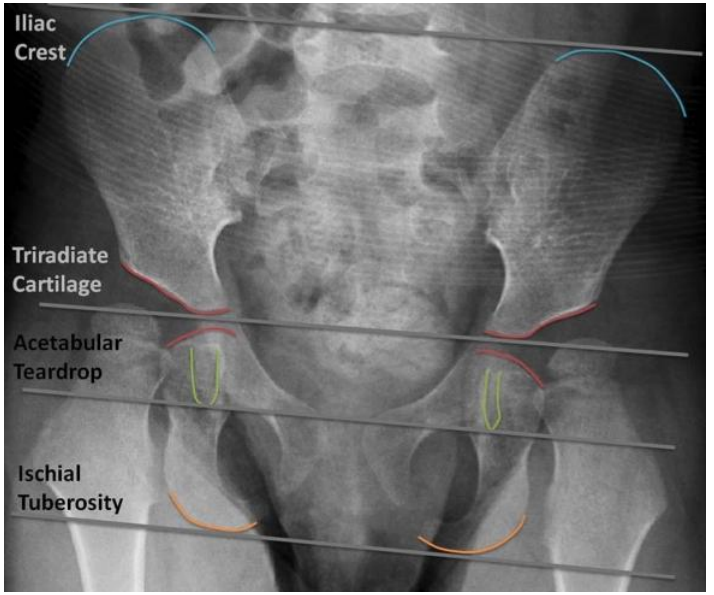
Fig 1. From Scrutton and Baird 1997. The RMI or migration percentage is the proportion (%) of t
capital epiphysis that appears to lie outside the acetabulum.

H-line (pelvis horizontal axis)

m/c landmark to use is the
Tri-Radiate Cartilage

Acetabular Sourcil

Radio-dense line of bone of the wt bearing portion of the acetabulum



Hip surveillance in ambulatory CP

New AACPDM guideline

- Discharge if skeletally mature and MP ≤30%
- Skeletal Maturity (SM) : closure of the triradiate cartilage

† In the presence of pelvic obliquity associated with clinical or radiographic evidence of increasing scoliosis, the hip /s continue to be at risk and should ideally be monitored even beyond skeletal maturity

Age (Years)	GMFCS I	GMFCS II	GMFCS III
2.0 years or at ID	#		
2.5			
3			
3.5			
4			
5			
6			
7			
8			*
9			
10			*
11			
12 to 16 or Skeletal Maturity (SM)			Bi-Annually to SM† / Bi-Annually to SM† *

*** Do not reduce from previous higher frequency if:**

(1) 24 months of surveillance have not yet been completed based on a child's surveillance start date;

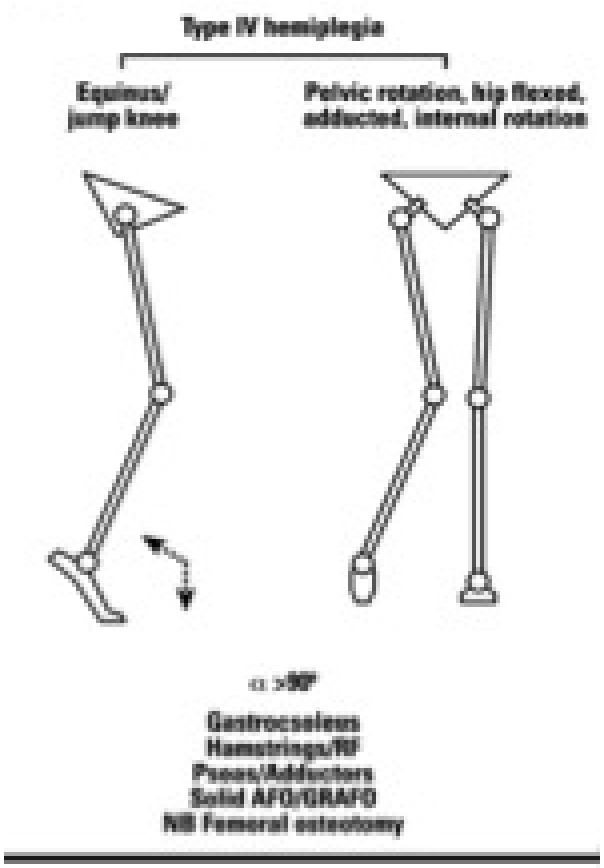
(2) stability is not yet achieved over a period of 2 years. Stability is defined as < 10% change in MP over a 12 month period;

OR
(3) MP > 30%.

Hip surveillance in ambulatory CP

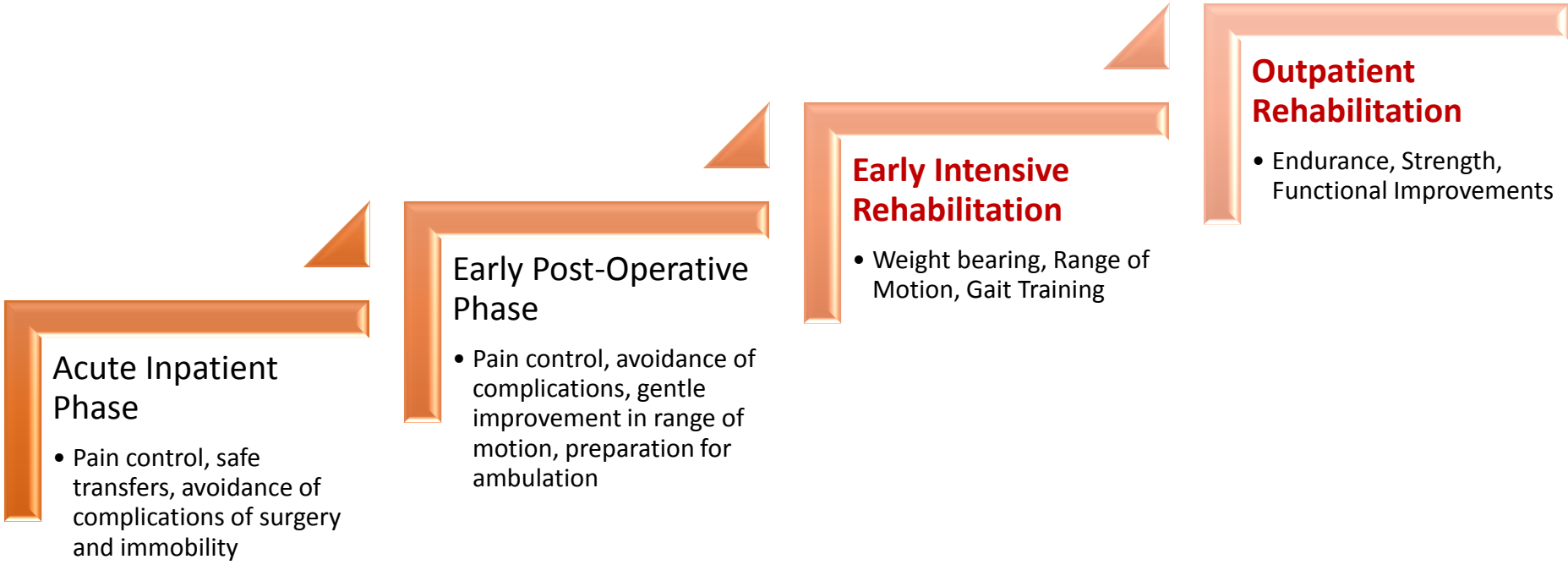
New AACPDM guideline

If child has hemiplegia, identify if WGH Gait Type IV
Any GMFCS Level with Winters Gage Hicks Gait Type IV



Age (Years)	Any GMFCS Level with Winters Gage Hicks Gait Type IV	
2.0 years or at ID		
2.5		
3		
3.5		
4		
5		
6		
7		
8		
9		
10		
11		
12 to 16 or Skeletal Maturity (SM)	Bi-Annually to SM†	Bi-Annually to SM†

Postop 4 Phases after SEMLS



Stages of Recovery After Surgery

- Healing of bone and soft tissues, prevention of post-op stiffness: approximately **6 weeks**
- Strengthening of muscles and regaining household mobility: approximately **12 weeks**
- Retraining of gait and continued strengthening/endurance: up to **12 months**

SEMLS

- The types and amounts of surgery vary by patient: GMFCS Level, goals, and severity of involvement

- Function, gait, and strength does not reach full recovery (pre-operative level) until 9-12 months post-operative
  - ✓ Harvey A, et al (2007)
  - ✓ Seniorou M, et al (2007)
  - ✓ Svehlik M, et al (2008)
  - ✓ Westwell M, et al (2009)

- Improvement continues 12-24 months following surgery and improvement was maintained for 5 years post-operatively.
  - ✓ Rodda JM, et al (2006)

Pre-operative Evaluation

Baseline Assessment

- GMFCS level
- Functional Mobility Scale (FMS)
- Pediatric Evaluation of Disability Inventory (PEDI)
- Pain
- ROM, Strength, Tone, SCALE, Cardiopulmonary Fx,
- Gait analysis : DDx - 1st/ 2nd/ compensatory mechanism of abnormal gait

GOAL Assessment

- COPM (Canadian Occupational Performance Measure): Self-care, productivity, Leisure
- GAS

✓ Clarification of goals (caregiver/patient, physician)
✓ Phase – inpatient rehab, outpatient PT, Long-term rehab

post-op prognosis
- Preop GMFCS level
(Godwin 2009, Harvey 2012, Rutz, Tirosh 2012)

Early Post-Operative Phase

Prevent stiffness during the period of immobilization

- Passive ROM exercise : manual or CPM
- CPM (Continuous Passive Motion)
  - 3 days post-op, 20-30 degree
  - then gradually increasing ROM. - 3wks, 70◦ (PTA/ FEO), 90 ◦ (RFT)
  - 3 set/ day

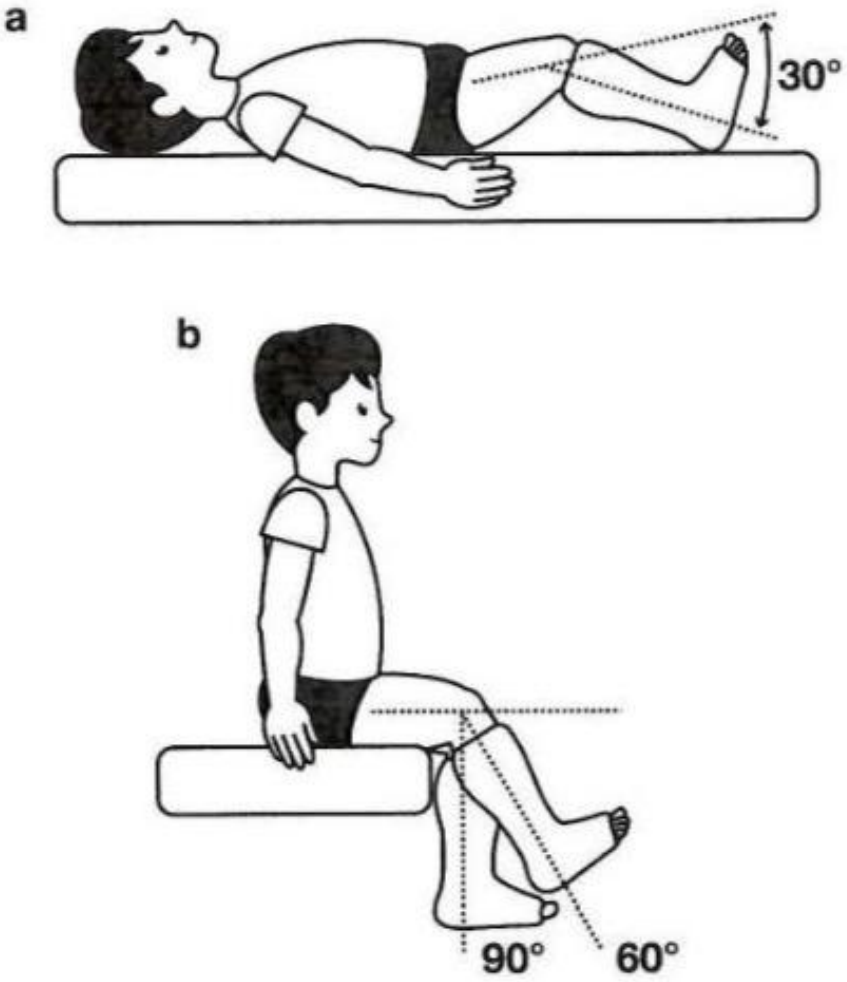


Figure 18.5 Early knee mobilization post rectus femoris transfer. Rectus femoris transfer requires early active and passive knee range of motion to prevent adhesions and scar formation. The goals are to achieve 30° knee flexion by end of week 1 (a), 60° by end of week 2 and 90° by the end of week 3 (b).

Early Post-Operative Phase

Prevent stiffness during the period of immobilization

- Passive ROM exercise : manual or CPM
- CPM (Continuous Passive Motion)
  - 3 days post-op, 20-30 degree
  - then gradually increasing ROM. - 3wks, 70◦ (PTA/ FEO), 90 ◦ (RFT)
  - 3 set/ day

Positioning

- Prone positioning: 50% of the time, beginning with 3x/day: FDO, Psoas Lengthening
- Casting, Knee immobilizers, Derotation bar

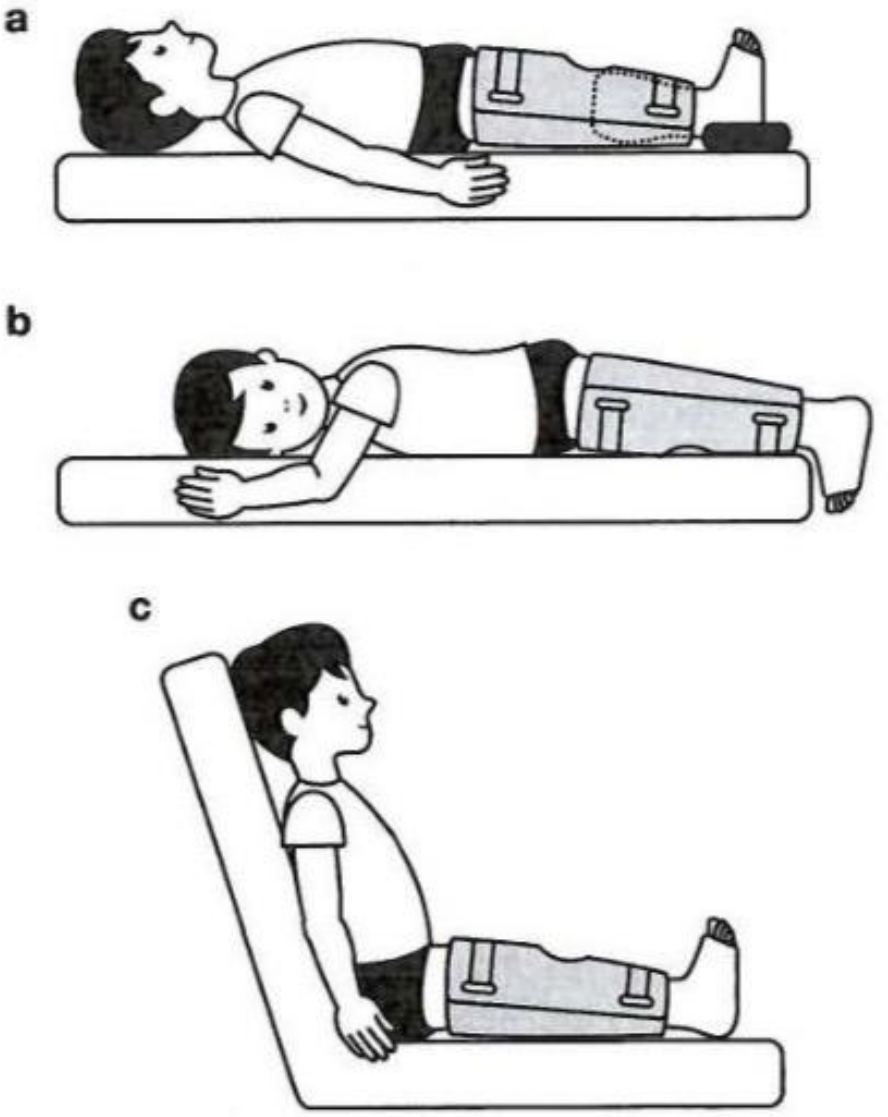


Figure 18.4 Post-operative positioning. Immediately after surgery, the lower limbs are maintained in neutral alignment by a combination of below-knee plaster casts, removable knee immobilizers, and sand bags (a) or pillows placed laterally, to prevent excessive external rotation. Early positioning in prone is important to maintain length in the iliopsoas (b). Progressive elevation of the bed is required to facilitate long sitting and an effective stretch in the lengthened hamstrings (c).

Early Post-Operative Phase : 3-6 weeks

PROM, AROM exercise : continue CPM if significant knee flexion limitation

Strengthening : proximal muscle (non-wt bearing strengthening)

Transfer/ Mobility: Pivot transfer, increase mat mobility as able

-> Partial Wt. bearing if possible

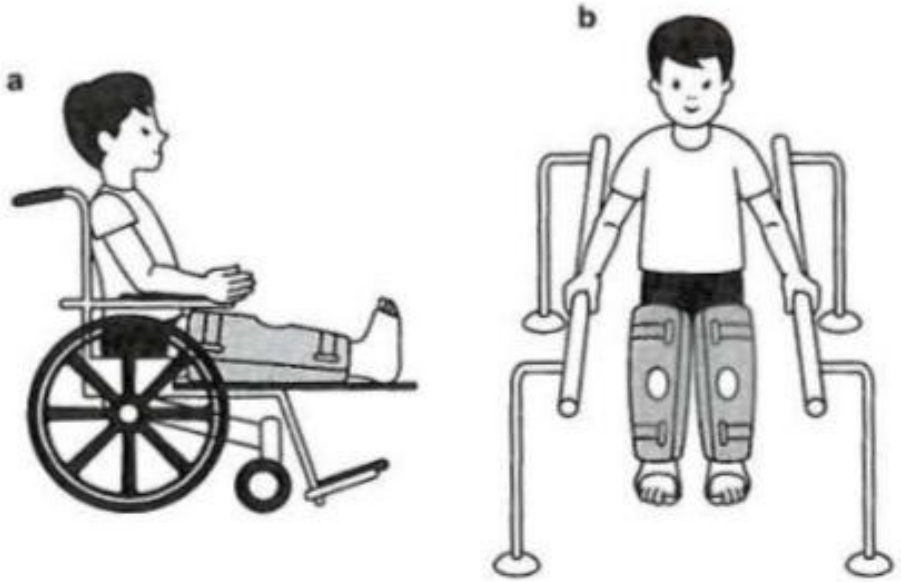
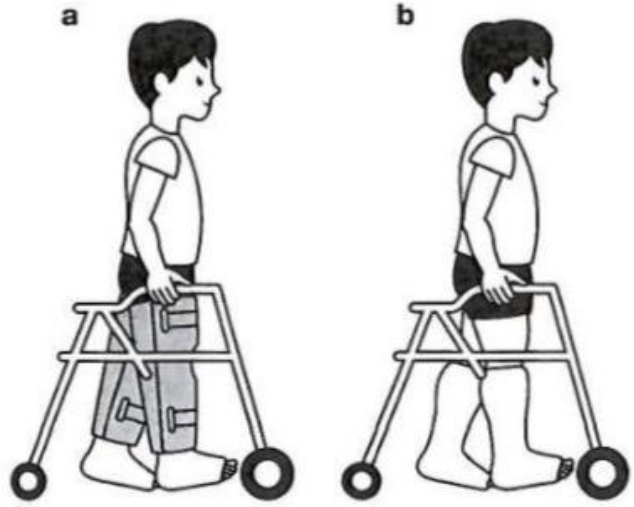


Figure 18.6 Preparation for discharge. The majority of children require a wheelchair with a board to elevate the lower limbs at the time of discharge (a). A trial of standing, in the Physiotherapy gym using parallel bars, and Zimmer knee immobilizers over the below knee casts (b) may be possible prior to discharge or soon afterwards.



Preop ambulatory, soft tissue surgery

Early Intensive Rehabilitation (After Cast Off)

GOAL: Focus on functional mobility and increasing tolerance to activity upon return to home and school settings
From: postop 6wks (Gillet) or 8wks-10wks
Length of inpatient rehab : 3-8 weeks

Intensive Rehabilitation program

- **Active ROM** and **Strengthening**
- **Mat mobility, Standing, Transfer** training
- **Gait training** (parallel bars, over-ground with AD, treadmill, partial weight support)
- Balance, Functional activity

- Orthosis if needed, Adaptive or stationary cycle, Pool Therapy
- Skin care/scar management
- Patient/caregiver education

Early Intensive Rehabilitation (After Cast Off)

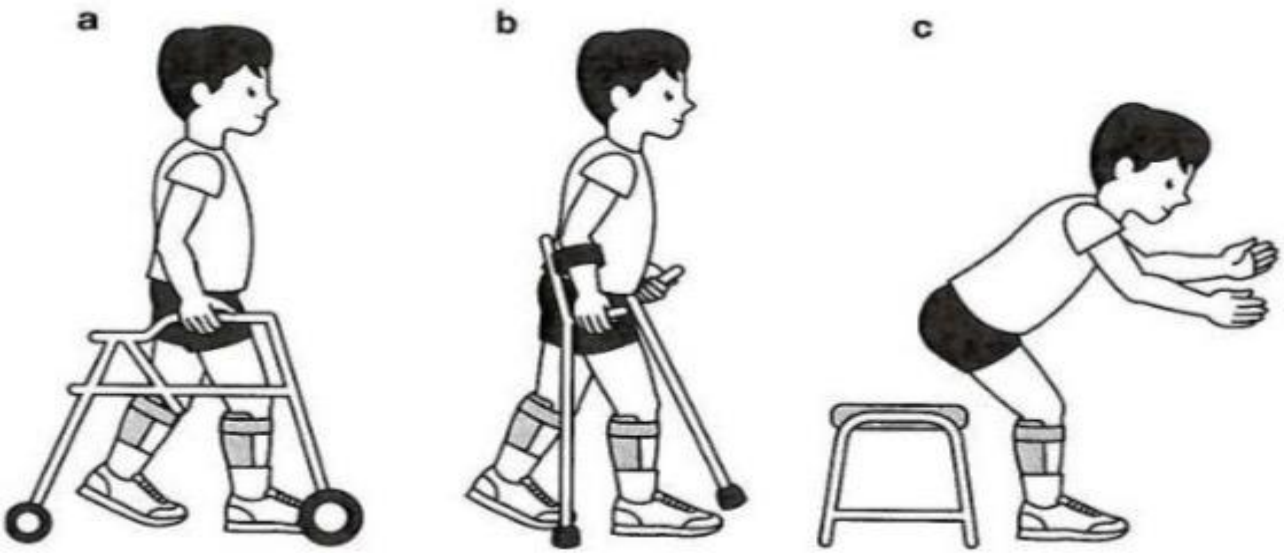


Figure 18.8 Rehabilitation progression 7–12 weeks. Children should rapidly progress from a posterior walker (a) to forearm crutches (b) and possibly to independent walking. GRAFOs or AFOs are worn for all weight-bearing activities (except in hydrotherapy). Strengthening and functional exercises progress in weight-bearing (c).

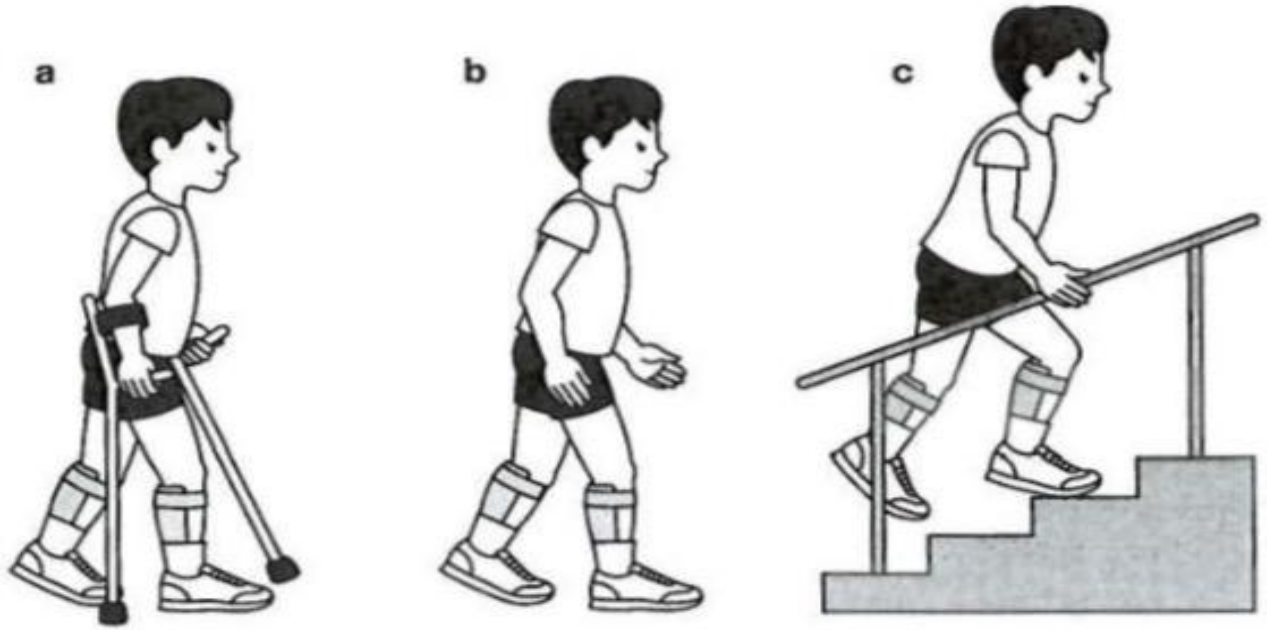


Figure 18.9 Rehabilitation progression 13–24 weeks. Progression of assistive devices to reduce dependence on wheelchairs and posterior walkers as quickly as possible, within the constraints of safety. Children should move to the use of forearm crutches (a) and independent walking (b) if possible. Children should be commencing more difficult functional tasks

Outpatient Rehabilitation

- ROM exercise: continue stretching exercise, Knee immobilizers at night
- Strengthening exercise: resistive strengthening
- Ambulation: by increasing distance and speed, endurance, balance, weaning or transition assistive devices - keep it challenging, high repetitions!

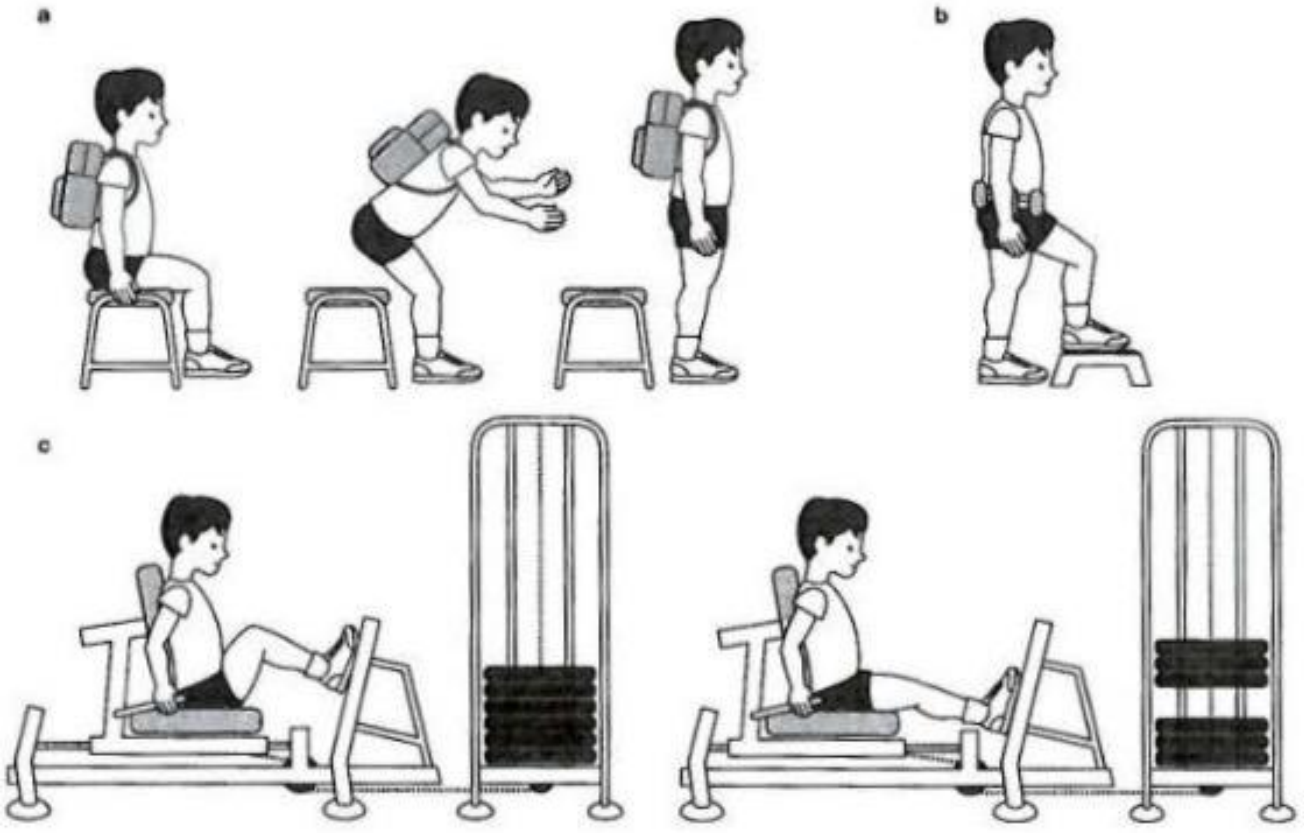


Figure 18.10 Rehabilitation progression 6–12 months. Progressive resistance strength training with functional activities (a, b) or with gym-based activities using a variety of standard equipment (c).

Medial/Lateral Hamstring Lengthening, Rectus Femoris Transfer, GSR/TAL without bony procedures

Phase	Casts/Immobilization	WB Status/Transfers	ROM/Strengthening	Functional Activities
1. **0 – 2 weeks** (Inpatient through first return to clinic visit)	• Short leg casts and knee immobilizers. *May have long leg casts if undergoing serial stretch casting (for 4-6 wks)*	• Non weight bearing • Dep lift, slide or scooting transfers to reclining w/c with elevating legrests • Stand pivot tx in case of unilateral surgery + excellent motor control	• No active or passive knee ROM permitted • Encourage AROM and gentle PROM trunk and UE's to prevent stiffness while on dec activity status	• Bed mobility, prone positioning, transfers • Up to w/c multiple times/day • Toileting with commode or bedpan; sponge bathing
2. **2-4 weeks post op** (Patient seen in clinic at 2 weeks post-op and at end of 4th wk)	• At 2 wks, short leg casts removed; pt molded for SAFOs & re-casted. • Knee immobilizers 23 hrs/day. Doff 2-3 time daily for gentle hip/knee ROM exercises and seated knee flexion	• Non weight bearing • Dep lift, slide or scooting transfers to reclining w/c with elevating legrests • Stand pivot tx in case of unilateral surgery + excellent motor control	• Active/Assisted hip and knee ROM when out of KIs 2-3 x/day • **For RFT – no AROM. PROM only** • Sit with knees flexed to comfort for approx. 15 min following ROM	• Bed mobility, prone positioning, transfers • Up to w/c multiple times/day • Toileting with commode or bedpan; sponge bathing
3. **5 weeks post-op** (IOTP at week 5: PT BID for 3-5 days)	• Casts removed; SAFOs fitted. • SAFOs 23 hours/day and for all WB activity. Breaks for hygiene, skin check/airing and AROM strengthening in NWB • Knee immobilizers at night and as needed during day (at discretion of PT) for support and to maintain knee ext ROM	• Begin WBAT in SAFOs • Stand pivot transfers with or without KIs, with walker or caregiver assistance as needed • Emphasis during IOTP is on greater patient participation and less caregiver assistance with transfers	• ROM and ther ex for strengthening. OK to doff SAFOs for AROM feet/ankles in non-weight bearing positions. • **No passive stretching** to surgically lengthened muscle groups. Emphasis on maintenance of ROM achieved in OR through bracing & AROM	• Pt now able to shower; skin care and desensitization • Mat mobility, standing, transfers & ambulation with SAFOs • Adaptive/stationary cycle • Emphasis on functional mob and ambulation needed for return to school
4. **6 – 12 weeks post-op** (Patient seen in clinic 4 weeks following IOTP)	• SAFOs for all WB activity • SAFOs and KI's at night	• WBAT in SAFOs for transfers and ambulation	• Patient continues strengthening in OP PT 2-3 x/week • **No passive stretching** to surgically lengthened muscle groups. Emphasis on maintenance of ROM achieved in OR through bracing & AROM	• Progress functional mob skills with least restrictive AD including ambulation, curbs, stairs, etc. • Pt should no longer be using wheelchair • When incisions fully healed, bathing, swimming ok
5. **3 – 12 months post-op** (Patient typically seen in clinic at 6, 9 and 12 months post op; scheduled for 1 yr post-op gait study in MAC)	• AFOs as needed to optimize gait; SAFO may be modified to PLSO during this period • Nighttime use of AFOs, KIs at PT/MD discretion	• Full weight bearing in SAFOs for transfers and ambulation • Depending on pt's progress, strength and control, MD may clear to begin WB & amb out of braces in physical therapy at 4 mos post-op	• Continued strengthening and AROM through ther ex and functional mobility in OP PT 1-2 x/wk • Emphasis on AROM vs passive stretch to surgically treated soft muscle groups • Closely monitor knee ext ROM in MHL, LHL kids	• Gradual return to pre-surgical mobility and activity levels • May return to previous activities incl swimming, horseback riding, etc. Running and jumping at MD/PT discretion • Encourage participation in regular community based recreational exercise and activity for lifelong wellness

Femoral Derotational Osteotomy, Tibial Rotational Osteotomy, Bony Foot/Ankle Procedures without Soft Tissue Surgery

Phase	Casts/Immobilization	WB Status/Transfers	ROM/Strengthening	Functional Activities
1. 0 – 3 weeks post-op (Inpatient through first return to clinic visit)	• Short leg casts for TRO, bony ankle/foot procedures • Typically no casting for FRO alone; may use hip abd pillow for comfort	• Non weight bearing on surgical extremities • Dep lift, slide or scooting transfers to reclining w/c with elevating legrests * • If procedure unilateral and pt with adequate motor control, may perform stand pivot txs	• Teach HEP for AROM and gentle PROM trunk, hips, UEs as appropriate for period of decreased mobility in early post-operative phase	• Bed mobility, prone positioning, transfers • Up to w/c multiple times/day • Toileting with toilet, commode or bedpan; sponge bathing
2. 3-6 weeks post-op (RTC at 3 weeks post-op and at end of 6th week)	• Casts removed at 3 weeks post-op for molding for SAFOs; pt is re-casted. • Casts removed at 6 weeks post op; x-rays to determine adequate healing for fitting with SAFOs	• As above • Pending adequate healing at 6 wk RTC visit, pt is cleared for WBAT in SAFOs and to begin IOTP following week	• HEP given for hip and knee A/AAROM and quads activation at 3 week post op RTC visit	• Bed mobility, prone positioning, transfers • Up to w/c multiple times/day • Toileting with toilet, commode or bedpan; sponge bathing
3. 7 weeks post-op (IOTP pending adequate healing and MD clearance)	• In case of TRO and bony ankle/foot procedures, pt in new SAFOs. If FRO only, pt may return to former brace use as indicated. • SAFOs to be worn 23 hours/day & for all WB activity. Breaks for hygiene, skin check/airing, AROM	• May begin WBAT in appropriate braces • Stand pivot or stepping transfers; emphasis during IOTP is on greater patient participation and less caregiver assistance with transfers	• AROM and ther ex for functional strengthening. OK to doff SAFOs for AROM feet/ankles in non-weight bearing positions. • HEP for trunk/core, hip and LE strengthening	• Mat mobility, transfers and gait training with appropriate assistive device. • Stairs, treadmill, adaptive or stationary cycling. • Emphasis on functional mob needed for return to school
4. 3 – 4 mos post-op (Pt seen in clinic 4 weeks following IOTP)	• In case of bony ankle/foot procedures, SAFOs for all WB activities and at night	• Full WB in appropriate braces • Pt should be returning to pre-op transfer methods	• Continued ROM and ther ex for strengthening in OP PT typically 2-3x/wk	• Progression of gait and functional mobility skills with least restrictive AD • Stairs, adaptive or stationary cycling. • Limited use of rental wheelchair
5. 6 – 12 months post-op (Pt is seen in clinic at 6, 9 and 12 months post-op; scheduled for 1 year post-op gait study)	• AFOs as needed to optimize gait; SAFO may be modified to PLSO or other during this period • Nighttime use of AFOs discontinued at MD discretion	• Full WB. Pt's ability to WB out of AFOs determined by MD based upon healing and motor control	• Patient continues functional strengthening in OP PT 1-2 x/week and with HEP	• Gradual return to pre-surgical mobility and activity levels. Running, jumping and sports participation at MD discretion • Encourage participation in community based recreation and fitness activities • Pt should no longer be using rental wheelchair

Distal Femoral Extension Osteotomy with Patellar Tendon Advancement (FESO with PTA)

Phase	Casts/Immobilization	WB Status/Transfers	ROM/Strengthening	Functional Activities
1. 0-6 weeks Post-Op (Inpatient → early post-op phase; Pt RTC at 3 wks post-op)	• Knee immobilizer	• Non weight bearing • Dep lift, slide or scooting transfers to reclining w/c with elevating legrests	• No active or passive knee ROM permitted • May perform isometric quads with KI in situ beginning post-op wk 3 • Encourage AROM and gentle PROM trunk, UE's, hips and feet/ankles	• Bed mobility, prone positioning, transfers • Up to w/c multiple times/day • Toileting with commode or bedpan; sponge bathing
2. 7 weeks post-op (IOTP given adequate healing and clearance by MD)	• Pt placed in hinged knee brace set from 0-30 degrees. • Brace locked in full knee extension overnight and initially for all WB activity	• May begin WBAT, initially with brace locked in ext; progress to unlocking within allowable range under PT supervision • Stand pivot or stepping transfers with necessary AD and PT assistance	• PT BID for A/AAROM and strengthening in brace within allowable range under PT supervision. No > 30° knee flex permitted • HEP for trunk, hip and LE strengthening	• Standing, transfers & amb with brace initially locked in ext; unlocked w/in allowable range per PT approval & with appropriate AD. • Emphasis on functional mob needed for return to school
3. 8 – 12 weeks post-op (Pt seen in clinic at 12 wks post-op)	• At 10 weeks post-op, brace may be progressed to 0-60 degrees; At 12 weeks post-op, brace progressed to 0-90 degrees both under PT supervision • Brace locked in full knee extension overnight	• Full WB in knee brace; unlocked given adequate quads strength and control • Pt should be returning to pre-op transfer method	• AROM and progressive strengthening in brace within allowable range under PT supervision • OP PT 2-3 x/wk • HEP for trunk, hip and LE strengthening	• Progress functional mob skills in hinged knee brace and with least restrictive AD including amb, curbs, stairs, etc. • At 12 weeks, if quads strength is ≥ 4/5, Pt may begin gait training out of brace with PT in controlled environment; cont use of knee brace 0 – 90 for all other ambulation
4. 3 – 6 months post-op	• At around 4 months post-op, MD will determine at RTC appt if knee brace may be discontinued. • Pt may still like support of hinged or off the shelf knee brace for school or periods of inc activity and ambulation	• Full WB • Transfers as performed pre-op	• Gradual return to full knee ROM with functional activities and mobility (no aggressive PROM) • OP PT 1-2 x/wk	• Gradual return to pre-surgical ambulation and functional mobility levels with prescribed bracing and least restrictive AD • Pt should no longer be using rental wheelchair
5. 6–12 months post-op (Pt seen in clinic at ~6, 9 and 12 months post-op; scheduled for 1 yr post-op gait study)	• Typically no brace required	• Full WB • Transfers as performed pre-op	• Full AROM • OP PT ≤ 1x/wk	• Pre-op or greater tolerance for ambulation and activity • Encourage participation in community based recreational exercise and fitness activities

Varus Derotational Osteotomy with DEGA Osteotomy

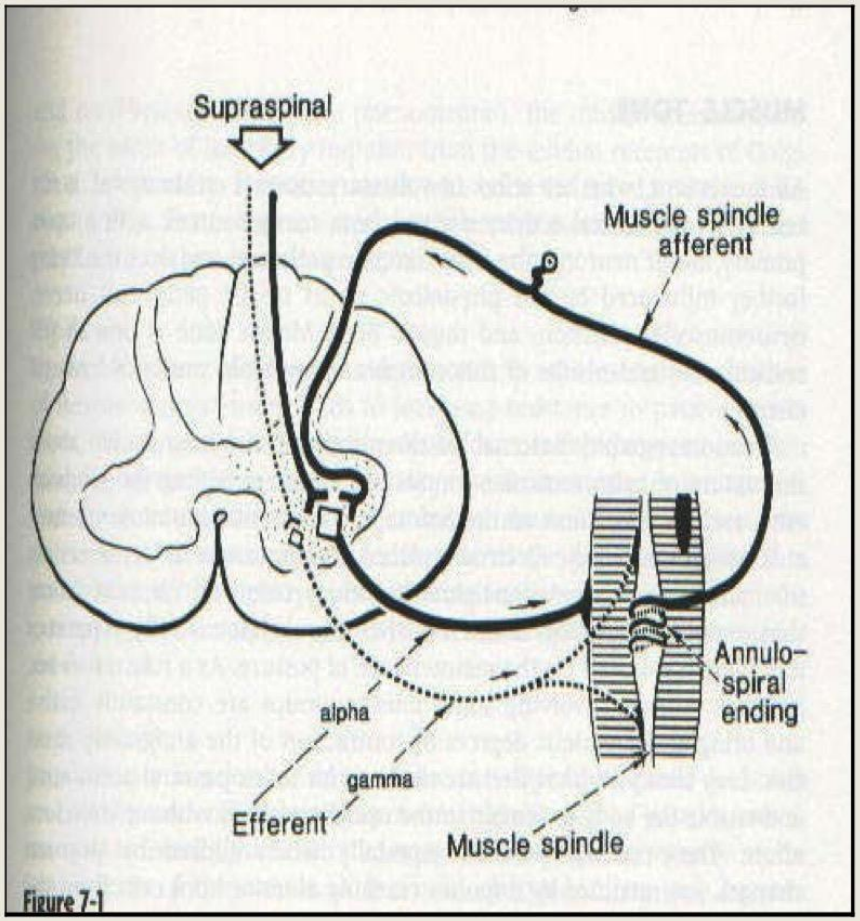
Phase	Casts/Immobilization	WB Status/Transfers	ROM/Strengthening	Functional Activities
1. 0 – 6 weeks post-op (Inpatient through early post-op phase; pt seen in clinic at 3 and 6 weeks post-op)	• Hip abduction wedge at all times (see: Care of Child with Hip ABD Pillow handout)	• Non weight bearing • Dep lift or slide transfers to rental reclining w/c with elevating legrests • Pt unlikely to be able to use personal wheelchair; may need EZ on vest for car transport home	• No hip flexion > 30° • Hip abd no less than 30° • Encourage gentle AA/PROM UE's in bed as tolerated	• Bed mobility, transfers • Up to rental w/c daily as tolerated (Pt unlikely to be able to use own wheelchair due to hip flexion restrictions and width of hip abd wedge). • Hygiene and sponge bathing in bed
2. 6 - 7 weeks post-op (Pt seen in clinic at end of post-op week 6; IOTP at week 7 for GMFCS I-III; return to (OP or school based PT as previously for IV –V)	• Given adequate bony healing, may discontinue use of hip abduction wedge during the day and use for naps and overnight as desired for pt comfort	• Given adequate healing, pt may begin WBAT with PT (GMFCS I – III), or return to sitting in personal w/c as tolerated (GMFCS IV and V)	• Gentle P/AROM as tolerated to achieve ROM needed for functional activities and use of positioning equipment	• Bed mobility, transfers, prone positioning as tolerated. • Resume use of previous seating system; referral for chair adjustments may be needed • Patient may resume showering
3. 8 – 12 weeks post-op (Pt RTC schedule determined by function and activity level; if IOTP, will be seen a 4 weeks post-IOTP)	• Hip abduction wedge for naps and overnight as desired for pt comfort	• WBAT; work towards transfers as performed pre-op	• As above	• Bed mobility, transfers, prone positioning • Return to use of own wheelchair • Return to use of previous equipment including standers, gait trainers, AFOs etc
6. 3 – 12 months post-op	• No positioning or mobility restrictions	• WBAT • Transfers as performed pre-op	• Patient should have full hip AAROM • Hip ROM should allow comfortable positioning in wheelchair	• Pt should be back to use of own wheelchair full time • Resuming transfers, standing and gait training as preop • Pt should be back to pre-op positioning and activity levels with less discomfort and better tolerance of functional positioning.

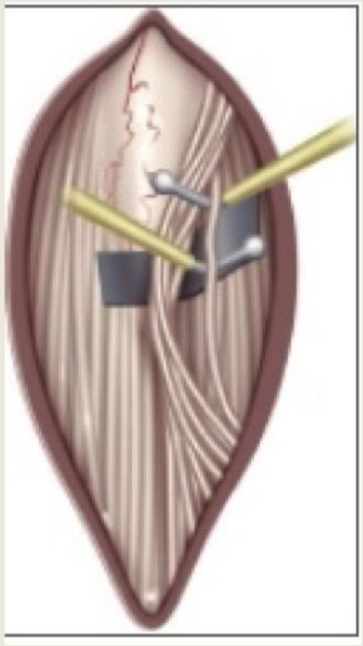
Neurosurgery

- SDR / ITB -

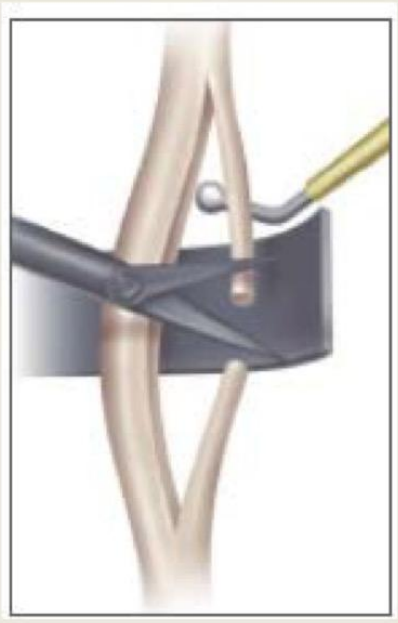
Selective Dorsal Rhizotomy

Dorsal spinal cord roots are selectively cut
→ Interrupts the reflex arc, decreasing spasticity





The innervation pattern of each dorsal root is examined with EMG



A rootlet is sectioned.

History of Selective Dorsal Rhizotomy

Foerster (1913)

- total sections of posterior nerve roots
- L2, L3, L5, S1 with sparing of L4

Gros (1960)

- partial dorsal rhizotomies, with nonselective sectioning
- **80%** of each of the nerve roots **from L1 to S1**

Fasano (1978)

- EMG selection of the posterior rootlets
- basis of the functional electrophysiological results of intraoperative electrical stimulation

Peacock Arens (1982)

- **Laminectomies, laminoplasty extending from L1 or L2 to the sacrum**
- m/c procedure

TS Park (1991)

- **L1 or L1 with upper L2** laminectomies (**single level laminectomy**)
- **Posterior root : From L1/2 to S 1**
- Fast recovery / Spinal stenosis, Scoliosis, Kyphosis, Hyperlordosis risk ↓

Selective Dorsal Rhizotomy

Table 27–1 Indications for Selective Dorsal Rhizotomy for Spastic Cerebral Palsy

Children Younger than 18 Years
At least 2 years of age
Diagnosis of spastic diplegia or spastic quadriplegia
Some form of independent mobility (e.g., crawling or walking) with or without an assistive device
History of premature birth; if born at term, child must have typical signs of spastic diplegia
Patients exhibit potential for improvement in functional skills after dorsal rhizotomy
Adults between Ages 19 and 40 Years
Diagnosis of spastic diplegia
History of premature birth
Currently ambulates independently without assistive device
Relatively mild fixed orthopaedic deformities
Patients exhibit potential for functional gains after dorsal rhizotomy
Patients exhibit motivation to perform home exercise program

Ideal Candidate

- has good strength in the lower extremities
- has **good trunk strength**
- has **not** developed fixed contractures and whose alteration of tone will lead to the desired improvements in function
- Age: 2-6 / 4-7 (RCH) / 3-12 years old
- Spastic diplegia who has potential of **ambulatory function (GMFCS II-III).**

Not recommended for

- Mixed CP with dyskinetic feature
- Severe neuronal migration disorder
- Severe spine deformities
- Severe HIE

Rehabilitation from SDR

Early recovery from single-level laminotomy SDR is usually fast

Acute Phase PT

- Start: day 3 – 4 post SDR
- Duration: 3 weeks inpatient rehab
- GMFCS II : typically regain some degree of walking within 3 weeks
- **Reduced sensory feedback** → limits the ability to maintain movement control , rather than post-surgical weakness

Intensive PT

- Post-SDR 3-6 month : most rapid gains usually occur
- PT: movement control, resistance strengthening, fitness, and endurance

Reduction in spasticity produced by SDR → may unmask

✓ dyskinesia → Trihexyphenidyl, BTX?

✓ uncover deficits in strength

✓ selective motor control

Outcomes of Selective Dorsal Rhizotomy

Long-term functional outcome after selective posterior rhizotomy

Mittal et al. (J Neurosurgery, 2002)

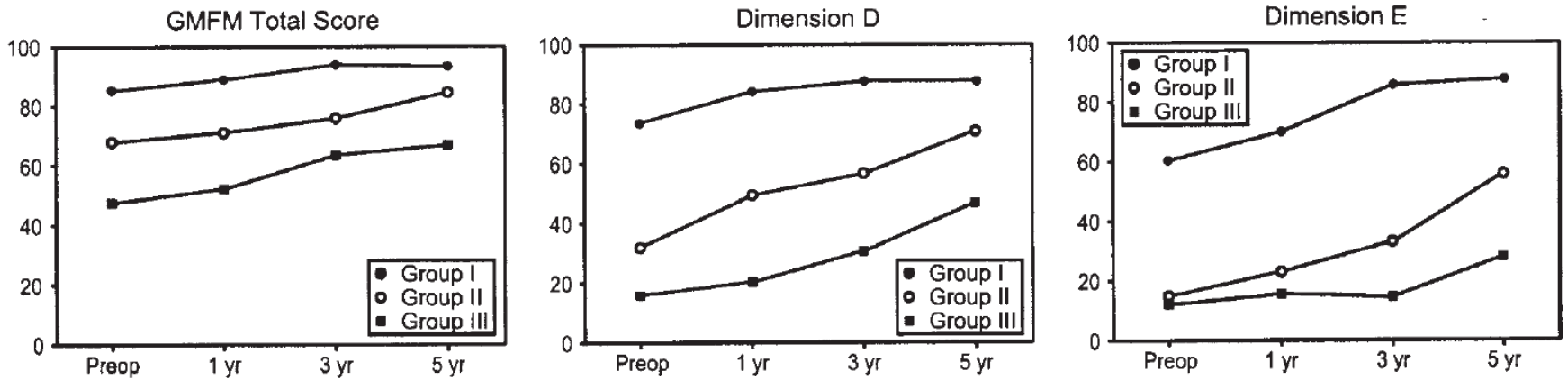


FIG. 5. Line plots comparing GMFM total scores *(left)*, dimension D *(center)*, and dimension E *(right)* between the patients in the study according to the preoperative level of functioning. Patients were subdivided into five groups according to their preoperative locomotive abilities. Dimensions D and E primarily relate to lower-extremity motor function and are the primary outcome measures of the GMFM.

Effect of selective dorsal rhizotomy in the treatment of children with cerebral palsy

Engsberg et al. (J Neurosurgery, 2006)

*Linear data scores measured in SDR-PT, PT-only, and ND groups**

Linear Data Variable	SDR-PT Group (29 children)			PT-Only Group (36 children)			ND Group (39 children)
	Preop	Postop (8 mos)	Postop (20 mos)	Pre-PT	Post-PT (8 mos)	Post-PT (20 mos)	
gait speed (cm/sec)†	81 ± 22‡	91 ± 25	101 ± 24§	91 ± 26‡	90 ± 22	93 ± 22‡	113 ± 18
stride length (cm)	79 ± 21‡	90 ± 22	96 ± 17§	85 ± 21‡	88 ± 18	90 ± 19‡	110 ± 21
cadence (steps/min)	122 ± 26	122 ± 28	126 ± 27	129 ± 25	124 ± 24	124 ± 21	124 ± 14

Outcomes of Selective Dorsal Rhizotomy

- Transition from walkers to crutches or a cane after SDR surgery
- Follow-up studies have shown greater mobility 5 to 10 years after SDR
- **Long-term improvement in muscle tone 10 to 15 years** after the operation

- Complication rates are generally less than 1 percent
  (Bolster EA et al.; Josenby AL et al.; Langerak NG et al.)

- Reduction in strength following SDR has historically been a concern, although more recent studies have not found objective loss of strength

Orthopedic surgery after SDR

1) SDR reduces orthopedic surgery requirements when compared with historical controls

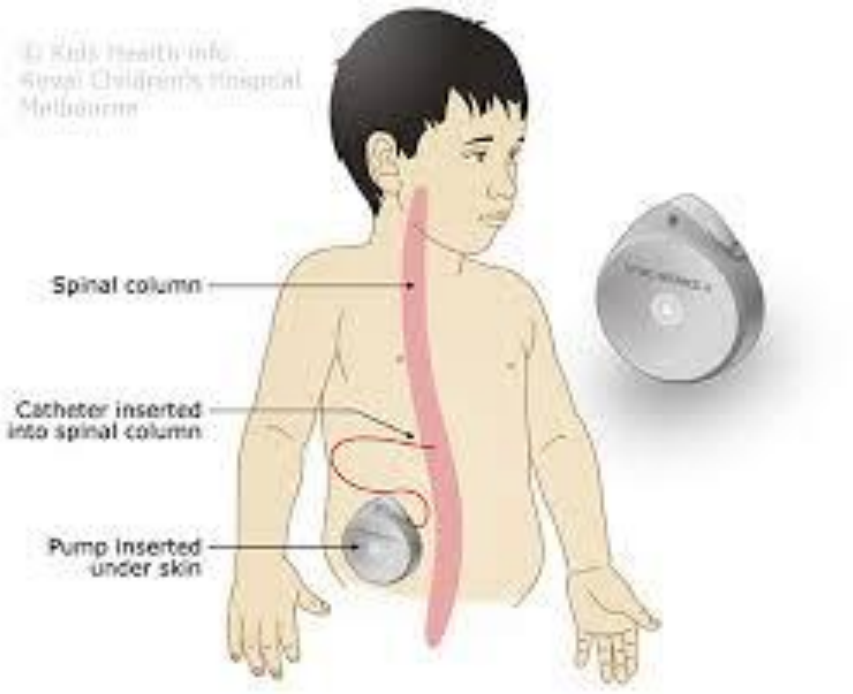
2) SDR performed in patients at a young age **(2–4 years)** can reduce future orthopedic surgery requirements

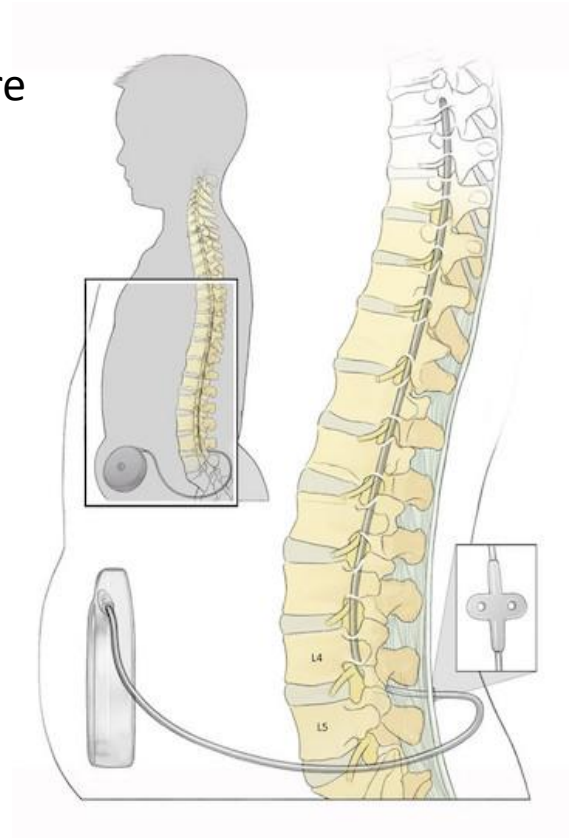
3) independent walkers and diplegic patients will have the smallest amount of orthopedic surgery post-SDR

Intrathecal Baclofen Therapy (ITB)

Pump implanted in the abdomen delivers baclofen directly into the cerebrospinal fluid (CSF), via a catheter inserted into the spinal canal

- Greater effect using very small doses (mcg), decreased sedating side effects
- Indicated for **severe spasticity (non-ambulatory**>ambulatory CP)
- Pump replace every 7 years, Refills every 6 months
- Trial to predict effect: screening test via lumbar puncture





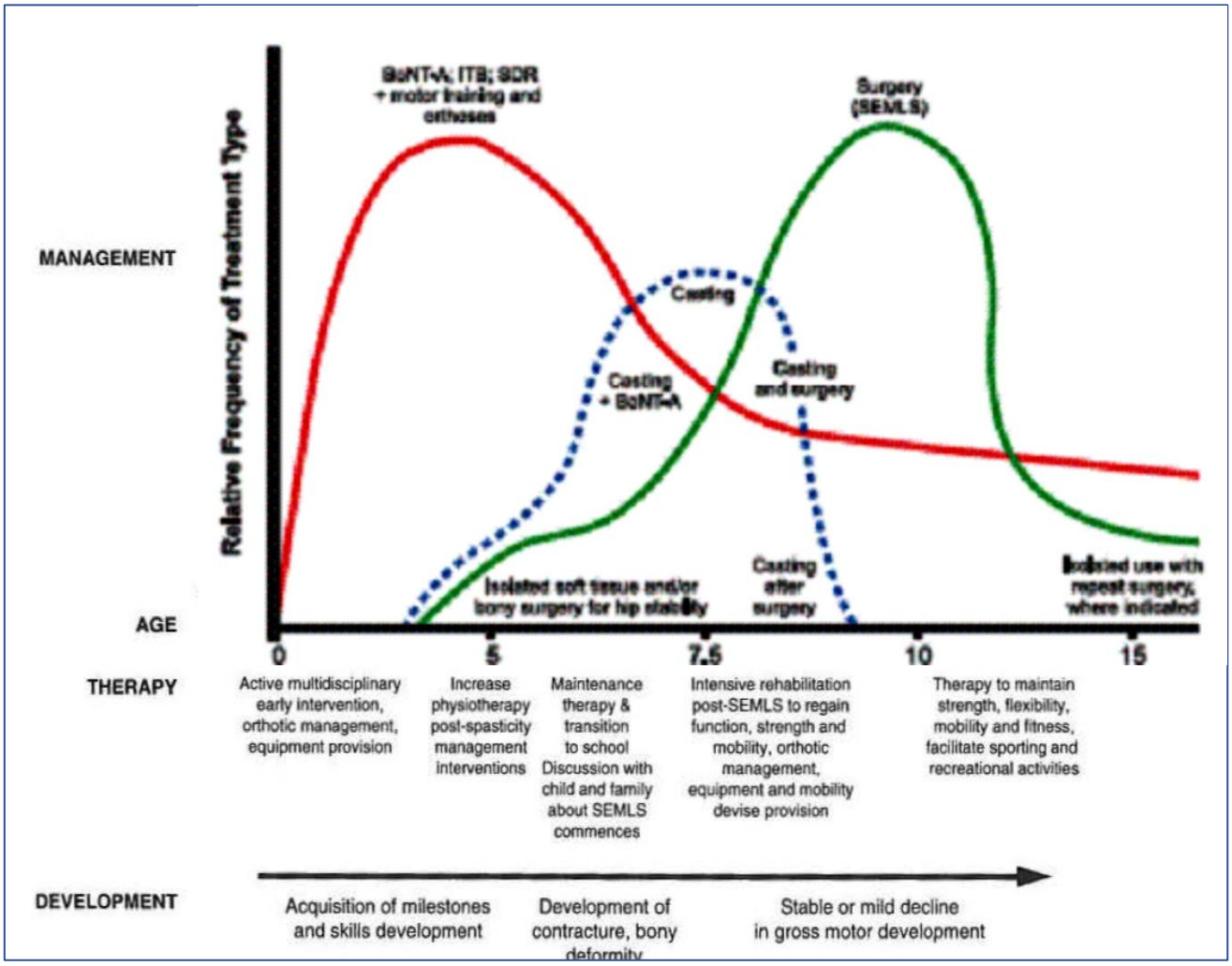
There are no studies in which these two treatment (SDR/ITB) modalities are compared in bilateral spastic CP => consider postop care & cost (ITB: reversible, but require re-op, refill)

Summary - Treatment principles

- CP is non-progressive, the deformities are progressive

- Deformities typically become worse during times of rapid growth

- Operative or nonoperative treatment should be done to minimize the impact it has on the patient's socialization and education



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