USE OF GAIT ANALYSIS IN SURGICAL TREATMENT PLANNING FOR PATIENTS WITH CEREBRAL PALSY

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GAIT ANALYSIS
I. General
   a. Objective
   b. Multilevel and multiplanar

II. Impact
   a. Improved problem identification
   b. Recommendations vary based on threshold for recommending interventions (e.g. rotational osteotomies)
   c. Facilitates planning for SEMLS (single event multilevel surgery)

III. Outcomes
   a. Decreased reoperation rate
   b. Improved outcomes if data are utilized

TOE WALKING
I. Main causes
   a. Ankle equinus
   b. Knee flexion

II. Equinus
   a. Reported in 61% of children with CP presenting to gait lab
   b. Observers tend to overestimate equinus visually (i.e. we tend to “see” equinus which is not truly present, which can lead to unnecessary/harmful surgery without gait analysis)
   c. Poor correlation between static equinus contracture and ankle dorsiflexion in stance
      i. People with contractures can “stretch them out” under body weight
      ii. Others without contractures can have significant dynamic equinus
   d. Important to make sure:
      i. Whether equinus is dynamic or due to static contracture
      ii. Be sure that toe-walking is due to equinus and not due to knee and/or hip flexion (Toe-walking in AFO’s is a tip-off that knee/hip are problems)
   e. Avoid surgery whenever possible (by using stretching, braces, serial casting...)
      i. Heelcords are better a little tight than a little loose
      ii. Calcaneus reported in up to 30-36% of patients following Achilles lengthening surgery
   f. Surgery
      i. Silfverskiöld test to determine whether both soleus and gastrocnemius are both tight
         1. If cannot dorsiflex adequately with knee flexed, then soleus is also tight

⇒ PEARLS: 1. Toe-walking in AFO’s implicates the hamstrings (and/or hip flexors). 2. Heelcords are better a little too tight than too loose. 3. Excessive dorsiflexion is common after heelcord surgery.
**PES VARUS**

I. General
   a. Compromises stability in stance
   b. Common gait deviation in CP
      i. Much more common in unilateral CP

II. Contributors
   a. Anterior tibialis ~ 1/3 of cases
   b. Posterior tibialis ~ 1/3
   c. Anterior & Posterior tibialis ~ 1/3
      i. Differentiate between flexible and rigid deformities
      ii. Surgery
         1. Balance soft tissues
         2. Bony surgery also needed for rigid deformity

III. Surgery
   a. Soft tissue
      i. Anterior tibialis: Split anterior tibial tendon transfer (SPLATT)
      ii. Posterior tibialis: Split transfer or lengthening
   b. Osseous (if deformity rigid)
      i. Calcaneal osteotomy (Dwyer)

⇒ **PEARLS:** 1. Anterior tibialis is a significant contributor to varus feet in children with CP, contrary to traditional teaching. 2. Soft tissues need to be balanced to minimize the risk of recurrence. 3. Calcaneal osteotomy needed for rigid deformity.

**LEVER ARM DYSFUNCTION**

I. General
   a. Moment = Force x Distance ("**Lever arm**" is the perpendicular distance from force to the center of rotation)
   b. Lever arm dysfunction can be caused by a number of abnormalities (e.g. a short lever, non-rigid lever, malrotated lever...)


c. Lever arm is not a significant problem in typically developing children due to typical balance, strength and coordination

II. Examples in CP
   a. GRF ends up behind knee in children with CP due to crouch and lever arm dysfunction
      i. Long bone torsion
      ii. Pes valgus
   b. Short lever for hip abductors
   c. Unstable fulcrum for hip abductors due to subluxating hip

III. Treatment
   a. Restore lever arms to maximize function in children with CP
      i. Operative – long bone osteotomies, pes valgus correction, hip stabilization
      ii. Non-operative – braces in pes valgus

⇒PEARL: Bony malignment is more problematic in children with CP (or other neuromuscular disorders) due to limitations in balance, strength and coordination.

INTOEING
I. General
   a. Results in lever arm dysfunction
   b. Causes in CP
      i. Femoral torsion
      ii. Tibial torsion
      iii. Varus foot – common in bilateral, rare in unilateral CP
      iv. Internal pelvic rotation
      v. Metatarsus adductus

II. Gait analysis
   a. Look at both knee progression angle (KPA) and foot progression angle (FPA)
   b. If KPA is internal, there is a problem above the knee (hip and/or pelvic internal rotation)
c. If KPA is neutral, hip rotation is likely OK, though sometimes may be neutral if pelvic rotation and hip rotation are in opposite directions.
d. If FPA is more internal than KPA, there is a problem below the knee (usually tibial torsion and/or varus foot).

III. Treatment
a. Non-operative
   i. Twister cables, etc. do NOT change natural history of transverse plane alignment of the legs
      1. Twister cables can “buy time” while awaiting surgery
b. Operative
   i. Long bone osteotomy
      1. Femoral osteotomy
         a. Comparable results for proximal and distal osteotomies
            i. Distal osteotomy
               1. Smaller incision
               2. Less dissection
               3. Can remove pins in office 1 month post-op
            ii. Proximal osteotomy
               1. indicated for hip subluxation or skeletal maturity
               2. More rigid fixation, but later surgery to remove plate
      ii. Tibial osteotomy
         1. Distal osteotomy is much safer than proximal osteotomy
            a. Can remove pins in office 3-4 weeks post-op
         2. Fibular osteotomy is almost never needed for rotational osteotomy
         3. Surgical correction should be 1:1 of what is deemed necessary clinically.
   iii. Varus foot correction (see “pes varus” section)

⇒PEARLS: 1. Femoral osteotomies have comparable results when done proximally or distally, whereas tibial osteotomies are best done distally. 2. Surgical correction should be 1.5 – 2:1 for femoral osteotomies and 1:1 for tibial osteotomies.

CROUCH GAIT
I. General
   a. Common in CP
   b. Frequency increases with age
II. Treatment
   a. Non-operative
      i. Hamstring stretching/Quad strengthening
      ii. Knee immobilizers
      iii. Botulinum toxin (typically combine with knee immobilizers at night)
b. Operative contracture/knee contractures
   i. Surgery
      1. Hamstring lengthening
         a. Avoid overlengthening (results in recurvatum and stiff-knee in swing and is hard to overcome)
         b. Recurvatum more common with medial/lateral lengthening than with isolated lateral lengthening (24% vs 6% in one study)
         c. Results worse with revision HSL
d. Neuropraxia in up to 10% of patients
   i. Risk increased with epidural anesthesia
   ii. Do NOT check a popliteal angle intra-op to minimize tension on peroneal nerve

2. Guided growth
   a. Consider in adolescents with knee flexion contractures ≥10-15° and open growth plates

3. Distal femoral extension osteotomy (typically with patellar tendon shortening/advancement)
   i. Consider in adolescents with flexion contractures ≥20°
   ii. May be done before or after skeletal maturity
   iii. Results are best in conjunction with patellar tendon shortening/advancement surgery

⇒ PEARLS: 1. Overlengthening of hamstrings is an under-appreciated problem with aggressive hamstring lengthening, and results in recurvatum and stiff-knee gait. 2. Lateral hamstrings often do not require lengthening, particularly in pre-adolescents. 3. Results of repeat hamstring lengthening are inferior to primary surgery. 4. Results of distal femoral extension osteotomies are better when combined with soft tissue surgery to address patella alta.

SELECTED REFERENCES 1-51


