Musculoskeletal Pain in CP: Opportunities for Prevention?

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Outline

- Musculoskeletal Pain in Cerebral Palsy (CP)
- Treatments to Prevent Spasticity
  - Upper Extremity
  - Hip
  - Knee
  - Foot and Ankle
  - Spine
  - Other Factors
  - Future Directions

Pain in Cerebral Palsy (CP)

- Majority (67-82%) of adults report chronic pain (Schwartz et al, 1999)
- Increased risk of osteoarthritis – aberrant load paths due to muscle spasticity/tone and biomechanics compounded by aging and time
  - 59% of 160 CP pts found with signs of osteoarthritis (radiographic) (Boldingh et al, 2005)
  - 27% (age between 15-25 yo) found with osteoarthritis as opposed to 4% in general population (Cathels et al, 1993)

General Theme

- Abnormal muscle tone → Disruption of normal load paths → arthritic joint degeneration
- Muscle – often the generator of pain
- Goal – Early Surgical Intervention as PREVENTION technique
- Other options include methods to reduce spasticity and abnormal tone

Intrathecal Baclofen

- Implanted pump with direct access to intrathecal space
- Muscle relaxant with additional effect in reducing nociception
- Intrathecal baclofen requires only ~1% of the oral dose to achieve similar or better response
Deep Brain Stimulation

- Implanted electrode that gives stimulation to targeted sites in brain based on physiological motor disability
- Stimulates areas of brain to enable better motor control to combat involuntary movements such as choreo-athetosis and dystonia

Bilateral pallidal deep brain stimulation for the treatment of patients with dystonia-chooreoathetosis cerebral palsy: a prospective pilot study

- Multicenter prospective study of 13 adult patients with CP
- Significant improvement in dystonia at 1 year (34.7 → 24.4) per Burke-Fahn-Marsden dystonia rating scale
- Significant improvement in domain of body pain

Selective Dorsal Rhizotomy (SDR)

- Relieves spasticity and increases function by interrupting reflex arcs of selective nerve roots
- Does not obviate need for orthopaedic surgery

Bilateral deep anterior cerebellar stimulation (DACS)

- 10 patients with CP and symptoms of focal/segmental dystonia
- Spasticity in upper extremities improved in 8 patients from median 3 → 1.5 (Ashworth scale)
- Unified Dystonia Rating Scale (UDRS) total score improved from median 18 → 10.3
Retrospective review of 42 patients with CP after SDR

- 92% of patients improved at least 1 Ashworth point in at least 2 independent motor groups
- Mean Modified Ashworth Scale score for all upper extremity muscle groups improved from 1.34 to 1.22 (p < 0.001)

Survey of 88 patients with CP (mean age 25.6 y), at 19.6 y after SDR

- 64% of patients extremely or very satisfied with SDR outcomes (Diener Satisfaction with Life Scale)
- However, 44% still reported recent pain (numeric rating scale) – prevalence similar to literature for chronic pain in adults with CP – Is SDR really beneficial for pain management and does reduction in spasticity help reduce pain?

Problem with Reporting Outcome Measures

- Important to measure HRQoL (Health-Related Quality of Life) and Symptoms as opposed to symptoms alone because we want to know impact of pain on patient’s ability to function in everyday life
- Goal - Look for validated, widely used instruments that measure a number of domains – again, the effect of the pain not just the symptoms

Botulinum Toxin in Treatment of CP

- Spastic muscle growth lags neighboring structures → contractures, deformity → pain → decrease function
- Hypertonic muscles → muscle shortening
  - Passive stretching of relaxed muscles may restore longitudinal muscle growth
- BTX hypothesized to restore muscle length since it causes weakening in spastic muscles → promote muscle growth and gain in strength → avoid abnormal forces on bones, contractures

Cross-sectional survey of 131 patients with spasticity (12% with CP)

- Does spasticity relate to pain and consequently, does BoNTa decrease pain?
- 85/131 (65%) patients with spasticity report pain (87% of CP)
- 80% reported pain related to self-perception of spasticity
- 62% believed BoNTa decreased pain
Physical Therapy

Survey Results of Pain Treatment in Adults with Cerebral Palsy

- Cross-sectional survey of 83 adults with CP
- 63% reported chronic pain
- Most common interventions (56% in the past, 35% presently) are physical including physical therapy and strengthening
  - Rated as moderately effective

Surgical Treatment: Upper Extremity

Constraint Therapy for Upper Extremity

- Constraint – induced movement therapy for arm function training in hemiplegic cerebral palsy
- Unilaterally affected patients with CP typically use less affected upper extremity (UE) to increase efficiency (developmental disregard)
- Constraint-induced Movement Therapy
  - Constraint of unaffected UE
  - Repetitive practice of movements of the affected UE
  - Behavioral/motion therapy to improve motor patterns

Effectiveness of constraint-induced movement therapy on upper-extremity function in children with cerebral palsy: a systematic review and meta-analysis of randomized controlled trials

- Analyzed 27 RCT
- Medium beneficial effect (d = 0.546) compared with conventional therapy

Upper Extremity

- Orthopaedic procedures used to improve function, spasticity, deformity and PAIN
- Consists of soft tissue releases, tendon transfers, and bone/joint stabilization
- Major deformities:
  - Elbow flexion
  - Forearm pronation
  - Wrist flexion
  - Finger deformity
  - Thumb-in-palm
- Mostly performed by hand surgeons
- Treatment plan: Surgery + Occupational Therapy → Spinning + Rehab
**Surgical Treatment: Hip**

**Hip Dysplasia in CP - Why does it matter?**

- Progression of hip subluxation or dislocation is associated with:
  - Chronic pain
  - Hygiene difficulty
  - Sitting imbalance
  - Gait abnormality
- Salvage options for the skeletally mature patient with a neglected hip are limited

**PREVENTION IS KEY**


**Cause of Hip Dysplasia**

- Normal hip growth: born with anatomically normal hips
- Normal hip develops due to growth, muscle strength, and normal position of femoral head in acetabulum
- Without opposing pressure, hips become dysplastic


**Cause of Hip Dysplasia**

- In CP, spastic hip adductors and flexors compress the femoral head against the posterolateral acetabulum and labrum, leading to progressive deformity
- Without normal pressure from femoral head in acetabulum, femoral head will migrate laterally and acetabulum shape will deform

**Hip Surveillance**

- Every 6 months, beginning at diagnosis of CP
  - Physical Exam
  - Radiographic Evaluation
- The more severe the hip pathology, the more intensive the surveillance

**Clinical Hip Surveillance**

- Worsening of GMFCS Level
- Ashworth Scale (spasticity of major muscle groups)
- Pain
  - Difficulty with sitting/standing/walking
- Passive and dynamic range of motion
  - Hip flexion/extension
  - Hip abduction/adduction
  - Hip internal/external rotation
  - Galleazzi/Windswept position
Radiographic Hip Surveillance

- AP X-Ray in supine position
- Initial radiographs at 1 year
  - Every year, if patient is ambulatory
  - Every 6 months, if evidence or high risk of dysplasia
- Reimer’s migration percentage:
  \[ \geq 30 \text{–} 40\% \quad \text{at risk for subluxation / dislocation} \]

Evidence for why hip dysplasia matters?

- 77 children/care-givers with CP surveyed
- 29% of caregivers reported hip pain
  - Painful hips vs painless hips (Migration percentage (MP):
    \(40.9\% \text{ vs } 26.5\%\))
  - MP \(\geq 50\% \) (subluxation/dislocation) - 60% report hip pain
  - MP \(< 50\% \) - 86% report no hip pain

Evidence for Hip Surveillance: Conclusions

- Good evidence for Hip Surveillance to prevent pain
  - Not new information…but still not universally applied!
- Dislocations can be reduced and prevented with careful surveillance
- Multi-disciplinary team approach is critical
- Standardized radiographic screening = early identification
- Timely surgical intervention once displacement is identified = increased likelihood of successful surgery
- Indication for surgery: 30% migration index

Evidence for Hip Surveillance

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What happens to untreated hips for adults?

- Significant number of adult patients with CP (as high as 75.5%) report of hip pain (Hodgkinson et al, 2001)
- Pain may be grossly underreported, especially for those with poor cognitive ability and limited communication skills
  - Survey of 123 GMFCS IV/V patients (manuscript)
  - 31% report moderate/severe/very severe pain in preceding 4 weeks
  - 7% report pain every/almost every day

Continuum of Pathology and Intervention
Treatment Options for Adult Dislocated Hip

- **Limited Options** for Severely Dysplastic Hip
  - Cause of hip pain, degenerative joint disease
  - Emphasizes importance of preventive surveillance programs

**Case Presentation:** 9 year old male, spastic diplegia
Bilateral Varus Rotational Osteotomy, R Pelvic Osteotomy, Hip Adductor Tenotomy Release, Botox Injections

Increased difficulty in walking with a walker
Surgery done to prevent losing ability to walk with the walker

Surgical Treatment: Knee

What if adult patients were not treated?

- Knee flexion deformity (crouch knee) (Morrell et al, 2002)
  - Most common knee abnormality in spastic CP
  - Associated with hip/ankle flexion contractures
- Progressive flexion → increase quadriceps force → overstretching quadriceps muscle fibers and infrapatellar tendon leading to:
  - Patella Alta → PAIN
  - Patellar fragmentation → PAIN
  - Chondromalacia → PAIN
  - Joint instability, muscle weakness, pain

Knee – Patella Alta

- 58-72% of pts with spastic CP
- Hamstring contracture with rectus spasticity → constant quadriceps contraction during stance phase of gait → chronic forces through patellofemoral joint → patella alta
- Insall ratio = B-C/A-B
  - A-B = greatest diagonal length of patella in 30 degrees knee flexion
  - B-C = patellar tendon length
  - Patella alta if ≥ 1.2

Bilateral Varus Rotational Osteotomy, R Pelvic Osteotomy, Hip Adductor Tenotomy Release, Botox Injections

At 1 year and 5 months postop from these surgical procedures and 5 months post-instrument removal surgery

Increased difficulty in walking with a walker
Surgery done to prevent losing ability to walk with the walker
Patella Alta

- Exacerbated by crouch gait
  - Extensors: (1) hip extensor, (2) knee extensor, (3) ankle plantar flexors
    - Weak in crouch gait and may be long
  - Standing/walking in flexion + spasticity → contractures of (4) iliopeos and (5) hamstrings
- Higher stresses at knee leads to knee pain, patella alta, and possible fragmentation/fracture of inferior pole of patella

(Crodda et al, 2006)

Patella Alta

- Conservative Treatment (Murphy 2010)
  - Quadriceps stretching to alleviate excessive rectus femoris tightness
  - Minimize anterior pelvic tilt
  - Increase prone lying; Abdominal wall and hip extensor strengthening
  - Improve patella tracking in trochlear groove
  - Patellar taping techniques
  - Patellar neoprene orthoses
  - Intrarticular injections (steroids, anesthetics)
  - Medications - NSAIDs

Case Study

- HPE: 24 YO M PMH right spastic hemiplegia cerebral palsy
- Recurrent R patellar subluxations and pain
- Prior to surgery, patient was experiencing significant decrease in ability to ambulate and to climb stairs.
- PE:
  - Significant patella alta to R knee
  - Slight valgus deformity

Patient/Caregiver Report

- Was told that there were no options to improve function or reduce pain by community providers
- No prevention advice received

Because of lack of prevention/prophylactic measures – now need surgical treatment
- Surgical Plan: OR for R MPFL reconstruction with tibial tubercle osteotomy

Pre-operative Radiographs
Intra-operative Radiographs

- Placement of screws to stabilize osteotomy
- Note correction of alignment

Achieving Improvement in Range of Motion

Case Study – Take Home Points

- My intention is NOT to talk about techniques for performing orthopedic surgery, but how to prevent them

- Hindsight Prevention Measures for this Patient
  - Spasticity control of lower extremities at appropriate age
  - Earlier treatment of patella alta

- There is no magical cure-all, BUT, with preventative measures, a major orthopedic surgery could have been avoided.

Surgical Treatment: Ankle and Foot

Foot and Ankle

- Foot and ankle deformities – as high as 92% in patients with CP (O’Connell, 1998)
- Need for correction in childhood otherwise worsens in adulthood
- Untreated cases Significant source of pain decline in function
- Most common foot deformities in CP include: Equinus, , Planovalgus, Equinovarus

Case: Bilateral foot osteotomy, foot/toe arthrodesis, multiple tendon lengthenings hip/thigh

- 15yo boy with spastic cerebral palsy
- Progressive, bilateral contracture deformity of his feet and ankles
- Deformity preventing proper bracing and interfering with his ability to stand.
- Skin threatened medially and over the bilateral dorsal bunions
Case: Bilateral foot osteotomy, foot/toe arthrodesis, multiple tendon lengthenings hip/thigh.

Pre-Op  Post-Op

Foot and Ankle – Preventative Measures
- Current tools:
  - Botulinum toxin for spasticity
  - Casting
  - Orthotics
  - Physical therapy
- Do we have the right tools…? Are they sufficient…?

Surgical Treatment: Spine

B = Sitters (GMFCS III - V)
A = Ambulators (GMFCS I, II)
C = Bedridden (GMFCS IV, V)

- Rapid progression of scoliosis during growth period
- Continued progression after growth period. Ambulators who did not progress for years can still progress after age 20.
- Severe scoliosis (Cobb angle > 60) seen mostly in bedridden patients or those with total-body involvement

Natural History and Progression
- Ongoing progression with curves ≥ 30°
- With progression:
  1. Lose ambulation
  2. Decreased sitting endurance → repositioning more often
  3. Shorter trunk → decreased GI and respiratory function
  4. Pain

Surgical Decision Making Algorithm
- Observe patients every 6 months
- Consider surgery when curve is ≥ 35° → likely to progress
- Strong indication for surgery in progressive curves and curves ≥ 40° - 50°
Risk Factors that Influence Surgery

- Promoting surgery:
  - Age/Skeletal Maturity ➔ intervene earlier
  - Pelvic Obliquity > 15 degrees
  - High GMFCS (IV & V) ➔ more aggressive with patients with more severe symptoms
  - Goals of care = quality of life, ease of care

- Discouraging surgery:
  - Comorbidities ➔ infection, pulmonary issues, cardiac, neurological conditions, malnutrition

Growing Rod Constructs

- Allows continued growth in actively growing children with abnormal spinal curves
- Indications:
  - Skeletal immaturity
  - < 10 years old
  - Maintenance of seated height
  - Prevent progression of curve
  - Preserve pulmonary function and thoracic volume which can be impaired by early fusion

Surgery for Scoliosis in Cerebral Palsy

- In modern U.S medical practice, it is rare for severe scoliosis to progress into adulthood without surgical intervention
  - 84 patients/families of patients with CP treated with spinal fusion
  - Overall satisfaction = 92%
  - Improvements: 93% in sitting balance, 94% cosmesis, 71% quality of life
  - 85% would definitely have surgery again
  - 99% considered surgery successful
  - Measurement of Pain – Based on Medication use – No Difference

Goals and Outcomes

- Successful surgery makes positioning and sitting easier
  - Increases endurance and halts loss of ambulatory function
  - Gauge success with surrogate outcome measures ➔ burden of care perceived

Magnetically Controlled Growing Rods

- External magnetic distraction
  - Minimizes one of the main issues of growth rods – recurrent surgeries for distractions
  - Bess et al, 2010 – 140 patients with 897 traditional growing rod procedures
    - 58% at least 1 complication
    - Complication risk increased by 24% for each additional surgical procedure
  - Early results have been favorable, with reduced number of surgeries, and comparable curve correction

(Déjà vu) - Problem with Evaluating Pain and Associated Outcomes

- Important to assess pain symptoms AND health-related quality of life (HRQoL)
  - Impact of pain on patient function
- For studies related to pediatric patients with CP, we often rely too much on surrogate measures of pain (proxy, pain medications)
  - Need for validated and widely used tools
  - CPChild, PROMIS? – Still have their deficiencies
But wait! What About Prevention of Scoliosis?

Non-surgical Treatment

- Botox injections into concavity of curve
- Physical Therapy to retain flexibility and mobility
- In-chair positioning devices (GMFCS III – V)
- TLSO and soft/postural braces may delay surgery
- Bracing can improve function/ stability/ maintenance of body position in chair

Impact of Orthoses on the Rate of Scoliosis Progression in Children with Cerebral Palsy

- 43 patients with CP and scoliosis, with mean curve of 64° at time of spinal fusion
- 21 patients treated with orthoses (23 hr/day for mean 67 months)
- Braced patients had curve progression to 50° by 12.5 yrs, compared to 50° by 14 yrs without brace
- Spinal orthotics had no statistically significant effect on scoliosis curve, shape, or rate of progression
- Apical vertebral rotation = indicator of rapid progression curve

New Initiative at CUMC - Actuated Spine Brace

- Static braces shown to be ineffective for curve progression
- Potential of dynamic bracing

Actuated Spine Brace

A New Perspective

- Another direction is to look at what we are already doing
- What are we doing to help patients who are already suffering from pain?
  - Psychiatric Issues
  - The Opioid Epidemic
Psychiatric Issues in Pain
Weinberg Family Center Pain Research Platform

Cycle of Pain and Depression

Survey of 56 patients with CP
- Compare CP vs General Population:
  - Chronic Pain: 75% vs 39%
  - Fatigue Severity Scale: 8 vs 2.9
  - Depression Symptoms: 23% vs 12%
- Concurrent chronic pain and severe fatigue in 34%
- Concurrent chronic pain, severe fatigue, and depressive symptoms in 16%

Exploring Opioid Use in Chronic Pain
Weinberg Family Center Pain Research Platform

Phase 1 – Identify the Problem
1. Study to assess the prevalence of opioid and antidepressant use in patients with CP

Phase 2 – Chronic Pain – Opioid-Naïve
2A. RCT to determine effectiveness of duloxetine/pregabalin for chronic pain in CP – PCORI grant LD submitted
2B. Prospective study to assess suboxone for CP

Phase 3 – Chronic Pain – Opioid Dependent
3. RCT – Randomize patients to:
   - Control
   - Suboxone (depending on Phase 2)
   - Duloxetine/Pregabalin (depending on Phase 2)

Future Directions
- Sarcomere length found to be increased in CP, with smaller cross-sectional area in muscle contractures
- Muscle growth is potentially inhibited in longitudinal fibers growth by the pathology in CP
- Satellite cells – source of muscle growth and repair
  - Postulated that satellite cell loss causes inability for muscles in CP patients to grow due to dysfunction of contractures
  - Smith, 2013 (Dev Med Child Neurol.)

Future of Prevention?
- Better understanding of muscle pathology ⇒ potential for preventing musculoskeletal pain in CP
- Stem Cell Therapy and other Regenerative Medicine
  - Ability to induce satellite cell regeneration?
  - Regeneration of insults to central nervous system?

The future is in YOUR hands
Thank You!