Lower Extremity/Neuromuscular Symposium
Thursday, May 17, 2012 • 1:15pm-4:35pm
Room: Mineral Hall A-Corridor

Chairs: James McCarthy, MD, Scott Hoffinger, MD
Faculty: James McCarthy, MD, Todd A. Milbrandt, MD, Robert Lark, Deborah Eastwood, MD, Arabella Leet, MD, Alfred Mansour, MD, Moon Seok Park, Jason Rhodes, MD, Tom Novacheck, MD, David Yngve, MD, James W Roach, MD, Jon R. Davids, MD, John E. Herzenberg, MD, James McCarthy, MD, Scott A. Hoffinger, MD, John G. Birch, MD, Paul W. Esposito, MD, Scott J. Mubarak, MD, James W. Roach, MD
Associate Societies: LLRS, AACPM

The Lower extremity/Cerebral Palsy Symposium coordinates an outstanding faculty that will focus on the orthopaedic and surgical aspects of lower extremity deformity assessment and treatment, including techniques used for children with cerebral palsy. Case presentations, scientific papers, and a master technique session will structured into the 3 hour symposium. Topics to be included are: Automated intramedullary rod techniques, femoral osteotomies and patellar advancement for crouch gait, Knee flexion contractures treatment, lengthening over a nail, The 3-C procedure for flat feet, plateau elevation in Blount’s Disorder, and congenital femoral deficiency treatment.

Guided Growth
1:15 LLRS Limb Deformity Score-How Do We Evaluate
James McCarthy, MD, Cincinatti, Ohio

1:19 3 Methods of Guided growth LE Angular Deformity
Todd A. Milbrandt, MD, Lexington, Kentucky

1:23 Predicting Results of Guided Growth Surgery: Coronal Plane Deformity
Robert K. Lark, MD, Durham, North Carolina

1:27 Guided Growth: An Audit of Its Use in Non-Idiopathic LE Deformity
Deborah Eastwood, MD, London, United Kingdom

1:31 Discussion

Osteogenesis Imperfecta
1:36 Bent Telescopic Rods in OI
Arabella I. Leet, MD, Honolulu, Hawaii

1:40 Biomechanical Comparison of Distal FD Rods
Alfred A. Mansour, MD, Denver, Colorado

1:44 Discussion

Knee disorders in CP
1:48 Anterior Knee Pain in CP
Moon Seok Park, Bundang-gu Seong Nam, Republic of Korea

1:52 Comparison of Patellar Adv Techniques in Children with Patella Alta and CP
Jason Rhodes, MD, Aurora, Colorado
1:56  Does Patellar Position Change with Growth After Patellar Tendon Transfer in CP  
  Tom Novacheck, MD, St. Paul, Minnesota

2:00  Complications Associated With Minimally Invasive Surgery in CP  
  David A. Yngve, MD, Galveston, Texas

2:04  Discussion/Wrap Up

2:10-  Break

2:25  Break

CASE PRESENTATIONS

Moderator: Scott A. Hoffinger, MD  
Panel: James W. Roach, MD, Scott A. Hoffinger, MD, Scott J. Mubarak, MD, John R. Davids, MD, John E. Herzenberg, MD, James McCarthy, MD

2:25  Knee Flexion Contracture in Arthrograposis  
  James W. Roach, MD, Pittsburgh, Pennsylvania

2:40  Blounts-Severe with Plateau Depression  
  Jon R. Davids, MD, Sacramento, California

2:55  Correction of the Hip in Congenital Femoral Deficiency  
  John E. Herzenberg, MD, Baltimore, Maryland

3:10  Older CP Patient with Subluxed Hip (Painful)-What To Do  
  James McCarthy, MD, Cincinnati, Ohio

3:20-  Break

3:35  Break

Masters Techniques:  
Moderator: James McCarthy, MD

3:35  Knee Extension Osteotomy and Patellar Advancement for Teenage Crouch Gait in Cerebral Palsy-  
  Scott A. Hoffinger, MD, Oakland, California

3:45  Surgical Techniques of Automated Intramedullary Rod Lengthening  
  John G. Birch, MD, Dallas, Texas

3:55  IM Rodding of the Tibia in OI  
  Paul W. Esposito, MD, Omaha, Nebraska

4:05  Flatfoot in Cerebral Palsy, the 3 C Procedure  
  Scott J. Mubarak, MD, San Diego, California

4:15  Questions, Discussion, and Wrap Up

4:30  End
I. Special Papers/Debate (3 bullet presentations followed by debate)

Evaluation of the reliability of the Limb Lengthening and Reconstruction Society AIM score (LLRS AIM)

James McCarthy, John Birch, Christopher Iobst, Rozbruch, S. Robert, Sanjeev Sabharwal, Nate Faulkner, Viral Jain, David Klimaski, Emily Eismann

Purpose: To develop a general limb deformity classification scheme that allows for the pre-treatment assessment of a broad range of lower extremity disorders and promotes a uniform method of evaluation.

Material and Methods: The resulting LLRS AIM classification is a 7-point scale that takes into account deformity, as well as issues related to soft tissue injury, bone quality and underlying health conditions. To evaluate the classification scale, 8 surgeons rated 10 theoretical patients by first ranking the patients from the simplest to the most difficult case, then used the LLRS AIM scale to rate the case.

Inter-rater reliability was analyzed by a two-way random ANOVA to determine the intra-class correlation between raters (ICC_{2,k}). Intra-rater reliability was evaluated by a one-way ANOVA to determine the intraclass correlation over time (ICC_{1,k}). Significant differences were analyzed with paired t-tests and a two-way repeated measures ANOVA by rater and trial. Rank scores were assessed for interrater reliability with Kendall’s W (coefficient of concordance). The relationship between the LLRS scores and rankings were evaluated through linear regressions.

Results: The LLRS displayed excellent intra-rater and inter-rater reliability, with highly consistent ratings over time with the same raters and between raters for trial 1 (ICC=0.97) and trial 2 (ICC=0.98). Patient rankings were significantly positively correlated with the LLRS-AIMS scores for trial 1 ($R^2 = 0.253, p < 0.001$) and trial 2 ($R^2 = 0.229, p < 0.001$) both before and after controlling for rater.

Conclusion: Preliminarily data suggest that the LLRS-AIM classification is a reliable method to assess limb deformity, and correlated with patient limb deformity severity scores.
Three Methods of Guided Growth for Pediatric Lower Extremity Angular Deformity Correction

David Ross, MD. Vishwas Talwalkar, MD, Janet Walker, MD, Henry Iwinski, MD Todd Milbrandt, MS, MD

Purpose: To compare the angular correction obtained in pediatric patients undergoing three different methods of guided growth correction for coronal plane deformities about the knee. The hypothesis was that no group would be more efficacious with angular correction.

Methods: A retrospective review was undertaken comparing the use of a titanium staple (Smith and Nephew Inc.), eight plate (Orthofix Inc.), and the PediPlate (Orthopediatrics Inc.) at a tertiary pediatric hospital after IRB approval. Full-length weight-bearing lower extremity radiographs were analyzed and standard angular measurements recorded as described by Paley. Clinical data was recorded with respect to underlying diagnosis, BMI, clinical outcome, follow-up length, and treatment related complications.

Results: 77 patients were included in the analysis with 18 in the staple, 24 in the eight plate, and 43 in the pediplate group. Average follow up was 18 months after implantation (range 7-22). The groups were similar with respect to underlying diagnosis; however there were more patients with a diagnosis of Blounts disease in the eight plate group. The change in mechanical tibiofemoral angle for the staple group was significantly greater than the eight plate group (6.5° vs 3.1°, p<0.05) and approached significance for the Pediplate group when compared to the eight plate group (6.4° vs 3.1°, p=0.056). The rate of angular correction per year was 4.34° for the pediplate, 4.16° for the staples, and 2.09° for the eight plate. The complication rate was significantly lower (p<0.05) in the pediplate group 11.6% (5/43), compared to 50% in the staples group (9/18), and 29.2% in the eight plate group (7/24). There was no significant difference between groups in age at implantation, BMI, initial deformity, or change in mechanical axis zone.

Conclusion: With respect to angular correction staples and pediplates achieved larger correction more rapidly than did the eight plate. The pediplate also had a lower rate of complications than either the eight plate or staple group. Our analysis supports previous data that patients with a diseased physis, more severe deformity, and higher BMI are more likely to be resistant to guided growth techniques and experience complications.

Significance: This large retrospective series provides data on the angular correction that can be expected with several popular guided growth techniques. Our series indicates that the pediplate provided rapid correction with the lowest complication rate.
PREDICTING THE RESULTS OF GUIDED GROWTH SURGERY: A Model for Coronal Plane Deformities Around the Knee

Jonathan C. Riboh, MD; Robert D. Fitch, MD; Robert K. Lark, MD

Purpose: Guided growth is commonly used for correction of coronal plane deformities about the knee. Previous work to help choose the timing of hemi-epiphysiodesis (HE) exists, however it is cumbersome and does not allow the user to predict the actual rate of correction after surgery. Our goal was to develop and validate a model to predict the rate of deformity correction after HE.

Methods: All patients undergoing HE for genu varum or genu valgum between 2008 and 2010 were reviewed. Exclusion criteria were: failure of hardware, simultaneous corrective osteotomy, or lack of appropriate follow-up (6 months). Medial proximal tibial and lateral distal femoral angles were measured pre-operatively and at all post-operative visits using long-standing radiographs. Two separate models were created: 1. A theoretical model based on knee geometry and limb-length multipliers, and 2. An empirical model generated by multivariate linear regression from demographic data. First, the patients were randomly divided into training and validation sets. The regression model was built using the training data, with only significant input variables (p < 0.05) retained in the final model. The predictive quality of the models was assessed on the validation set, using the $R^2$ and root mean square error (RMSE) statistics.

Results: 32 patients (8 idiopathic, 8 with Blount’s disease, 6 with a skeletal dysplasia, 6 with metabolic bone disease, 2 post-traumatic and 2 with multiple hereditary exostosis), were included in the final analysis, which generated 130 independent measurements of deformity over time. Training and validation sets included 65 data points each. The final variables included in the regression model were: 1. Time since surgery, 2. Bone length, 3. Physeal width, 4. Deformity angle, and 5. Underlying diagnosis. Prospective comparison on the validation set showed superior results with the empirical model ($R^2 = 0.32$, RMSE $= 3.70$) as compared to the theoretical model ($R^2 = 0.08$, RMSE $= 4.30$).

Conclusion: We have created a model capable of predicting angular correction as a function of time after HE of the knee, with a standard error of 3.70. By way of comparison, the inter-observer measurement error for coronal knee deformities is 20 to 30.

Significance: This study provides a new tool to help the pediatric orthopedist predict the results of guided growth surgery of the knee. This may help guide family education, reduce the frequency of radiographic follow-up, and help with the early identification of patients failing guided growth.
**Guided Growth: An audit of its use in cases of non-idiopathic lower limb deformity**

M Atinga, A de Gheldere, P Calder, C Bradish, DM Eastwood

**Aim:** To assess the efficacy of guided growth in the management of deformity secondary to pathological physeal growth and note the complications associated with this procedure.

**Methods:** An audit was performed of the notes and radiographs of all patients attending our institution in whom guided growth had been performed for non-idiopathic deformity with the aim of correcting alignment to neutral. All data points were collected prospectively. The most common aetiologies were: metabolic bone disease (25%), congenital anomalies (22%) and skeletal dysplasias (17%). Complications were noted and defined as perioperative, implant-related or growth-related.

**Results:** 71 patients (106 limbs, 131 segments) have been treated with the 8-plate device (Orthofix). All have completed a minimum 18month follow-up. Mean age at surgery was 10yrs (range 3:16yrs), 20% underwent additional major surgical procedures. In 104 cases correction was at knee level. 75% corrections were for valgus deformity. 85% limbs have completed correction and/or are skeletally mature. Improvement in limb alignment has been seen in 97% limbs with significant improvement in distal tibial alignment when correction was at the proximal tibia/distal femur. Incomplete correction correlated significantly with age at surgery and severity of initial deformity. Correction was most rapid and reliable in cases of metabolic bone disease and slower and less effective in skeletal dysplasias. The current complication rate is 17% (29% perioperative, 21% implant related, 50% growth-related). In 2 cases where there was inadvertent over correction, improvement did not occur with time.

**Conclusion:** Guided growth improves mechanical alignment in cases where the deformity is due to pathological growth and may be a useful adjunct to other limb reconstruction techniques simplifying the overall treatment plan. Severe deformity may not correct fully.

**Significance:** Abnormal pressure on the physis in cases of severe deformity may prevent correction and thus early surgery for more minor deformity is advocated.
BENT TELESCOPIC RODS IN OSTEOPENESIS IMPERFECTA PATIENTS

R. Jay Lee, MD; Michael D. Paloski, DO; Paul Sponseller, MD; Arabella I. Leet, MD

Purpose: To characterize implant bending as a mode of failure in telescopic rods used in the treatment of Osteogenesis Imperfecta (OI)

Methods: IRB approval was obtained for a retrospective review of OI patients treated at our institution. Patients with bent telescopic rods were included and contralateral unbent rods were examined for comparison.

Results: 6 males and 6 females were identified. Average age at surgery was 3.6 years. Average interval between surgery and bending was 4.0 years (range 0.9-8.2). 51 telescoping rods were implanted: 43 Fassier-Duval (FD), 8 Bailey-Dubow (BD). Overall 35% (18/51) bent, 11 in the femur and 7 in the tibia; 13 FD, 5 BD.

Of the FD rods, 32 were implanted in the femur and 11 in the tibia. In the femur, bent FD rods ranged from 3.2 to 6.4 mm in diameter, and unbent FD rods ranged from 3.2 to 6.0 mm. In the tibia, bent FD rods ranged from 3.2 to 4.0 mm, and unbent FD rods ranged from 3.2 to 4.8 mm. There was no statistically significant difference in the mean size between the bent and unbent implants.

Of the 8 BD rods, 4 were implanted in the femur and 4 in the tibia. In the femur, all four rods were 5/32, and 1 of them bent. The BD rod size was not recorded for the tibial implants, but all 4 rods bent.

6 rods bent at the junction of the smaller and larger rod, 8 bent over the larger rod, and 6 bent over the smaller rod. 3 rods bent in two areas.

10 of the 18 bent rods presented with an acute fracture. 8 of the rods bent slowly over time as the underlying bone bowed. At the time the bent rods were identified as bent, 1 had cut out proximally and 3 distally, 1 had disengaged proximally and 7 distally.

Conclusion: While telescopic rod pull out or cut through has been described, the bending of these implants has not been well characterized. Rod bending can present acutely with a fracture or progress in a chronic fashion. In revision of the bent rod, we recommend using the largest diameter to prevent bending; however, this may lead to stress shielding. More research is necessary to determine the best rod size for the treatment of OI.

Significance: This study emphasizes the importance of bending as a mode of failure of telescopic rods.
Biomechanical comparison of augmented distal fixation of Fassier-Duval telescoping rods

Alfred Mansour, MD; James Barsi, MD; Todd Baldini, MS; Gaia Georgopoulos, MD

Children’s Hospital Colorado, Aurora, CO

Purpose: Antegrade telescoping rods have been introduced for use in osteogenesis imperfecta to decrease the incidence of long-bone fractures while allowing growth in skeletally immature patients. Recent studies have documented increased failure rate of antegrade telescoping intramedullary rods due to inadequate distal fixation resulting in prevention of telescoping. The purpose of this study was to evaluate the pullout strength of distal fixation of the telescoping rod with and without synthetic calcium phosphate (bioabsorbable-CP) or polymethylmethacrylate (PMMA) augmentation.

Methods: Four sets of six telescoping 4.0 mm long-thread distal fixation rods were fixated according to standard insertion technique through a custom frame into a open cell rigid foam synthetic bone block (0.09 gm/cc) simulating the severely osteoporotic bone found in osteogenesis imperfecta. The following groups were tested: control (no augmentation), 0.75ml of PMMA-augmented, 0.75ml of PMMA-rescued (stripped distal fixation, then re-secured after PMMA augmentation), and 0.75ml of bioabsorbable-CP-augmented. All groups were cured at 37 degrees Celsius for 24 hours before testing. Single load to failure was performed at 0.2mm/second and the peak load was recorded.

Results: The average pullout strength in Newtons (N) (+/- standard deviation) for the four groups were as follows: control – 20 (+/-6.6) N; PMMA-augmented – 125 (+/-16.8) N; PMMA-rescued – 137 (+/-11.9) N; bioabsorbable-CP-augmented – 81 (+/-10.3) N. All augmented groups had significantly higher pullout strength compared to control (p<0.001). The PMMA-augmented and PMMA-rescued groups failed at the PMMA/bone interface whereas the bioabsorbable-CP-augmented group failed at the cement/rod interface.

Conclusions: All augmented constructs improved pullout strength by at least 400% compared to control. Bioabsorbable cement may be less detrimental to the physis if pullout still occurs despite augmentation due to its mode of failure.

Significance: This study provides biomechanical evidence to support the use of either PMMA or bioabsorbable cement augmentation to improve pullout strength of distal telescoping rod fixation.
ANTERIOR KNEE PAIN IN PATIENTS WITH CEREBRAL PALSY

Chin Youb Chung, MD, Moon Seok Park, MD, Kyoung Min Lee, MD, Sang Hyeong Lee, MD, Dae Gyu Kwon, MD, Ki Hyuk Sung, MD, Tae Won Kim, MD, Seung Yul Lee, MD, In Ho Choi, MD, Tae-Joon Cho, MD, and Won Joon Yoo, MD.

Purpose: The risk factors of anterior knee pain has not been sufficiently investigated in patients with cerebral palsy. This prospective study was to assess the risk factors of anterior knee pain in ambulatory patients with spastic cerebral palsy in terms of walking, resting, and provocative pain.

Methods: One hundred and twenty-seven consecutive patients with spastic cerebral palsy were included. Demographic data including gender, age, functional level, and extent of involvement were collected. Physical examinations including knee flexion contracture, unilateral and bilateral popliteal angles were performed. Patella heights were measured on lateral knee radiographs using Insall-Salvati method or Koshino-Sugimoto method depending on their applicability, and patella alta was identified. The presence of anterior knee pain was inquired in terms of walking, resting, and provocative pain. The provocative pain was assessed by patellar compression test. The risk factors of anterior knee pain was analyzed using multivariate analysis with generalized estimating equation.

Results: Sixteen of 127 patients showed anterior knee pain (12.6 %). Age was found to be the significant risk factor of walking pain and resting pain with odds ratios of 1.08 (95% confidence interval, 1.02-1.14) and 1.09 (95% confidence interval, 1.03-1.15). Age, knee flexion contracture, popliteal angles, and patella alta were not significant risk factors for provocative anterior knee pain.

Conclusion: Age was the most significant risk factor for anterior knee pain in patients with cerebral palsy. Even though 60.6 % of patients showed patella alta on radiographic measurement, it was not a significant risk factor for anterior knee pain.

Significance: Anterior knee pain is problematic in patients with cerebral palsy. This study provided useful information regarding the risk factors of anterior knee pain in patients with cerebral palsy.
Comparison of Patellar advancement techniques in children with Patella alta and Cerebral Palsy

Jason Rhodes MD, Qing-Min Chen MD, Mark Hotchkiss BA, Kate Worster MD, Bryan McNair MS, Amy Nguyen MS, Frank Chang MD, James Carollo PhD, PE

Purpose: No standard surgical technique exists for the correction of patella alta in children with cerebral palsy and persistent crouch gait, with multiple surgical techniques being employed. The purpose of this abstract is to compare the efficacy of the proximal tendon resection (PT) and imbrication (IM) surgical techniques with respect to radiographic measures of patellar height.

Methods: Patients who underwent patellar advancement from 2000-2011 were identified. The Koshino-Sugimoto Index (KI) of patellar height was calculated for available radiographs at the pre-operative, post-operative, and most recent time-points. To control for variation in patellar position with increasing knee flexion, KI values were converted to standard deviations above or below the normal population mean at various knee flexion angles to give Adjusted KI (AKI). A linear mixed model was used to evaluate differences between knees treated with PT and IM in terms of AKI. Correlation across limbs and time points was appropriately considered.

Results: Radiographs from 55 patients (38 males, 17 females) and 106 knees were measured. Pre-operative radiographs were a median of 5.1 [Interquartile Range (IQR): 5.8-2.5] months before surgery, while post-operative and most recent radiographs were a median of 0.8 [IQR: 0.7-1.4] and 10.8 [IQR: 4.3-18.0] months after surgery, respectively. 82 knees (77.4%) were treated with PT, and 24 (22.6%) were treated with IM. In the PT group, 57 knees (69.5%) were treated with concomitant distal femoral extension osteotomy (PA+DFEO) and 25 (30.5%) were isolated patellar advancements (PA). Knees in the IM group were split evenly between PA and PA+DFEO. Surgery technique was not a significant predictor of AKI [p=0.7493]. However, the pattern of change over time differed significantly between the groups [p=.0288]; see figure 1. Specifically, AKI for knees in the PT group dropped 1.71 standard deviations [95%CI: 0.2019-3.2206] farther than those in the IM group between the pre- and post-operative measurements [p=0.0225, Bonfferoni corrected]. Subsequent change was equivalent between the groups.

Conclusions: Both PT and IM effectively correct patella alta, with PT showing potential for greater improvement in the immediate post-operative period.

Subsequent loss of correction is equivalent between the groups, such that the PT technique maintains greater correction through most-recent radiograph.

Significance: The PT technique may have the potential for larger improvement in cases of severe deformity. Similar deterioration in AKI across both groups is observed. There may be many biomechanical explanations for this, and further investigation is necessary to determine the cause.
DOES PATELLAR POSITION CHANGE WITH SUBSEQUENT GROWTH AFTER PATELLAR TENDON ADVANCEMENT IN CHILDREN WITH CEREBRAL PALSY?

Tom F Novacheck, MD; Ranjit Varghese, MD; Jean Stout, PT; Mike Schwartz, PhD

Purpose: Terminal knee extensor insufficiency is a major contributor to crouch gait in individuals with cerebral palsy. Tightening the extensor mechanism via patellar tendon advancement (PTA) is an essential part of the treatment to effectively correct crouch gait. If performed prior to skeletal maturity, the patellar tendon insertion is elevated from the tibial tubercle apophyseal cartilage and advanced under a periosteal sleeve distal to the tibial tubercle apophysis. Both loss of surgical correction and progressive patella baja with subsequent growth have been a concern. Radiographic findings of subjects who underwent PTA prior to the end of skeletal growth were reviewed to assess the effect of subsequent growth on patellar position.

Methods: The Koshino Index (KI) was measured on pre-operative, 3 month post-operative (after tendon healing), and final follow up radiographs at or near skeletal maturity (minimum 3 years). The KI Z-score was assessed for effectiveness of the procedure by comparing the early post-operative to the pre-operative value. The final follow up KI Z-score was compared to the pre- and the 3 month post-operative values to evaluate the effect of growth on patellar position.

Results: Twenty-nine subjects (46 knees) were reviewed. 70% also underwent concomitant distal femoral extension osteotomy (DFEO). Average age was 11.3 +/- 1.3 years. Average length of follow-up was 4.5 years (range 3.0 – 7.9). Average pre-op KI Z-score was +1.14. At 3 months postop, patellar position was overcorrected (average KI Z-score = -1.99 PTA only and -3.93 DFEO+PTA). Three years later, the patellar position remained overcorrected in both groups (average KI Z-score = -2.71 PTA only and -2.99 DFEO+PTA).

Conclusion: Correction of terminal knee extensor insufficiency using this technique of patellar tendon advancement prior to skeletal maturity is safe and effective. The results are maintained with minimal risk of loss of correction or progressive patella baja.

Significance: Crouch gait can lead to knee pain and is energy expensive. Both pain and gait inefficiency can contribute to decreasing ambulatory function in adulthood. Terminal knee extensor insufficiency is an important contributor to crouch gait. Patellar position remains corrected despite subsequent growth using this surgical technique for patellar tendon advancement.


COMPLICATIONS ASSOCIATED WITH MINIMALLY INVASIVE SURGERY FOR CHILDREN WITH CEREBRAL PALSY

Benjamin Turnbow, MD, Antonio Rodriguez, MD, and David Yngve, MD

Purpose: The purpose of this study was to examine the complications associated with the minimally invasive multilevel surgical technique known as selective percutaneous myofascial lengthening (SPML) in children with cerebral palsy. The technique lengthens musculotendinous units in the calf, hamstring, and hip adductor regions and, when indicated, includes obturator nerve block with ethanol.

Methods: A retrospective review of all hard copy charts and electronic medical records of all patients aged 2-18 years with cerebral palsy who had SPML surgery between 2006 and 2009 was performed. All patients were 1 year or more postoperative at the time of review. The number and type of complications were recorded. A total of 184 children underwent 1102 individual SPML surgeries. The most common combination was surgery at bilateral hip adductors with nerve blocks, hamstrings, and calves, which was counted as 8 surgeries. There were 101 boys and 83 girls; 471 procedures were performed in the hip adductor region, 305 at the hamstrings, and 226 at the gastrocsoleus muscles. One hundred procedures were performed in other regions, including the biceps, palmaris longus, peroneal, and Achilles tendons. The mean age at the time of surgery was 8.9 years.

Results: There were 27 reported complications (2.4%): 1 fever, 2 hematomas, 8 paresthesias, 4 tight casts, 11 flexion contractures, and 1 ruptured muscle. None of the complications required hospital admission for treatment or resulted in chronic pain.

Conclusions: The complication rate with SPML surgery is low.

Significance: Minimally invasive surgery can be performed with minimal risk in children with cerebral palsy.
II. **Case Presentation (ARS) with expert panel**

**Moderator** Scott Hoffinger

**Panel:** Jim Roach, Scott Hoffinger, Scott Mubarak, John Davids, John Herzenberg, Jim McCarthy

**2:30 Knee flexion contracture in arthrogryposis-J Roach**

Severe knee flexion contractures are common in patients with arthrogryposis and pterygium syndromes and are very difficult to treat[1]. Several surgical procedures have been recommended [2-5] unfortunately subsequent recurrence of the deformity is predictable unless the quadriceps muscle has some active power. A two year old arthrogrypotic child with severe knee flexion contractures will be presented and the possible surgical options discussed.


2:42 Blounts-severe with plateau depression-Jon R Davids, MD

Case History:

An 8 year old female presents with late sequelae of untreated infantile Blount Disease involving the left leg. Physical examination, diagnostic imaging, surgical decision making, surgical technique options, management of post-operative complications, and ultimate functional outcome will be discussed.

Selected References:

Accadbled F, Laville J-M, Harper L. One-Step treatment for evolved Blount’s disease. J Pediatr Orthop 2003;23:747-752. Retrospective review of 4 limbs in 4 children with sequelae of infantile tibia vara. Mean age at surgery was 8y+2m. Mean follow up was 6y+10m. Primarily technical domain outcomes reported. Single surgery was performed to correct extra-articular varus limb malalignment, internal tibial torsion, intra-articular varus deformity, and limb length discrepancy. Surgery consisted of percutaneous epiphyseodesis of the proximal lateral tibial physis and proximal fibula, elevation osteotomy of the medial tibial plateau, osteotomy of the fibula, dome osteotomy of the proximal tibia, and progressive lengthening. Photographs of case examples show slender European children.

Gregosiewicz A, Wosko I, Kandzierski G, Drabik Z. Double-elevating osteotomy of tibiae in the treatment of severe cases of Blount’s disease. J Pediatr Orthop 1989;9:178-181. Retrospective review of 13 limbs in 8 children with sequelae of infantile tibia vara. Mean age at surgery was 8y+2m. Mean follow up was 8y+1m. Primarily technical domain outcomes reported. The authors describe acute correction of all elements of deformity, with autograft for the medial plateau elevation osteotomy. No significant surgical complications and no discussion of sagittal plane procurvatum deformity. Best technical description of this classic procedure.

Hefny H, Shalaby H, El-kawy S, Thakeb M, Elmoatasem E. A new double elevating osteotomy in management of severe neglected infantile tibia vara using the Ilizarov technique. J Pediatr Orthop 2006;26:233-237. Retrospective review of 7 limbs in 5 children with sequelae of infantile tibia vara. Mean age at surgery was 11y+7m. Mean follow up was 6y+1m. Primarily technical domain outcomes reported. Single setting surgery was designed to address all intra- and extra-articular deformities. Double osteotomies (oblique beneath the medial tibial plateau, and transverse at the proximal tibial metaphysis) were controlled with half pins, wires, and ring fixator. Sequential gradual correct of the intra-articular varus deformity, through the oblique osteotomy, was performed first, followed by distraction osteogenesis through the transverse osteotomy to correct extra-articular varus and limb length deformities. Advantages include less soft tissue dissection, no internal fixation, gradual multi-planar correction, and “fine-tuning” of correction to achieve optimal ultimate alignment.

Hefny H, Shalaby H. A safer technique for the double elevation osteotomy in severe infantile tibia vara. Strat Traum Limb Recon 2010;5:79-85. Retrospective review of 12 limbs in 8 children with sequelae of infantile tibia vara. Mean age at surgery was 9y. Mean follow up was 5y. Primarily technical domain outcomes reported. Description of modification to technique previously described (Hefny et al 2006). The oblique osteotomy beneath the medial tibial plateau is performed utilizing an anteroposterior drill hole in the midline of the tibia, just distal to the physis. A Gigli saw is placed through the drill hole and the osteotomy is performed from the midline in a medial and distal direction. The authors believe that this technique is safer due to decreased chance of the osteotomy extending proximally across the physis and epiphysis into the knee joint.

Schoenecker PL, Johnston R, Rich MM, Capelli AM. Elevation of the medial plateau of the tibia in the treatment of Blount disease. *J Bone Joint Surg* 1992;74-A:351-358. Retrospective review of 7 limbs in 7 children with sequelae of infantile tibia vara. Mean age at surgery was 12y+5m. Mean follow up was 3y+2m. Primarily technical domain outcomes reported. Elevation osteotomy was performed concomitantly with transverse metaphyseal osteotomy in 3 cases, or in a staged sequence in 4 cases. Additional femoral osteotomy was performed in 4 cases. Commonly quoted classic reference.

Tavares JO, Molinero K. Elevation of medial tibial condyle for severe tibia vara. *J Pediatr Orthop* 2006;15-B:362-369. Retrospective review of 6 limbs in 5 children, 4 with sequelae of infantile tibia vara, 1 with multiple epiphyseal dysplasia. Mean age at surgery was 9y+8m. Mean follow up was 3y+11m. Primarily technical domain outcomes reported. Oblique and transverse osteotomies were performed in staged fashion. All cases utilized external fixators, auto- or allograft. Indications for plateau elevation included varus / valgus stress radiographs showing >10 degrees difference. The magnitude of intra-operative elevation of the medial tibial plateau was determined by the correction of laxity to the medial collateral ligament.
Correction of the hip in Congenital Femoral Deficiency - J Herzenberg

A toddler with congenital femoral deficiency (CFD), coxa vara, delayed ossification of the femoral neck, and a hip flexion contracture is presented. Predicted leg length discrepancy will be considerable, and multiple lengthenings are anticipated. Principles of stabilization of the hip prior to lengthening, and protecting the hip and knee during lengthening will be discussed.


44 patients with congenital unilateral short femora types I, II, and IIIA were included. 17 had type I, 9 had type II, and 18 had type IIIA. 20 underwent simultaneous lengthening of the femur and tibia, and 24 had only femur lengthening. In type IIIA, the acetabular dysplasia and coxa vara are severe, and are associated with subluxation/dislocation of the hip with lengthening. Recommendation: correction of the varus femur bow and the neck-shaft angle to 120° and the acetabular index to <25° prior to lengthening of type IIIA femora.


Femoral lengthening done on 26 femurs (18 patients), aged 6 to 17 years (mean 13). Lengthening was 2 to 7.5 cm (mean 5 cm). There were 14 hips with CE angle > 20° and 12 hips with CE angle of < or = 20°. No hip with CE > 20° deteriorated. Five of 12 hips with CE angle of < or = 20° deteriorated. In cases in which the CE angle is < or = 20°, bony innominate osteotomy should precede femoral elongation.


Description of the techniques used for pre-lengthening preparation of the CFD hip, and methodologies for treating associated knee instability.


Description of the surgical techniques involved in femoral lengthening.


Report of three hip dislocations that occurred during lengthening for CFD after an average lengthening of 9 cm. Progressive acetabular dysplasia and decreasing center edge angle were noted. Closed reduction failed. Treatment included open reduction, femoral shortening, and acetabular procedures.

Late Hip Deformity in Cerebral Palsy - What to do - Scott A. Hoffinger, M.D.
Andrew, 13 years old, quadriplegia. Communicates verbally, understands and follow instructions, cognitively limited. Was able to stand transfer but having more hip pain this year.

Advice – too risky to put hip in. Likely to fail, could be worse, eventually won’t be able to transfer, therefore resect proximal femur – declined.

Two years later, age 15, now on codeine daily, unable to stand on right LE
Options? Put it in? Take it further out? Remove femoral head?

At 2 weeks, off narcotics, at 8 weeks standing without pain


Masters Techniques

Moderator Jim McCarthy

3:30 Knee extension osteotomy and patellar advancement for teenage crouch gait in Cerebral Palsy - Scott Hoffinger

- Crouch Gait – persistent stance phase knee flexion
  What resists crouch? What extends the knee?
- Knee flexion is normal part of stance, loading response, typically to 20 degrees or so then knee extends

- The quads don’t extend the knee, the knee extends because of the plantar-flexion knee extension couple. Plantar flexion of the foot causes the extension force across the knee. Loss of this knee extension vector leads to persistent stance phase knee flexion THUS crouch gait.
- The force from the plantar flexion MUST be sufficient to overcome the force of knee flexion – these two are RELATED
- IF PLANTAR FLEXION force > KNEE FLEXION forces result is BACK KNEE
- IF PLANTAR FLEXION force < KNEE FLEXION forces result is CROUCH

Contributors to Crouch therefore are:

- Loss of plantarflexion force – weak gastrosoleus complex, poor mechanicos of gastrosoleus complex, foot deformity, external tibial torsion
- Excess knee flexion force – knee flexion contracture, statically short hamstrings, TOO DEEP loading response from weak quadriceps

To eliminate crouch gait one must restore plantarflexion force:

- Good gastrosoleus strength
- Straight foot
- Foot in line with knee (appropriate plantarflexion vector)

AND reduce knee flexion force:

- Hamstring lengthening if appropriate
- Eliminate static knee contracture
- Improve quadriceps strength and power

Best success in crouch is PREVENTION! Avoid overlengthening or isolated lengthening of Achilles.
Limited success restoring fully upright gait once crouch is well established especially when static knee contracture present.
Distal Femoral Extension Osteotomy first described in 1913 by Osgood for cases of old infection, polio, fracture

Patellar Tendon Shortening described in 1933 by Chandler, revised by him in 1940, further by Roberts and Adams in 1953.

Best recent description these techniques presented by Selber at POSNA, Vancouver, 2000, then technique further refined by Stout, Gage, Schwartz, Novacheck, 2008.

Indication for distal femoral osteotomy with patellar tendon shortening:

Ambulatory patient with cerebral palsy with persistent stance phase knee flexion during gait and fixed flexion deformity of the knee.

Important to maximize the plantar flexion knee extension couple prior to addressing the knee as indicated. Procedures often include:

- Foot osteotomy
- Tibial rotation osteotomy
- Subtalar or triple arthrodesis

Procedure for distal femoral osteotomy:

- Lateral approach to femur
- Subvastus approach
- Determine amount of extension desired, and rotation
- Place chisel (if blade plate) or template (if distal femoral locked plate) as far distally as you can WITHOUT injuring the physis
- This will determine the amount of extension so careful measurement is important
- Cut the distal femur – can cut a wedge, a trapezoid, or simply do this perpendicular
- Place the plate, rotate if indicated, and affix to shaft of femur
- Remove spike of bone posteriorly
• Beware lengthening the path of sciatic nerve (shorten bone where needed)

Procedure for patellar tendon shortening:

• Extend incision over patellar tendon
• Carefully incise the paratenon for repair later
• Cut the patellar tendon off the distal pole of the patella
• Resect distal 5 mm of patella to fresh bleeding surface
• Pull patella distally so that distal pole reaches the tibio-femoral joint (finger in the notch) and overlap tendon
• Resect the overlapped amount of tendon
• Place two Mitek suture anchors (super anchor) in the patella and then Krackow stitch (one laterally and one medially) along patellar tendon
• After tying the Mitek sutures use 0 Vicryl for whip stitch where necessary
• Repair paratenon

Post operative regimen:

• Cast or splint in mild flexion to avoid sciatic stretch
• Mobilize at 3 – 4 weeks in hinge knee brace to restore flexion
• FWB at 6 weeks
• Floor reaction braces for the first six months
3:40 Surgical techniques of automated intramedullary rod lengthening—John Birch

Texas Scottish Rite Hospital for Children
I receive royalties through my employer (TSRH) from Orthofix for a circular external fixator.
I have no contractual arrangement or conflict of interest regarding Fitbone™ or Wittenstein Intens.

- Totally implantable intramedullary lengthening device (femur or tibia).
  - Rod has locked, telescoping, and imbedded electric motor components.
  - Activator sends radio-frequency waves to antenna transcutaneously.
  - Initiation starts sequence of 9 “pulses”; repeated 3x daily = 1 mm. distraction
- Developed by Professor Rainer Baumgart et al, Munich, Germany.
  - Manufactured by Wittenstein Intens, a German elevator and aerospace company.
  - Not currently FDA-approved.
  - TSRH cases have been done on individual, FDA compassionate-use bases.
  - This is a retrospective, UTSW Medical School IRB-approved study.

- Other Very Important Points:
  - Baumgart’s “Reverse Planning Method” (Operative Orthopädie und Traumatologie, 2009).
  - Starting deformity (shortening, angular, and torsional) analyzed, osteotomy planned.
  - End point (deformity corrected and length achieved) diagrammed.
  - Bone segments telescoped (“reverse planning”) along straight rod to demonstrate end-surgery goals.

<table>
<thead>
<tr>
<th>Complication Category</th>
<th>Description</th>
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<tbody>
<tr>
<td>Category I</td>
<td>Minimal intervention, treatment goal achieved (e.g., pin tract infection)</td>
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<tr>
<td>Category II</td>
<td>Significant change in treatment plan, including unplanned return to surgery, but goal achieved</td>
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<tr>
<td>Category IIIA</td>
<td>Failure to achieve treatment goal, but no new pathology or permanent sequelae (e.g., premature consolidation with aborted lengthening)</td>
</tr>
<tr>
<td>Category IIIB</td>
<td>Failure to achieve treatment goal and/or new pathology (e.g., joint stiffness or subluxation, regenerate fracture with shortening and deformity)</td>
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Comparison of complication rate/nature in patients with congenital femoral deficiency undergoing femoral lengthening using circular external fixator TO: patients (11/12 with CFD) undergoing retrograde femoral lengthening using Fitbone nail.
Complication rate/nature during femoral lengthening by circular external fixation compared to: same patients during subsequent Fitbone femoral lengthening.

### Final Thoughts:

Anecdotally, the patients:
- Have **significantly** less pain.
- Have greater range of motion, and regain motion more quickly at end-distraction.
- Require **much** less PT, psychology, and nursing support.
3:50 IM rodding of the tibia in OI-Paul Esposito

Bowed tibias don’t improve spontaneously
   Cast treatment alone may lead to recurrent fractures
   Tight gastrocnemius deforming force

Indications for realignment and IM nailing
   Recurrent fractures in a child trying to stand
   Persistent pain/fractures in a non ambulatory child

Pre op evaluation
   Full length AP and Lat x-rays preferably digital
   Allows for deformity assessment as well as sizing and templating

Bisphosphonates-hold pre op-can lead to increased bleeding
   Timing to resume treatment still controversial

Positioning and approach
   Decubitus if femur and tibia done same day
   Supine if just tibias to be treated
   Medial peripatellar incision
      May need to release the medial retinaculum

Approach 2 options- care to avoid injury to medial meniscus
   Just posterior to patellar tendon
      More anterior entry point
   Just anterior to ACL insertion
      Straighter shot into canal

Guide pin- advance either manually or with drill
   Pins tend to go lateral and posterior
   Soft tissue guide can help guide medial and anterior

Correction-must completely correct all deformity
   Residual ant bow leads to recurrence, non union and failure of rods
   Usually 2 bows, mid and distal thirds
   Can correct with either two osteotomies or segmental resection
      Shortening decompresses soft tissues
   Occasionally can do closed osteoclysis rather than osteotomy
   Rarely need to do fibular osteotomy

Advance guide to distal metaphysis
   Advance with tibia held in posterior bow to overcorrect
   Posterior on lateral/slightly lateral on AP
   May need to advance pin into epiphysis in soft bone
   Ream to metaphysis

Nails- solid nail or wire in youngster/ telescoping when epiphysis ossified
   Cut male nail before or after inserting
      Anterior insertion if nail to be cut in situ
Female nail cut before inserting
Leave room between male and female to allow compression
Can distal interlock smaller FD nails if necessary

Post op immobilization
  Depends on fixation
  Usually can weight bear by 4 weeks

Problems
  Higher incidence of incomplete union in tibias
    Tend to migrate anteriorly
  Younger children require earlier revision for growth
  Rods can back out into knee especially if smooth wire used
4:00 Flatfoot in cerebral Palsy, the 3 C procedure-Scott Mubarak

Surgical technique of Calcansous-Cuboid-Cunieform osteotomy

A. Indication – Severe valgus foot – 6-16 years

B. Soft tissue release
   i. Soft tissue release as indicated: TAL + peroneal brevis

C. Calcaneal (medial) sliding and closing (varus) wedge
   i. Peroneal tendons and sural nerve retracted
   ii. Lateral cortex and “corners” cut with osteotome or saw
   iii. Closing varus wedge calcaneous

D. Cuboid opening osteotomy
   i. Peroneal tendon retracted
   ii. Osteotomy mid cuboid

E. Cuneiform closing osteotomy
   i. Medial incision
   ii. Talo-navicular reefing
   iii. Plantar wedge

F. Pin fixation
   i. Cuneiform closing wedge
   ii. Cuboid open wedge graft
   iii. Calcaneus medial slide

G. Post-operative management
   i. Short leg non-weightbearing cast x 5 weeks;
   ii. Pin removal at 5 weeks
   iii. Short leg weightbearing cast x 3 weeks

H. Excellent/Good 90%  Fair – 10%

I. Complications/Problems
   i. Wound (Hypergranulation tissue) – 5%
   ii. Non/delayed union cuneiform osteotomy – 1%
   iii. Do only when over 6 years