

## Abstracts

# Orthopedics

### Mid-term Results of Ponseti Method for Clubfoot in Patients with Myelomeningocele (MM)

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**Background** Clubfoot is present in 30–50% of patients with MM. The Ponseti method is now widely applied to clubfoot associated with MM, however, few studies have reported results. Most available studies include heterogeneous diagnoses or report short-term results. The purpose of this study is to report mid-term outcomes in patients with MM who were treated for clubfoot using the Ponseti method.

**Methods** This is a retrospective review of 16 patients (26 feet) with MM treated with Ponseti method for clubfoot. Charts were reviewed for age at treatment initiation, total # casts required, surgeries performed, recurrence of deformity, and further treatment. Primary outcome was recurrence of deformity requiring further treatment. Data was analyzed using t-tests for means and  $\chi^2$  tests for categorical data.

**Results** Initial correction was achieved in 26/26 feet. 23/26 underwent TAL at an average age of 105 d, 12 percutaneous and 11 open excision. At average follow-up of 5 y (1.8–7.5 y), 11 feet (42.3%) were successfully treated. Of the 15 feet (57.7%) with recurrence, 8 required posterior release, 6 PMLR, and 1 tendon transfers. Average age at further treatment was 1.5 y (0.9–3.1 y). Those with recurrence required more casts prior to TAL (7.3 vs 5.2,  $p = 0.011$ ). 100% patients with percutaneous TAL had recurrence requiring further treatment, compared to 18% recurrence in patients with open excision ( $p < 0.0005$ ).

**Conclusions** Mid-term evaluation of Ponseti method for clubfoot in MM shows a successful outcome in

42% of patients hence is useful to decrease need for extensive soft-tissue release. Recurrence in those who underwent open Achilles excision was significantly lower than percutaneous TAL, and also substantially lower than previously published recurrence rates in MM (33.3–68%). Families should be counseled prior to initiation of treatment about realistic expectations regarding risk of recurrence and potential need for further treatment.

### Foot Pressure Sores in Patients with Spina Bifida

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**Background** We investigated the relationship between pressure sores of the foot, demographic factors, ambulatory status and neurologic level using NSBPR data at a single institution. We hypothesized that more functional ambulatory status and lower neurologic level would be associated with a higher rate of pressure sores due to increased demands on feet that nevertheless have abnormal sensation.

**Methods** We reviewed patients with data pertaining to foot pressure sores in our pediatric and adult clinics who have had at least 1 visit since 2009. We then performed univariate (Chi square, t-test) and multivariate (logistic regression) analyses to determine associations between clinical and demographic variables and the presence of a foot pressure sore.

**Results** A total of 665 individuals are included. 337 (50.7%) patients reported having a pressure sore within the last 12 months of their office visit.

21.4% (72/337) reported that the pressure sore was on their foot. 88.9% of patients with a foot pressure sore have a diagnosis of myelomeningocele. Univariate analysis found functional level of lesion ( $p = 0.001$ ) and diagnosis ( $p = 0.033$ ) were both significantly as-

sociated with foot pressure sores. Multivariate analysis determined that thoracic ( $p = 0.002$ , OR 0.178), mid-lumbar ( $p = 0.001$ , OR 0.201), and low-lumbar ( $p = 0.000$ , OR 0.186) functional lesion levels had statistically significant, independent associations. Although 31.9% of patients with a foot pressure sore had a thoracic functional level of lesion they were less like to have any foot orthopedic procedures to correct foot deformity (OR 0.347,  $P = 0.021$ ).

**Conclusions** Pressure sores of the foot were most often associated with thoracic and mid/low lumbar lesion levels. This may have implications in decision making for maintenance of plantigrade feet in non-ambulators with a higher level of lesion. Further study should focus on how foot position and corrective foot surgery impact foot pressure sores.

#### Assessing Plantar Pressure Characteristics in Children with Spina Bifida by Neurological Level of Impairment

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**Background** Children with Spina Bifida (SB) have unique gait characteristics predicated on their neurological level of impairment. Characterizing SB gait patterns can be useful in intervention assessment, surgical planning, or monitoring for tethered cord. Unfortunately, gait laboratories are not always accessible and may be cost prohibitive. An affordable way to record an aspect of gait is through plantar pressures (PP). Comparison of PP by neurological levels has not been performed.

**Methods** Children in our SB clinic complete baseline observational gait studies and PP at ages 4–6 and 8–10. Twenty-two plantar pressure studies from 6yos with SB were qualitatively analyzed by the child's neurological level and trends were described. The PP are currently being analyzed quantitatively using original software developed by our Center for Motion and Gait Analysis, which will offer additional insight.

**Results** Children with upper lumbar lesions demonstrate the most dramatic difference in PP when compared to controls. They have very little contact with the surface, especially under the forefoot and toes. PP of children with SB look more similar to controls as the neurological level descends. There is less differentiation between lumbosacral and sacral PP, but this sample may display unique hotspots, particularly under the

metatarsal heads (the 5<sup>th</sup> being most common). Quantitative evaluation is ongoing.

**Conclusions** Characterization of PP in children with SB by neurological level of impairment has not been well established prior to this study.

Baseline understanding of the effect of neurological levels of impairment on foot strike will allow us to better interpret gait mechanics in children with SB, assess interventions (i.e., orthotics and surgery), help with orthopedic surgical planning, and monitor for serious complications (i.e., tethered).

#### Hip Status and Long-Term Functional Outcomes in MM

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**Background** 30–50% of patients with MM will develop hip instability. Previously reduction was recommended but no long-term functional evidence supports this. The purpose is to determine influence of hip status on functional outcomes in a cohort of adult patients with MM.

**Methods** Patients with MM  $\geq 18$  y were prospectively enrolled. Neurologic level, functional mobility scale, and history of hip surgery were obtained. Clinical exam included hip range of motion (ROM) and leg length discrepancy (LLD). Migration percentage was calculated on AP pelvis xray. VR –12 and NIH PROMIS<sup>®</sup> outcomes measures were used for pain interference and physical function.  $\chi^2$ , Pearson Correlation Coefficients and linear regression models evaluated influence of hip status on outcomes.

**Results** Thirty-one patients, 8 thoracic, 9 lumbar, 14 sacral, with average age 31 y (range 19–49) were included. Twenty had bilateral located hips (Group 1), 5 unilateral subluxation/dislocation (Group 2), 6 bilateral dislocation (Group 3). In univariate analysis, Group 1 performed better in lower extremity function (LEF) scores than Group 2 (36.7 vs. 26.0,  $p = 0.03$ ) but worse in pain interference than Group 3 (52.0 vs. 43.3,  $p = 0.03$ ). After controlling for neurologic level, there was no significant difference in the VR –12 mental (MCS) ( $p = 0.32$ ) or physical component summary ( $p = 0.32$ ) scores, nor was there any difference in the PROMIS LEF ( $p = 0.26$ ) or pain interference

scores ( $p = 0.33$ ) between groups. Decreased extension and abduction were both indirectly correlated with VR -12 MCS ( $p = 0.0038$ ,  $p = 0.0032$ ). LLD was not associated with any measure.

**Conclusions** Long term functional outcomes are not associated with hip status in MM, but are more closely correlated with neurologic level and ROM. Discordant outcomes in univariate analysis likely reflect neurologic level rather than hip status. Efforts to keep hips reduced are without functional benefit and should be avoided in favor of maintaining motion with contracture release as needed.

### Comparing Outcomes of Tibial Derotational Osteotomy (TDO) in Cerebral Palsy (CP) vs Myelodysplasia (MM)

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**Background** Tibial rotation deformities are common in patients with MM and CP. In both groups, improvement in gait biomechanics has been reported following TDO. Complication and re-rotation rates are widely variable. The purpose is to review outcomes of TDO as a function of complication and revision rates comparing a cohort of children with MM to a cohort with CP.

**Methods** All TDOs performed on patients with MM or CP > 3.5 y with > 2 y follow-up were reviewed for demographics, direction/degree of derotation, complications, and need for repeat TDO. Two-sample T-tests were used to compare characteristics. Two-tailed  $\chi^2$  tests compared complications. Generalized linear logit models identified independent risk factors for complication and re-rotation amongst the 2 cohorts.

**Results** One hundred thirty-five patients (217 limbs) with average f/u 7.83 y met inclusion criteria. Complication rate was 10.1% with 4.6% major complications (ie fracture, deep infection, hardware failure). After adjusting for sex and age, odds of complication were not significantly different between groups ( $p = 0.424$ ). Prior to adjusting for sex and age, CP cohort were less likely to require re-rotation compared to MM (OR, 0.067; [95%CI, 0.009–0.522];  $p = 0.0102$ ). Adjusting for sex and age, neither group was more likely

to require re-rotation ( $p = 0.0934$ ). Repeat TDO was 31.9% less likely per y increase in age ( $p = 0.0083$ ). Initial thigh-foot angle, degree/direction of correction were not associated with re-rotation in either group. Neither level of involvement nor GMFCS reached significance in predicting need for repeat TDO.

**Conclusions** TDO is a safe, effective treatment in MM and CP, with acceptable overall (10.1%) and major (4.6%) complication rate. Risk of repeat TDO decreases in both groups with increasing age. Association between age at initial surgery and need for repeat TDO helps guide treatment and aid providers in appropriate counseling of patients considering TDO.

### Diversities of Neck-Shaft Angle of Proximal Femur in Patients with Spina Bifida

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**Background** Deformities of proximal femur are very common in patients with Spina Bifida and generally assumed as a part of sequelae of paraplegia, including muscle imbalance and impaired motor function. Neck-shaft angle on plain radiograph is the most common sign of proximal femoral deformity and amount of NSA correction indicates postoperative stability of hip.

**Methods** In 414 children examined from 2006 to 2015 neck-shaft angle was calculated on AP radiographs of hips. Neurosegmental level of Spina Bifida according to the Sharrard classification and motor status by Hoffer's criteria were evaluated.

**Results** From total amount of 828 hips in patients with Spina Bifida, NSA was within normal age-matched values in 126 (15,2%). Most of patients (85,6%) with normal values of neck-shaft angle had level I motor status by Hoffer (independent walking).

Increased neck-shaft angle (coxa valga) revealed in 678 of 828 hips (82%). In 24 (2,8%) hips decreased neck-shaft angle (coxa vara) was seen. We divided "coxa vara paralitica" into 3 types according to Weisl classification: 1) spontaneous separation of upper femoral epiphysis; 2) spontaneous fractures of the neck of the femur; 3) iatrogenic avascular necrosis of upper femoral epiphysis. All 3 types of varus deformity were seen in our series. Lysis of the femoral neck was found in 6 hips. All the patients with coxa vara had thoracic or L1-L2 level of neurosegmental lesion and were non-ambulators. They had no pain in the hip joints

and no contractures, which could interfere with using a wheelchair.

**Conclusions** Neck-shaft angle correlates with neurosegmental level and motor status of patient. Coxa vara is relatively rare variant of deformity in children with Spina Bifida. Nevertheless, taking into consideration of this type of hip morphology and parallel assessment of neurosegmental and functional level is crucial to avoid unnecessary treatment.

### Gait Analysis Data Alters Surgical Decision Making in Youth with Spina Bifida

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**Background** Children with Spina Bifida often need surgical interventions for gait deviations. The impact of computerized gait data on surgical recommendations in this population is unclear. This study evaluated the influence of gait analysis (GA) on surgical recommendations in children with Spina Bifida.

**Methods** Forty-seven patients with Spina Bifida (11.6 ± 4.0 yrs; 57% male; 28 sacral, 19 lumbar) previously seen for GA were included. Two pediatric orthopaedic surgeons from different gait labs recommended lower extremity surgery based on slow motion video and physical therapy evaluation alone and again with the addition of GA data (kinematics, kinetics, electromyography). Both surgeons assessed each side separately (94 sides). Frequency of surgical recommendations based on video/physical therapy evaluation only vs. video/physical therapy evaluation plus GA data were compared. Percent agreements between conditions were calculated by dividing the number of sides with surgery recommended in both conditions by the number of sides where surgery was recommended in either or both conditions.

**Results** Overall, surgical recommendations changed with the addition of GA for 35% of patients. No surgery (22% of limbs without GA data; 19% with GA) or tibial derotational osteotomies (14% without GA; 18% with GA) were the most commonly recommended interventions. No differences were found between without and with GA for recommendations of any single surgery ( $p \geq 0.40$ ). Agreement between recommendations without and with GA was relatively high for the most common surgeries ( $\geq 50\%$ ).

**Conclusions** Gait analysis information alters surgical decision making for individual patients. Changes were most frequently seen in the transverse plane; otherwise, no clear pattern of recommended surgeries was discerned. Nonetheless GA changed surgical recommendations in over a third of children highlighting the importance of GA for surgical decision making in youth with Spina Bifida.

### Use of Plantar Pressures and Observational Video in the Diagnosis of Tethered Cord in Spina Bifida: An Update

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**Background** Tethered cord (TC) is a common condition with serious sequelae in individuals with Spina Bifida (SB), though the diagnosis can be very challenging. Traditionally, symptoms such as back pain, loss of sensation or strength, and spasticity have been used. Urodynamics and gait laboratory analysis may be helpful objective measures but their cost is prohibitive. At the 2<sup>nd</sup> World Congress we presented a pilot study from our Center of Motion and Gait Analysis on the use of plantar pressures (PP) and observational video as a potential tool for diagnosing TC. We offer an update on this study, with a larger sample size, and suggest that a baseline high definition (HD) observational gait video and PP may be used to document changes in gait and foot position in those individuals at risk for TC.

**Methods** Thirty ambulatory children with SB were referred for baseline observational gait and PP studies. Children at risk or suspected of having TC were referred for comparison studies. HD digital video of gait from side and front view were compared qualitatively, as were PP obtained during the study. PP were quantitatively analyzed for change using custom software.

**Results** Approximately 75% of comparison studies did not reveal major differences in gait or PP. The vast majority of children who did show gait perturbations underwent cord detethering procedures with good results. Preliminary data from quantitative comparison of PP is consistent with qualitative evaluation.

**Conclusions** TC is a difficult clinical diagnosis in children with SB and better diagnostic tools are needed. Observational gait videos and PP measurements are a quick, easy, and relatively inexpensive means for identifying children at risk. Quantitative PP analysis may provide even more insight or sensitivity, but further analysis is needed.

### Three-Dimensional Gait Data Influences Pathology Identification in Youth with Spina Bifida

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**Background** Accurate identification of pathology is crucial to maintaining functional ability in patients with Spina Bifida. Gait analysis (GA) provides objective information that may assist in identifying gait abnormalities. This study evaluated the effects of GA on pathology identification in youth with Spina Bifida.

**Methods** Forty-four children with Spina Bifida (27 males;  $11.0 \pm 3.7$  years) previously seen for GA were included. Two pediatric orthopaedic surgeons and 2 therapists from 2 different gait labs identified primary gait pathologies for each side (88 sides) based on slow motion videos and physical therapy evaluations alone and again with the addition of GA data (kinematics, kinetics, electromyography). Frequency of pathology identification was compared between video/physical therapy evaluation only versus video/physical therapy evaluation plus GA data.

**Results** Crouch, tibial rotation, and pes valgus were the pathologies most commonly identified by surgeons and therapists before GA (surgeons: 24–41%, therapists: 40–63%). GA increased surgeons' identification of crouch by 12% ( $p = 0.03$ ) and decreased therapists' identification of genu valgum by 16% ( $p = 0.001$ ). GA also increased the identification of excessive hip flexion (surgeons: 34%, therapists: 9%) and abnormal hip rotation (surgeons: 22%, therapists: 12%;  $p \leq 0.02$ ). Tibial rotation remained a commonly identified pathology for both surgeons and therapists after GA data ( $p \geq 0.16$ ).

**Conclusions** Excessive hip flexion and abnormal hip rotation were often identified only after GA. Hip rotation is difficult to assess due to complex rotational profiles that may include large transverse plane rotations of the pelvis. Gait abnormalities in Spina Bifida are complex and often interrelated, making it difficult to determine primary pathologies using only visual assessment; gait analysis can assist clinicians in more accurately and objectively determining primary gait pathologies.

### Prophylactic Detethering Does Not Prevent Perioperative Neurologic Loss in Myelomeningocele Scoliosis Surgery

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**Background** The study seeks to determine if children with repaired myelomeningocele and assumed spinal cord tethering are at risk for neurologic complications from surgery for the correction of scoliosis deformity and if that risk is minimized by prophylactic spinal cord detethering procedures.

**Methods** A retrospective review was performed for all myelomeningocele patients undergoing the surgical correction of scoliosis and having a 1 year minimum postoperative follow-up. The neurologic status and functional levels were determined before and after the surgery and spinal cord detethering procedures were recorded. A radiographic analysis of the deformity patterns and pre and postoperative curvature magnitudes was performed.

**Results** Sixty-two patients, 26 males and 36 females, were identified. The average age was 14 yrs(8–31 yrs.). The neurologic levels were thoracic in 19, upper lumbar in 11, lower lumbar in 31 and sacral in 1. Six patients, representing 14% of those with lower extremity function, had a peri-operative neurologic complication and in 3 patients that neurologic problem persisted. Two of the 3 with persistent neurologic complications had prophylactic spinal cord detethering at the time of their spinal surgery. The average curvature and correction in those with and without a neurologic complications were  $89^\circ$  (73% correction) and  $86^\circ$  (74% correction) respectively.

**Conclusions** The incidence of neurologic complications in repaired myelomeningocele patients undergoing a surgical correction of scoliosis is significant (14% of those with lower extremity function). In general the neurologic changes were transient or not sufficient to cause a significant functional change, Prophylactic detethering did not provide protection and may have been harmful.

### Distraction Based Growth Friendly Surgery for the Treatment of Hyperkyphosis in Children with Myelomeningocele: Rib Based Systems Are Safer Than Spine Based Systems

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**Background** The study was undertaken to evaluate the results of distraction growth friendly techniques when performed without a direct surgical correction of the hyperkyphotic deformity in children with myelomeningocele.

**Methods** A multicenter early-onset scoliosis database was mined for children with the diagnosis of myelomeningocele that had undergone distraction growth friendly surgical treatment for a primary kyphotic deformity. Demographic data was collected. The subjects were divided into those undergoing spine-based (Group S) and rib-based (Group R) surgery. Radiographic measurements were made and the surgical complication classification system of Smith et al. was used.

**Results** Fourteen patients, 9 in Group R and 5 in Group S were identified. There were 7 boys and 7 girls with a mean age of 4.3 years for group R and 6.8 years for Group S. The average number of lengthenings was 6.0 and 6.6 for R and S Groups respectively. The maximum kyphotic deformity prior to initial correction and after the last recorded lengthening for Group R was 131 and 97 (26% correction) and for Group S was 91 and 58 (36%). The T1-12 and T1-S1 lengths prior to initial lengthening and after final lengthenings were 121 mm–145 mm (20%) and 209 mm–257 mm (23%) in Group R and 140 mm–180 mm (26%) and 226 mm–294 mm (30%) in Group S. The T1-S1 length gain per year of lengthening averaged 14.0 mm in Group R and 14.7 mm in Group S. There were 21 Type II complication in 4 of 5 Group S patients and 11 Type II complications in 5 of 9 Group R patients.

**Conclusions** The groups appear self-selected with the rib based surgery required for the more severe deformities. For this group of patients rib based growth friendly techniques offer comparable spinal growth preservation with far fewer complications.

### Sub-Laminar Polyester Band Fixation Construct in the Treatment of Neuromuscular Scoliosis

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**Background** Spinal deformity correction is a mainstay in the treatment of progressive neuromuscular scoliosis. Sub laminar band constructs offer a fixation method that may be easier to perform and can be placed in spines with hypo-plastic pedicles.

**Methods** A retrospective review was conducted of 28 cases of pediatric neuromuscular scoliosis treated with posterior spinal fusion using a predominant sub laminar bands construct from 2013–2016. Preoperative, immediate postoperative, and two year follow up radiographs and clinical records were reviewed. Correction of coronal and sagittal plane deformity, pelvic obliquity, blood loss, length of surgery, and complications were reviewed from immediate post operative clinical records and radiographs.

**Results** Average post-operative and two year coronal plane correction was 53% (0–92%) and (49%) (range) respectively. Sagittal balance was corrected to within 2 cm of the C7 plumb line in 76% of patients immediately post operatively and maintained at 2 year follow up. Average lumbar lordosis angle was unchanged from preoperative x-rays and was within normal range (45°) post operatively and maintained at 2 year follow up.

Post operative average thoracic kyphosis angle increased by 9° from preoperative imaging (23° to 32°) and was unchanged at 2 year follow up. Post operative average pelvic obliquity decreased by 50% from pre-operative x-rays. (14° to 7°) and was unchanged at 2 year follow up.

**Conclusions** This study investigates outcomes after predominant sub laminar band constructs particularly constructs with sub laminar bands used at the top of the construct. These finding suggest that a predominant sub-laminar polyester band construct with band fixation at the most cephalad level of the construct is a viable option for correction of deformity correction in pediatric patients with neuromuscular causes of scoliosis.

### Factors Associated with Mobility Outcomes in a National Spina Bifida Patient Registry

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**Background** To provide descriptive data on ambulatory ability and muscle strength in a large cohort of individuals with Spina Bifida enrolled in a National Spina Bifida Patient Registry (NSBPR) and to investigate factors associated with ambulatory status.

**Methods** Cross-sectional analysis of data from a multi-site patient registry.

**Results** Descriptive analysis of mobility variables for 2604 individuals with Spina Bifida age 5 and above are presented from 19 sites in the United States. Analysis of a subset of NSBPR data from 380 individuals from three sites accompanied by data from a specialized Spina Bifida electronic medical record revealed that those with no history of a shunt, lower motor level, and no history of hip or knee contracture release surgery were more likely to be ambulatory at the community level than at the household or wheelchair level.

**Conclusions** This study is the first to examine factors associated with ambulatory status in a large sample of individuals with myelomeningocele and non-myelomeningocele subtypes of SB. Results of this study delineate the breadth of strength and functional abilities within the different age groups and subtypes of SB. The results may inform clinicians of the characteristics of those with varying ambulatory abilities.

This project was funded by the National Center on Birth Defects and Developmental Disabilities, Centers for Disease Control and Prevention, Atlanta, Georgia, grant #1U01DD000744.01 and by the Center for Rehabilitation Research using Large Datasets (CRRLD), Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health (R24HD065702-03). The authors have no conflicts of interest to report. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the National Institutes of Health.

### Maximizing Ambulatory Potential in Spina Bifida

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**Background** Spina Bifida is a complex neurological condition that has associated neural axis deformities, including Arnold-Chiari malformation, hydrocephalus, hydromyelia, diastematomyelia, leptomylolipoma, and spinal cord tethering. There are associated musculoskeletal deformities from paralysis, spasticity, positioning, and muscle imbalance. Management requires interdisciplinary team including Pediatrics, Nursing, Neurosurgery, Urology, Orthopaedic Surgery, Physical Therapy, Occupational Therapy, Orthotist, Psychologist, Social Worker, and Dietician. The goals of interdisciplinary management is to mainstream children, develop independence, competence in the community, personality development, and transition into adulthood. Evaluations must detect functional deterioration, progressive weakness, spasticity, scoliosis, cognitive impairment, muscle atrophy, neurogenic bladder changes, and progressive musculoskeletal deformities.

**Methods** Identify significant physical impairment leading to the inability to maintain ambulatory status. Identify significant physical impairment leading to the inability to maintain independent sitting activities. Define criteria for ambulation including power, range of motion, and crutchable upper extremities. Define criteria for independent sitting activities.

**Results** Etiologic factors include anatomic, neurologic, and spinal cord pathology.

**Conclusions** Prevention of deformity and loss of functional skills:

1. Early aggressive management.
2. Orthotic management coincidental with initiation of ambulatory skills.
3. Protect insensate skin.
4. Routine thorough neurologic re-evaluation.
5. Interdisciplinary care.
6. Surgery only to facilitate orthotic management.