
Prepared by: Danielle Wilt, OTR/L, OTD; Lauren White, PT, DPT, Glendaliz Bosques, MD and the Pediatric Committee of the American Spinal Injury Association

1The International Center for Spinal Cord Injury at Kennedy Krieger Institute, Baltimore, MD;
2Johns Hopkins School of Medicine, Department of Physical Medicine and Rehabilitation, Baltimore, MD

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CLINICAL SCENARIO: Paralytic or neuromuscular scoliosis is a common secondary complication following spinal cord injury, particularly in cases where neurologic insult occurs at a young age. Pediatric patients develop scoliosis more frequently than adults; nearly all patients injured prior to the adolescent growth spurt will develop a progressive spinal deformity. Paralytic spinal deformities can have a devastating impact on children, ranging from pelvic obliquity and increased propensity for skin breakdown, to compromised pulmonary function; and often requires surgical intervention. Identifying a means to prevent development or slow the progression of neuromuscular scoliosis is essential.

FOCUSED CLINICAL QUESTION: For children with spinal cord injury who have not reached skeletal maturity, how does wearing a thoracic-lumbar-sacral orthosis (TLSO) or back brace compare with not wearing a back brace on the development of progressive neuromuscular scoliosis?

CLINICAL BOTTOM LINE:
• Nearly all patients with spinal cord injury onset prior to puberty will develop scoliosis if no intervention is provided.
• Aggressive bracing, initiated prior to development of scoliosis, in pre-adolescent patients with spinal cord injury may delay, and possibly prevent, the need for surgical stabilization and fusion of the spine.

SUMMARY of Search, ‘Best’ Evidence’ appraised, and Key Findings:
4 articles met inclusion criteria and helped answer clinical question best:

• Scoliosis develops in 97% of children injured prior to adolescence and 52% of those injured post-puberty. Results support brace use to decrease curve progression in pre-adolescent children with spinal cord injury.

• Orthotic treatment was difficult in pre-adolescent patients with spinal cord injury; although it generally delayed need for surgical stabilization and fusion of the spine.

• Results support aggressive prophylactic orthotic treatment for pediatric patients with spinal cord injury.

- Brace treatment in neuromuscular scoliosis is questionable; however evidence indicates that the outcomes of brace treatment would improve if treatment is started earlier and on smaller curves.

**Limitation of this CAT:** This critically appraised paper has not been peer-reviewed another independent person. There is limited evidence reported during the past ten years, since no retrospective trials have been published relating to the prevention and management of neuromuscular scoliosis. All prospective trials found in the literature were specific to idiopathic scoliosis and evaluated effectiveness of specific brace types.

**SEARCH STRATEGY:**

**Terms used to guide Search Strategy:**
- **Patient/Client Group:** Children with spinal cord injury who have not reached skeletal maturity
- **Intervention (or Assessment):** Thoracic-lumbar-sacral orthosis (TLSO) or back brace
- **Comparison:** Not wearing a back brace
- **Outcome(s):** Development or progression of neuromuscular scoliosis

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<tr>
<th>Databases and sites searched</th>
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<tr>
<td>PubMed</td>
<td>Spinal cord injury, pediatric spinal cord injury, scoliosis, paralytic scoliosis, neuromuscular scoliosis, back brace, TLSO, surgery in scoliosis</td>
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**INCLUSION and EXCLUSION CRITERIA**

**Inclusion:**
- Peer-reviewed literature evaluating development of spinal deformity following spinal cord injury.
- Effectiveness of brace treatment on neuromuscular scoliosis; surgical incidence in neuromuscular scoliosis

**Exclusion:**
- Studies in the development, progression or management of adolescent idiopathic scoliosis with bracing.
- Articles from non peer-reviewed sources were excluded.
- Studies focused on effectiveness or comparison of specific brace types on spinal deformity.
- Articles published prior to 1980 were excluded.

**BEST EVIDENCE**

The following study/paper was identified as the ‘best’ evidence and selected for critical appraisal. Reasons for selecting this study were: these were the only peer-reviewed studies, to date, which specifically examined the development and evaluated the effectiveness of brace treatment on progression of neuromuscular scoliosis resulting from spinal cord injury.

**SUMMARY OF BEST EVIDENCE**
Effect of bracing on paralytic scoliosis secondary to spinal cord injury (Mehta et al, 2004)

**Objective:** To review the efficacy of early bracing of children with spinal cord injury in prevention or delay of surgical fusion.

**Design:** Retrospective medical record and imaging review

**Setting:** Single site pediatric hospital

**Participants:** 123 patients with cervical or thoracic spinal cord injury prior to skeletal maturity

**Intervention:** Patients were divided into 5 groups based on curve severity and compared braced and non-braced patients within each group.

**Outcome Measures:** Radiograph review for measurement of curve including: coronal Cobb angle, determination of apical vertebrae, and kyphosis measurement; incidence of surgical correction; time from presentation to surgical correction

**Results:** 117 of 123 patients (95%) developed a scoliotic curve greater than 10°. Surgical stabilization was required in 79 of 123 patients (65%). When comparing braced patients to non-braced patients, 59% and 80% of patients required surgery, respectively; the greatest significance was seen in patients who were braced with curves less than 20°.

**Conclusion:** Bracing children with spinal cord injury prior to significant curve formation (less than 20°) delays the time to surgical correction. When bracing is initiated at less than 10°, it may even prevent the need for surgery. As the curve progressed to greater than 20°, the role of bracing seems limited.

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Brace treatment in neuromuscular spine deformity (Olafsson et al, 1999)

**Objective of the Study:** To evaluate brace-induced correction in neuromuscular spine deformities and to identify possible prognostic factors for outcomes in brace treatment

**Design:** Retrospective medical record and imaging review

**Setting:** Single site hospital

**Participants:** 90 patients with various neuromuscular diseases and progressive spine deformity. Patients mean age at the start of treatment was 9.2 years (range 1.4 - 17.7 years)

**Intervention:** Clinical and radiologic follow-up was completed on patients who were treated with a prefabricated Boston-type brace for neuromuscular spine deformity. Patients were divided into 4 subgroups.

**Outcome Measures:** Radiograph measuring Cobb angle before bracing and in brace, and at follow-up.

**Results:** Immediate brace-induced curve correction of Cobb angle was good in all groups, averaging 60%. Pelvic obliquity was improved in the brace in thoracic curves (32%), thoracolumbar curves (59%) and lumbar curves (53%). Pelvic rotation in the sagittal plane was unaffected. There were 83 total cases at follow-up of which 23 were considered successful, 19 made progress in the brace, and 41 patients discontinued bracing.

**Conclusion:** Brace treatment in neuromuscular scoliosis is questionable; however evidence indicates that the outcomes of brace treatment would improve if treatment is initiated earlier and on smaller curves.

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Scoliosis in pediatric spinal cord-injured patients (Dearolf et al, 1990)

**Objective of the Study:** (1) To examine occurrence of scoliosis in children and young adults with spinal cord injury as it relates to age and puberty. (2) To examine the efficacy of bracing to decrease or impede curve progression.

**Design:** Retrospective medical record review and radiographic analysis

**Setting:** Single site pediatric hospital

**Participants:** 130 children with spinal cord injury who sustained spinal cord injuries between birth and age 21 years.

**Intervention:** Patients were divided into those that were injured before their growth spurt (females under 12 years-old and males under 14 years-old), and those that were injured after adolescent growth spurt.

**Outcome Measures:** radiographic measures of lordosis, kyphosis and curve progression, incidence of surgery, incidence of orthotic intervention;
Results: 97% of pre-adolescents and 52% of post-adolescent patients developed scoliosis following SCI. Bracing was effective in decreasing curve progression in 7/12 pre-adolescent patients.

Conclusion: Bracing was effective in delaying progression in preadolescent group. Patients with curves greater than 40 degrees may benefit from surgical stabilization. The older patient is at much less risk for paralytic scoliosis, but still requires routine examination.

Spine deformity subsequent to acquired childhood spinal cord injury (Mayfield et al, 1981)

Objective of the Study: To evaluate development of spinal deformities and types of treatment required in pre and post-adolescent patients with spinal cord injury.

Design: Retrospective review

Setting: Single site hospital

Participants: 40 children who incurred a spinal cord injury between birth and the age of 18 years were reviewed at two to 26.8 years (mean, ten years) after injury. Twenty-five were injured prior to adolescent growth spurt.

Procedures: Retrospective review of hospital charts and roentgenograms. Patients had to have minimum follow-up at least two years after injury. Twenty-two patients, returned for follow up evaluation and roentgenograms as part of the study. Patients were grouped by age at the time of injury (pre-adolescent growth spurt and post-adolescent) and paraplegia versus quadriplegia for comparative purposes.

Outcome Measures: Sitting roentgenogram

Results: All 25 patients injured prior to growth spurt developed paralytic spinal deformity; in all but one case, deformity was progressive. 17 patients ultimately required spinal fusion. Progressive paralytic spinal deformity was uncommon in post-adolescent patients; although history of thoracic or thoracolumbar laminectomy was always associated with increased kyphosis progression.

Conclusion: Management of spinal deformities is difficult with bracing; although it generally delayed need for surgical stabilization and fusion of the spine. Progressive paralytic spinal deformity was uncommon in the post-adolescent patient.

IMPLICATIONS FOR PRACTICE, EDUCATION and FUTURE RESEARCH

Practice:
- Historical data dictates that patients who sustain paralytic spinal cord injury prior to the adolescent growth spurt will develop a spinal deformity. As such, bracing should be considered for each of these patients.
  - Early initiation of bracing – prior to significant (less than 20 degrees) curve development – is associated with better outcomes.
  - Patients should be evaluated for bracing once medically appropriate and ready to progress to upright sitting.
  - Brace compliance is a primary limiting factor for successful outcomes. Identifying the least restrictive brace may be helpful in improving compliance and decreasing risk of skin breakdown.
- In patients who are injured after skeletal maturity, development of skeletal deformity is less common; however, scoliosis rates are reported in approximately 40-50% of cases. The need for bracing should be evaluated on a case by case basis.
  - Some evidence suggests that history of laminectomy increases development of scoliosis.

Education:
- Clinicians should be educated in the following areas:
  - Risk factors for development of scoliosis including the following: age at onset of paralysis, level of impairment, and surgical history; in addition to the role of muscle strength/imbalances and tone or spasticity on the development and progression of a skeletal deformity.
  - Thorough assessment of postural alignment, including pelvic and spinal alignment, as well as muscle strength and tone evaluations.
Available orthotic options including neoprene bracing, semi-rigid and rigid TLSOs; and the benefits of each. Additionally, how to ramp up wear time to increase tolerance.

Available positioning options within a seating system, in order to optimize spinal and pelvic alignment.

- Patient and family education should include the benefits/risks of wearing versus not wearing the brace; propping donning techniques and wear schedule in order to improve tolerance, as well as brace compliance.

Research:
- Research in this area is limited, and low level at best. Further research should be conducted to answer the following:
  - Bracing compared to a customized, supported seating system
  - Bracing compared to and/or paired with functional electrical stimulation
  - Semi-rigid compared to rigid bracing
  - Minimal wear times for successful outcomes