Original Clinical Article

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Sublaminar polyester band fixation construct in the treatment of neuromuscular scoliosis

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Abstract

Purpose Multiple fixation techniques exist for treating progressive neuromuscular scoliosis including pedicle screws, sublaminar bands/wires, hooks or a combination of instruments. Most sublaminar band constructs are supplemented with pedicle screws, hooks and/or sublaminar wires particularly at the top of the construct. There are no studies to date that describe an all/predominant sublaminar band construct. The purpose of this study was to investigate the outcomes of a sublaminar polyester band construct to treat neuromuscular scoliosis.

Methods A retrospective review was conducted of 32 cases of neuromuscular scoliosis treated with posterior spinal fusion using a sublaminar band construct between 2013 and 2016 by a single surgeon at a single centre. Preoperative, immediate postoperative and two-year follow-up radiographs and clinical records were reviewed. Sagittal, coronal and pelvic obliquity correction was measured. Blood loss, length of surgery and complications were recorded.

Results In all, 29 patients were included. Mean postoperative coronal plane correction was 57% (0% to 92%) and maintained at two-year follow-up. Mean sagittal balance was 2.3 cm (-2.5 to 6.4). Mean lumbar lordosis angle decreased by 7° (44° to 37°). Mean thoracic kyphosis angle increased by 9° (23° to 32°). Mean pelvic obliquity decreased by 50% (from 15° to 7°). There were four major complications (14%) and eight minor complications (21%). Mean blood loss was 1304 cc (250 cc to 2450 cc).

Conclusion Sublaminar polyester band fixation constructs provide a viable option in correction of deformity in patients with neuromuscular scoliosis with comparable outcomes with what is reported with other constructs.

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Introduction

Spinal deformity correction is a mainstay in the treatment of progressive neuromuscular scoliosis.[1] Multiple fixation devices exist including pedicle screws, sublaminar bands, sublaminar wires, hooks or a combination of such implants.[2,3] Pedicle screw and hybrid constructs have shown to be some of the most effective at deformity correction.[4-6] Pedicle screws can be difficult to place in some paediatric scoliosis patients due to hypoplastic pedicles and difficulty estimating screw trajectory in the severely deformed spine.[7-9] In addition, pedicle screws, especially those places in the thoracic spine, pose significant risk of injury to contiguous neural and vascular structures.[10] Sublaminar wires have fallen out of favour for some spine surgeons due to the potential for neurological complications.[11] Pedicle screws also require fluoroscopic guidance thus increasing patient radiation exposure. Sublaminar band constructs offer a fixation method that is technically easier to perform[12] as spinal lamina are more accessible than spinal pedicles. This is especially true in cases with hypoplastic/deformed pedicles.[8,9] The use of sublaminar polyester bands has been shown to be neurologically safe[13] and has been shown to not increase the chances of postoperative surgical site infections compared with other fixation constructs.[14]

In the current literature, most sublaminar bands constructs are supplemented with pedicle screws, hooks and/or sublaminar wires, especially at the most cephalic level of the construct, to ensure stable fixation.[13,15] The purpose of this study is to investigate the immediate and long-term outcomes of a predominant sublaminar polyester band construct when treating paediatric neuromuscular scoliosis.

Materials and methods

A retrospective review was conducted of consecutive cases of paediatric neuromuscular scoliosis treated with

posterior spinal fusion using a predominant sublaminar band (Medicrea, Rillieux-la-Pape, France) construct between 2013 and 2016 by a single surgeon (SR) at a single center (Children's Hospital of Orange County, CA, USA). Preoperative, immediate postoperative and two-year follow-up radiographs and clinical records were reviewed. Coronal deformity, sagittal deformity and pelvic obliquity were measured on preoperative radiographs. Correction of coronal and sagittal plane deformity, pelvic obliquity, presence of junctional kyphosis, blood loss, length of surgery and complications were reviewed from immediate postoperative clinical records and radiographs. Complications were classified as 'minor' (temporary/did not require a return to the operating room) or 'major' (required return to the operating room).[15]

Maintenance of coronal, sagittal and pelvic obliquity correction was measured on two-year follow-up radiographs. Thoracic kyphotic angles (TKAs), lumbar lordotic angles (LLAs) and a radiographic plumb line centred at C7 were used to evaluate sagittal balance and correction. Major curves were measured using the Cobb technique. Pelvic obliquity was measured using the lumbosacral angle as described by Allen and Ferguson.[16] Junctional kyphosis was measured on two-year follow-up lateral spinal radiographs.[17,18] All measurements were taken by a single individual (SK) who was a co-author on the study and who did not participate in the surgical cases. Radiographs were taken in the supine position for all patients who were wheelchair-bound and standing in ambulatory patients.

TKAs, LLAs, sagittal balance, major curves and pelvic obliquity were measured in each patient. Each of these measurements were taken preoperatively, postoperatively and at two-year follow-up. Differences between each measurement (preoperative to postoperative and postoperative to two-year follow-up) were recorded and percentage change was calculated. All other data (blood loss, levels of arthrodesis, complications) were extracted from each patient's chart.

Inclusion criteria consisted of all patients with neuromuscular scoliosis that were treated with a predominant sublaminar polyester band construct between 2013 and 2016. This was a consecutive series of all sublaminar band constructs performed during this time period that met the inclusion criteria. 'Predominant' sublaminar band constructs were defined as those that only had pedicle screws used at levels with spinal dysraphism. Patients with pedicle screws at levels other than those with deficient lamina were excluded. Patients without two-year follow-up were excluded. Institutional review board approval was obtained for this study. Microsoft Excel (Redmond, Washington, USA) version 16.15 was used for all data calculations.

Patients were placed in the standard prone position. Neuromuscular monitoring was used in all cases. No preoperative or intraoperative traction was utilized. A standard posterior approach to the spine was performed. Double sublaminar polyester bands were placed at all spinal levels with normal laminar anatomy. The double bands were passed once, separated from each other and one was used to instrument each lamina at each vertebral level. Pedicle screws were used at levels with deficient lamina. Reasons for a deficient lamina include spina bifida and surgical history of dorsal root rhizotomies. In addition, patients with intrathecal baclofen pumps required pedicle screws at the level of catheter introduction. The most level cephalad was augmented with an additional band that spanned two laminae. Pelvic fixation was performed in all cases using Galveston fixation or iliac screws[16] (Fig. 1). Inferior facet resection and decortication was performed at each level of the construct to mobilize the deformity and facilitate arthrodesis. The facet resection did not compromise the integrity of the lamina. The band connectors to the rods were positioned away from the facet to allow bone graft impaction to facilitate fusion. Blood loss minimization techniques used in all cases included intraoperative use of aminocaproic acid, hypotensive anesthesia and Cell-Saver autologous blood transfusion.

Results

In all, 32 patients with neuromuscular scoliosis who underwent segmental spinal instrumentation with predominant sublaminar band constructs were reviewed. A total of 26 of the 32 patients had all sublaminar band constructs and six had predominant sublaminar band constructs with pedicle screws only at levels with spinal dysraphism. All patients had been diagnosed with neuromuscular scoliosis from a variety of diseases (Table 1). In all, 28 of the 32 patients were classified as Gross Motor Function Classification System (GMFCS) 5.[19] Three patients were classified as GMFCS 4 and one patient was classified as GMFCS 1. Mean patient age at the time of surgery was 13.9 years (9.7 to 19.5). Of the 32 patients 15 were male and 17 were female. A total of 29 of the 32 patients underwent posterior spinal fusion from T2 to pelvis. The remaining three patients were fused from T1 to pelvis. The major curve preoperatively was a mean of 62° (25° to 112°; sd 20.9). Mean follow-up was 45 months (27 to 66). Three patients were not available for two-year follow-up. One patient passed away due to unrelated medical problems, one patient moved out of state and was not reachable via the contact information on record and the last patient was seen at two-year follow-up and was doing well clinically but was not able to complete radiographs. The data from the three patients not available for two-year follow-up was excluded from all data analysis.

All 32 patients had posterior spinal instrumentation with predominant or all sublaminar polyester band constructs (Fig. 2). Mean immediate postoperative coronal plane correction was 57% (0% to 92%; sd 13.4) and coronal plane

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Fig. 1 Anteroposterior and lateral radiographs demonstrating typical spinopelvic fixation used in this patient cohort.

correction was maintained at last follow-up (65% mean correction; 0% to 94%; sd 25%). The mean preoperative, postoperative and two-year postoperative major curve was 62.5° (25° to 112°, SD 20.9°), 25° (4° to 63°, SD 13.4°), and 21.5° (3° to 66°, SD 14.2°) respectively. One patient had a preoperative curve of 33° which was unchanged after surgery. At two-year follow-up the mean sagittal balance was 2.3 cm (-2.5 to 6.4; sd 2.9). Mean preoperative, postoperative and two-year follow-up lumbar lordosis angles were 44° (21° to 84°; sd 10.2°), 44° (10° to 73°; sd 12.8°) and 37° (10° to 59°; sd 13.5°), respectively. Mean preoperative, postoperative and two-year follow-up thoracic kyphosis angles were 23° (4° to 51°; sd 17.7°), 32° (3° to 56°; sd 12.4°) and 32° (12° to 55°; sd 12°), respectively. Average preoperative, postoperative and two-year follow-up pelvic obliquity angles were 15° (1° to 33°; sd 8.4°), 7° (0° to 21°; sd 5.5°) and 5° (0° to 18°; sd 4.5°), respectively. One patient developed junctional kyphosis postoperatively of the 29 patients available for two-year follow-up.

There were no intraoperative implant failures of 328 implanted devices. There were no cases of lamina fracture in any of the studied patients. There were four major complications in four patients (14%). These major complications consisted of two deep infections with cultures positive for pseudomonas, one postoperative seroma and one patient with a retained drain fragment which necessitated incision, irrigation and debridement in the operating room. There were eight minor complications in six patients (21%). The minor complications included dural tear (two), pulmonary oedema (one), contact dermatitis (one), superficial wound dehiscence (one), pneumonia (one), acute blood loss anaemia (one) and displacement of intrapelvic rod that did not require revision (one). In the case with the intrapelvic rod displacement, a subsequent hospital visit for a non-related medical issue occurred and the rod displacement was found incidentally. After reviewing the CT scan, it was noticed the one of the rods had protruded slightly from the bone but was not near any other vital

Table 1 List of diagnoses and number of patients with each diagnosis leading to neuromuscular scoliosis

Diagnosis	Patients, n
Cerebral palsy	15
Duchene muscular dystrophy	3
Rett Syndrome	2
Charcot Marie Tooth	1
Congenital muscular dystrophy	1
Congenital Brain Deficiency	1
Congenital neuroaxonal dystrophy	1
Mitochondrial disorder	1
Trisomy 8	1
Prader-Willi Syndrome	1
Ullrich muscular dystrophy	1
Spinal muscular atrophy 2	1
Leptomyelolipoma	1
Spina bifida	1
Spinal cord injury	1

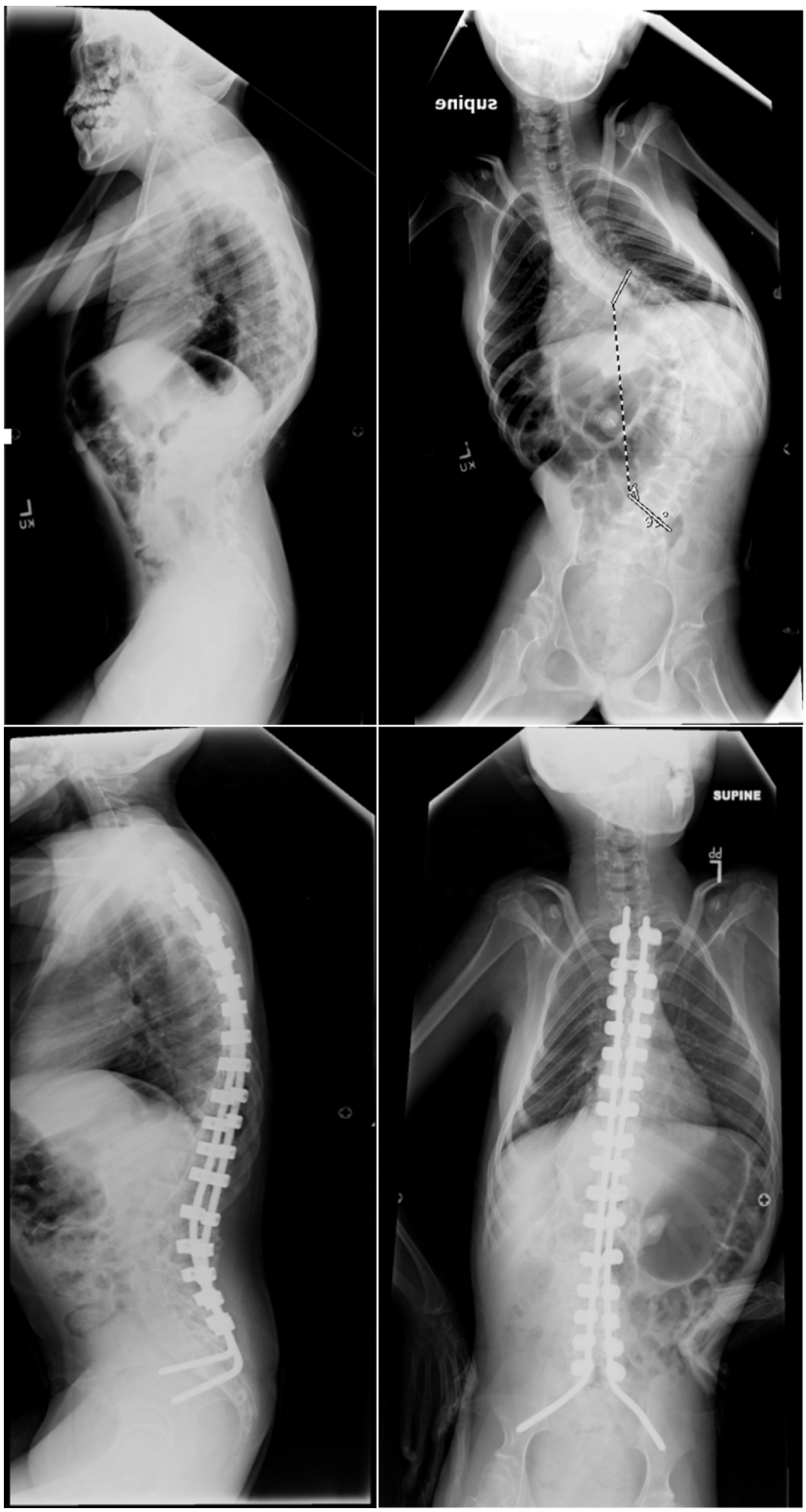

Fig. 2 Anteroposterior and lateral preoperative and two-year follow-up radiographs demonstrating all sublaminar band construct.

structures. We, therefore, elected to not revise the rod. Postoperative imaging was reviewed and there was no indication of rod migration from the postoperative images. However, CT scans are not routinely ordered postoperatively and perhaps if there was one ordered we would have noticed this rod position. Mean blood loss was 1304

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cc (250 cc to 2450 cc). Mean net estimated blood loss was 771 cc (125 cc to 1525 cc). Mean net estimated blood volume loss was 33% (5% to 71%). Mean surgical time was 297 minutes (223 minutes to 369 minutes).

Discussion

Results from this study demonstrate that acceptable outcomes may be obtained with the use of an all or predominant sublaminar polyester band fixation construct in correction of deformity in patients with neuromuscular scoliosis. Postoperative coronal deformity was corrected by 57% on average and maintained at two-year follow-up (65%). The difference between the percentage correction between immediate postoperative studies and two-year studies could be explained by normal measurement error. The average percentage correction in this study compares with other studies using hybrid constructs to correct severe scoliosis.[20] Six of the 28 patients included in the study had a postoperative coronal correction greater than 75% which is comparable with correction seen in all pedicle screw constructs.[6] Other measures of deformity correction including the TKA, LLA and pelvic obliquity angle were improved and maintained postoperatively and at two-year follow-up, respectively.

There was a large range of correction of the major curve postoperatively and at two-year follow-up. Although the exact reason for this large range is unknown, this could be explained by a few patients with a more rigid curve. If a more rigid curve was found intraoperatively, perhaps a decision against more aggressive correction was made in order to avoid complications. This explanation is one possibility to account for the large range of major curve correction.

There was also a large range in estimated blood loss among this cohort. The exact cause of this wide range is likely attributable to each individual surgery. Possible explanations include higher intraoperative blood pressures, increased bleeding from bony surfaces after facetectomy, and a given patient's individual medical problems and inaccurate surgeon estimation of blood loss.

Sublaminar bands provide multiple advantages to the operating surgeon including ease of placement, shorter operating room times and decreased or no radiation risk. Another advantage of sublaminar bands is the ability to achieve bicortical fixation as opposed to unicortical fixation achieved with pedicle screws. This is particularly important in patients with neuromuscular scoliosis as these patients are almost always osteopenic. Sublaminar bands can provide a stout construct in treating patients with neuromuscular scoliosis. In addition, estimated blood loss was decreased or comparable with that reported in the current literature when using pedicle screws or hybrid techniques.[8]

In a previous study, Desai et al[12] showed an increase in neurological complications with the use of sublaminar polyester bands. They noticed these neurological complications during passage of the bands under the lamina and attributed these neurological deficits directly to the passage of the polyester bands. In our cohort, there was only one patient who developed a neurological complication. This complication was a loss of motor potentials at the end of the case after all instruments were in place. In this patient, a wake-up test was performed and motor to her bilateral lower extremities was still absent. An emergent postoperative CT scan was ordered which showed no reason for neurological injury related to the implanted devices. This patient's motor to her lower extremities did completely resolve during the patient's postoperative course. This patient was one of the patients who was lost to follow-up after her one-year follow-up appointment so longer-term outcomes were not able to be obtained. There was no reason to believe that this patient's neurological complication was directly related to the sublaminar polyester bands. We agree with previous studies[13] that sublaminar bands, when used by an experienced surgeon, are a safe and effective way to correct both mild and severe scoliosis.

The cases included in this study were performed by a single surgeon at a single centre and, therefore, operative technique was standardized across all patients. This could be considered a strength of the study. Other strengths include the fact that multiple aspects of typical neuromuscular scoliosis deformity were analyzed, including coronal and sagittal deformity, and pelvic obliquity was evaluated. In addition, this study not only focused on radiographic outcomes and deformity correction but also investigated clinical outcomes such as complications, returns to the operating room and blood loss. None of these patients required preoperative or intraoperative traction to obtain deformity correction.

The relatively small sample size of patients included in this study could be seen as a weakness to the study. In addition, the fact that surgeries were performed by a single surgeon in a single facility who is very proficient with this technique may generate better outcomes than would be seen in the general population of surgeons due the operating surgeon's experience. Another potential weakness could be that our sagittal balance measurements may not reflect the true sagittal balance when the patient is sitting or standing. Radiographs were taken standing if the patient was able to stand independently, sitting if the patient was able to sit independently, otherwise they were taken supine. All but one of the patients included in the study were unable to sit or stand unsupported. We believe that a supine radiograph was the best way to standardize positioning for all patients. Despite these potential weaknesses, these findings still provide valuable data demonstrating the potential for better or satisfactory outcomes that may be seen in cases where sublaminar band constructs are used for deformity correction.

We do not believe that the method of using sublaminar bands at all levels except those with deficient lamina

caused a selection bias. There was no judgement call on which device was to be used as the patient's anatomy dictated which device would be used.

These findings suggest that a predominant sublaminar polyester band construct with band fixation at the most cephalad level of the construct is a viable option for spinal deformity correction in paediatric patients with neuromuscular scoliosis. Further, this study shows that sublaminar band constructs are safe and low-morbid options for neuromuscular scoliosis correction. Future studies with larger patient cohorts would be beneficial to compare outcomes with the present study.

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COMPLIANCE WITH ETHICAL STANDARDS

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ETHICAL STATEMENT

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors. All participants involved in the study were given the opportunity to not participate in this study.

Informed consent: Informed consent was obtained from all individual participants included in the study. This study was submitted to our institution's institutional review board and was granted approval.

ICMJE CONFLICT OF INTEREST STATEMENT

SR reports consultancy to Medicrea Spine and OrthoPediatrics Spine outside the submitted work.

The other authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

SK: Study Design, Data Collection, Statistical Analysis, Manuscript Preparation.
SR: Study Design, Data Collection, Manuscript Preparation.
ER: Study Design, Data Collection, Manuscript Preparation.

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