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TECHNICAL NOTE - PEDIATRIC SPINE

Carbon fibre instrumentation for scoliosis surgery in children with spinal cord intramedullary tumours: a novel technical note

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Abstract

Introduction Scoliosis in children is the most common spinal deformity seen by general practitioners, paediatricians and spinal surgeons. Progressive scoliosis can result in the development of a worsening deformity and cosmesis. Patients usually present with aesthetic concerns. Progressive scoliosis that fails conservative management may require or be offered surgical intervention. Intramedullary tumours may be associated with scoliosis. Management of patients with these dual pathologies can be challenging. Classical scoliosis instrumentation utilising titanium implants impairs post-operative MRI evaluation with metal artefacts. Carbon fibre instrumentations has the potential to reduce the imaging metal artefacts but has not been described in scoliosis correction.

Methods Surgical technical note describing correction of scoliosis in two adolescents' with intradural tumours utilising carbon fibre implants.

Results We developed a hybrid approach where we initially used titanium implants to manipulate the deformity then replaced the construct with carbon fibre implants in the same setting to maintain the deformity correction with good follow up outlook.

Conclusion Our technique is robust, safe and replicable. It enabled appropriate post-operative MRI evaluation of the neural structures with a reduced risk of metal artefacts.

Keywords Scoliosis · Pilocytic astrocytoma · Surgery · Carbon fibre · Titanium alloys

Introduction

Surgical intervention is indicated for progressive scoliosis in children. Pedicle screw-based posterior spinal fusion surgery has become the gold standard for the treatment of scoliosis [5]. This is because the pedicle screws can transmit force through the pedicle to the vertebral bodies to directly obtain a better correction. [5, 7] Direct vertebral derotation (DVD) and rod derotation are the two major manoeuvres used to correct spinal deformities intraoperatively [10]. The most popular spinal material implants are metals such as titanium and its alloys [11]. Titanium implants provide sufficient stiffness to correct and stabilise the spine; however, the material carries disadvantages. Titanium implants significantly impair evaluation of postoperative magnetic resonance imaging (MRI) by metal artefacts. In patients with spinal cord tumours, it is crucial that imaging can reliably be performed for diagnostic, postoperative and long-term follow-up purposes. The implants metal-induced artefacts on magnetic resonance imaging (MRI) will result in signal loss, pile-up artefact and geometric distortion [3].

To overcome the artefacts of metallic implants, non-metallic, high-strength, carbon fibre-reinforced polyetheretherketone (CF-PEEK) pedicle screws have been developed [6]. CF-PEEK has a lower density than titanium (similar to bone), thus producing fewer artefacts in MRI. [6, 12] As such, CF-PEEK allows postoperative evaluation of neural structures and spinal tumours. Such implants have been successfully used in instrumenting the spine following decompression for metastasis [12]. Nonetheless, the force

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applied in scoliosis correction surgery is high, and CF-PEEK implants may fracture in bending moments.

Scoliosis in children with concomitant intramedullary tumour is uncommon.[14]Surgery for the two pathologies and follow-up with MRI scans can be strenuous. In this report, we describe a novel scoliosis surgery technique in two paediatric scoliosis cases that were incidentally found to have spinal cord pilocytic astrocytoma. In order to resect the tumour, perform scoliosis surgery and allow satisfactory follow-up imaging with MRI; they had tumour resection then underwent scoliosis surgery where titanium implants inserted. The spine deformity was corrected before replacing the titanium implants with CF-PEEK.

Methods

This is a surgical technical note of utilising carbon fibre pedicle screws in correction of scoliosis in patients with intradural intramedullary tumours.

Clinical presentations

Case 1

A 10-year-old boy presented with 2-month history of back pain that settled on non-steroidal anti-inflammatories and stopping playing PE and games. His neurological examination was entirely normal. He had no family history of scoliosis. He had a left-sided thoracolumbar scoliosis with a Cobb angle measured 18° on plain x-ray at the time.

He was followed up on yearly basis with plain x-rays which showed progression of his curve. His pre-surgery plain x-ray at the age of 15 showed progression of the smooth segment scoliosis concave to the right centred on T8-9. Approximate Cobb angle was 57° (Fig. 1A). His pre-scoliosis surgery MRI showed the known left thoracolumbar scoliosis centred on T8, with no pedicular abnormality or paraspinal mass. Even so, there was an extensive syrinx with intramedullary heterogenous enhancing predominantly cystic mass lesion within the low cervical and thoracic spinal cord (Fig. 1B–E).

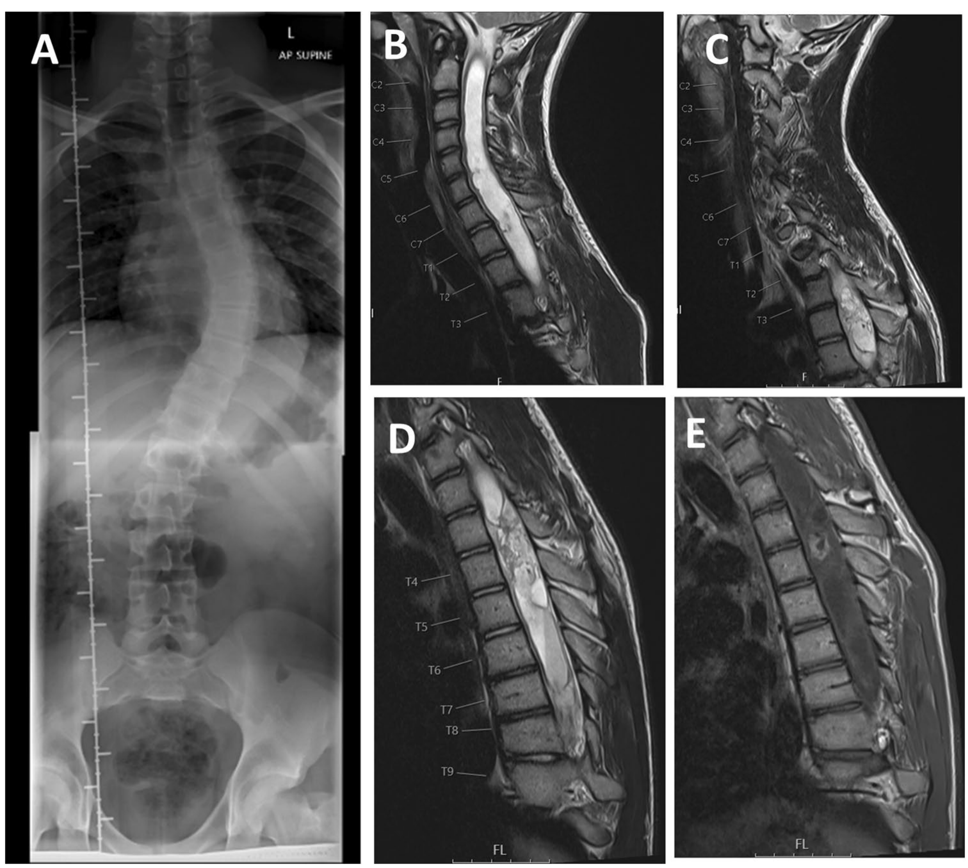

Fig. 1 Pre-surgery images for case one. **A**) Pre-surgery X-ray whole spine which shows left-sided thoracolumbar scoliosis centred at T8/9. **B**) Sagittal T2W MRI image showing the cervical syrinx. **C**) Sagittal T2W MRI image showing the upper thoracic intradural tumour. **D**) Sagittal T2W MRI image showing the mid thoracic intradural tumour. **E**) Sagittal post contrast T1W MRI image showing the enhanced part of the thoracic intradural tumour

Case 2

A 13-year-old boy presented after noting the presence of a prominence over the posterior aspect of his back. He had no pain, and his neurological exam was entirely normal. There was no family history of spine deformity. His whole spine x-ray revealed a long segment thoracolumbar scoliosis convex to the right, with its apex centred on L1. The Cobb angle was 49° with no underlying vertebral anomaly seen. A year later, his scoliosis was progressing, and surgery was offered (Fig. 2A–B). His pre-surgery MRI showed a mid-thoracic intramedullary mass with associated extensive syrinx formation throughout the cord (Fig. 2C–D). He was then followed up for his scoliosis on a yearly basis with progression of his curve. Four years down the line at age 17, the patient had a Cobb angle of 88° and decided to go ahead with surgery.

Results

Case 1

The patient underwent joint operation with thoracic laminectomies (T2–5) with near total excision of the thoracic intradural tumour under neurophysiological monitoring. He then had correction of the scoliosis at the same setting (see the technical procedure below). His histopathology sample demonstrated WHO grade I pilocytic astrocytoma that is BRAF negative. He had an uneventful post-operative period and was discharged on day 5. The follow-up images were satisfactory with no recurrence of the tumour 5 years down the line. He has fused, and his spine x-ray demonstrated stable appearance of the corrected scoliosis (Fig. 3).

Case 2

The patient underwent thoracic laminectomies (T6–7) and debulking of the thoracic intradural tumour under neurophysiological monitoring. His histopathology sample demonstrated WHO grade I pilocytic astrocytoma. He endured an uneventful post-operative period and was discharged home on day 6. He then underwent a scoliosis correction under neurophysiology monitoring. The surgical technique is described below. He had follow-up, MRIs and x-rays (Fig. 4) and had no further surgical intervention for his tumour.

Both patients presented with progressive scoliosis without neurological deficits. Their images revealed intradural tumours. Their surgery and initial post-operative care were uneventful as described earlier. Case one had satisfactory follow-up images with no recurrence of the tumour 5 years down the line. He has fused, and his spine X-rays demonstrated stable appearance of the corrected scoliosis (Fig. 3).

Case two had 5-year follow-up so far, MRIs and X-rays (Fig. 4) and had no further surgical intervention for his tumour and continued to be on regular follow-up for his pilocytic astrocytoma.

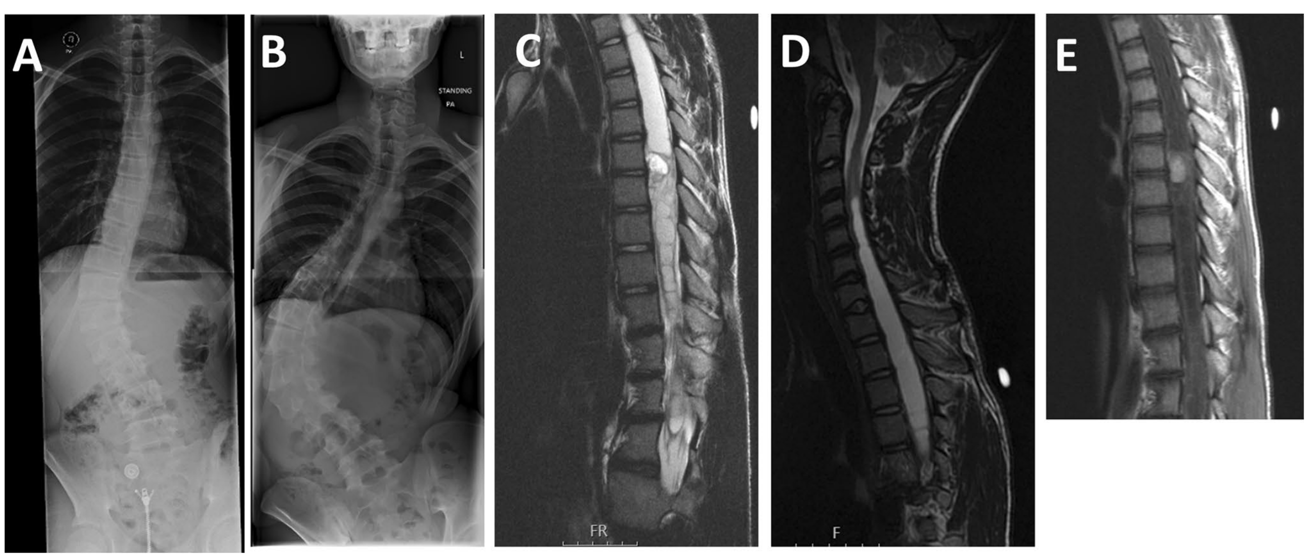

Fig. 2 Pre-surgery images for case two. **A**) Diagnosis whole spine X-ray. There is a long segment thoracolumbar scoliosis convex to the right, with its apex centred on L1. **B**) Pre-surgery whole spine X-ray which shows progression of the scoliosis curve. **C**) Sagittal T2W MRI image shows the thoracic intradural tumour. **D**) Sagittal T2W MRI image shows the cervical syrinx. **E**) Sagittal post contrast T1W MRI image shows the enhanced part of the thoracic intradural tumour

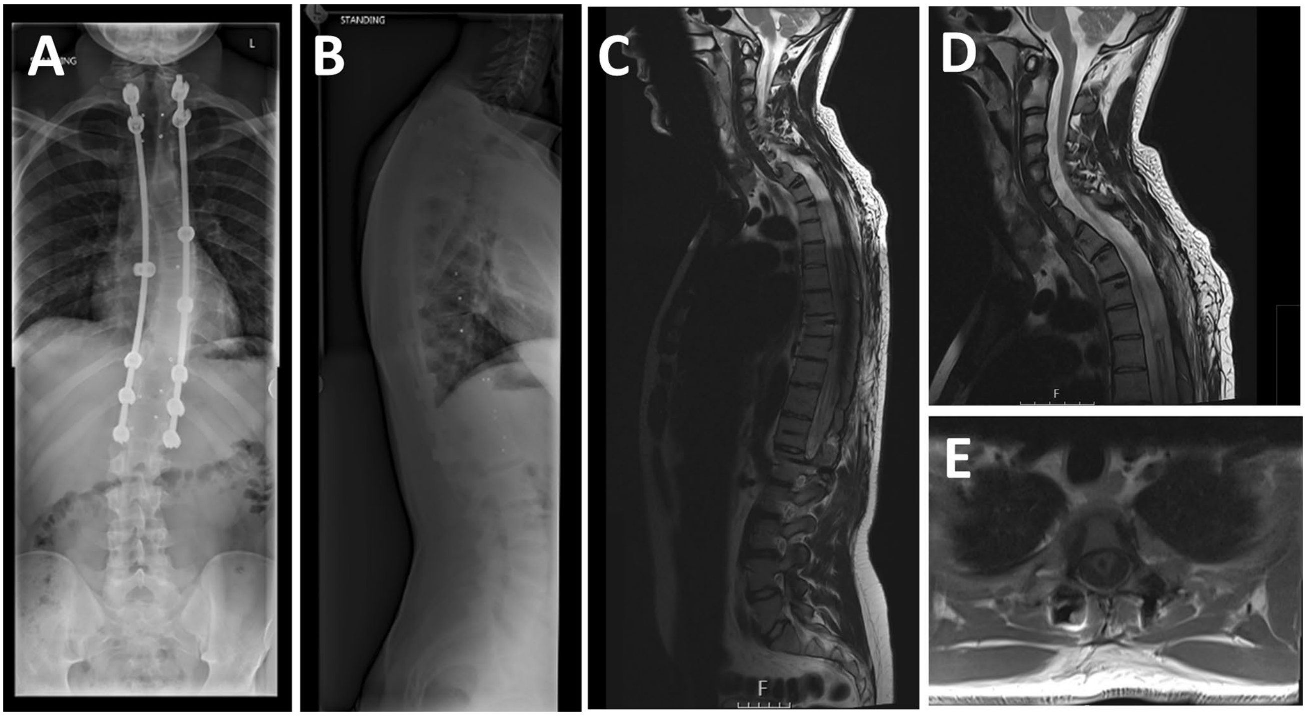

Fig. 3 Latest follow-up images for case one. **A**) Follow-up AP whole spine X-ray which shows the corrected scoliosis. **B**) Lateral whole spine X-ray which shows the carbon fibre screws. **C**) Follow-up sagittal T2W MRI whole spine image. **D**) Sagittal T2W MRI C-spine and upper thoracic image showing resolution of the cervical syrinx. **E**) Axial T2W MRI mid thoracic image shows the reduced artefact from the carbon fibre screws

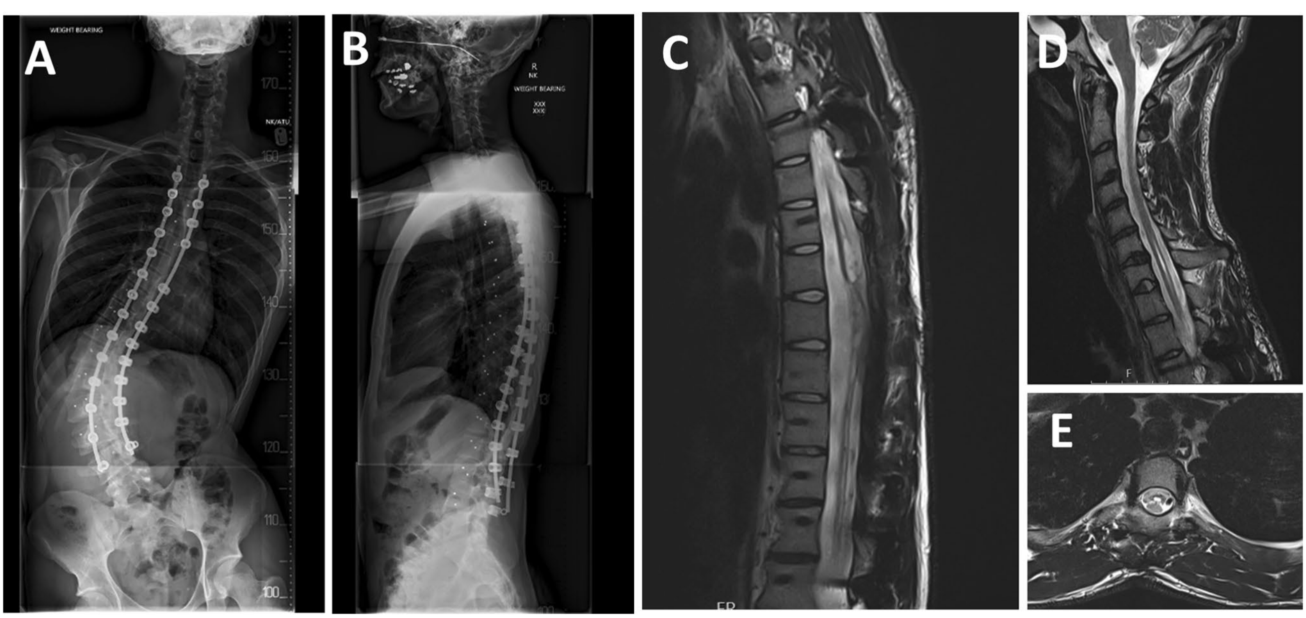

Fig. 4 Latest follow-up images for case two. **A**) Follow-up post-surgery AP whole spine X-ray. **B**) Lateral whole spine X-ray which shows the carbon fibre screws. **C**) Follow-up sagittal T2W MRI thoracic spine image. **D**) Sagittal T2W MRI C-spine and upper thoracic image showing resolution of the cervical syrinx. **E**) Axial T2W MRI mid thoracic image shows the reduced artefact from the carbon fibre screws

Surgical technique

After consent and adequate pre-operative preparations, the patients had general anaesthesia. They were placed prone on Allen spinal table. Antibiotics prophylaxis was administrated at induction of anaesthesia. Neurophysiology monitoring of somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs) were employed before and throughout the surgery. Red blood cell salvage was used. Following surgical exposure of the dorsal spine, polyaxial titanium pedicle screws were sited on the concavity of the curve using a freehand technique. Facetectomy was carried out at each segmental level to assist in mobilising the spine and facilitate correction of the curvature. A 5.5-mm titanium rod was contoured and applied to the screws on the concavity and a Cotrel-Dubousset manoeuvre (direct vertebral derotation plus disc levelling) applied to facilitate correction of the scoliosis. Once this was achieved, icotec carbon fibre screws (5.5 mm × 30 mm at T2 and T3 (rostrally), 5.5 mm × 40 mm at the level of the apex and 5.5 × 45 mm screws at either sides of the apex) were inserted in the pedicles on the convexity of the curve using high screw density (i.e. a screw at each segmental level). Carbon fibre-reinforced polyetheretherketone (CF/PEEK) pedicle screws (icotec ag, Industriestrasse 12, 9450 Altstätten, Switzerland) are radiolucent and non-magnetizable and thus allow to minimise imaging artefacts in CT and MRI imaging. A titanium rod was inserted and set screws applied and torqued to lock the rod on the convex side of the construct (icotec carbon fibre screws side). Now that the scoliosis correction had been achieved, the titanium concave screws and rod construct were removed and exchanged for an icotec carbon fibre screw construct (5.5 mm × 30 mm for T2 and T3 (rostrally), 5.5 mm × 40 mm screws at the apex and 5.5 mm × 45 mm screws at either sides of the apex) (icotec ag, Industriestrasse 12, 9450 Altstätten, Switzerland). The instrumentation was performed between T2 to L2 in case one and T3 to L4 in case two. Finally, bony decortication, wound washout with copious amount of 0.9% warm saline, antiseptic (betadine- 1 L) and another washout with warm 0.9% saline were used (6 L in total). Epidurals for post-operative analgesia were inserted at upper thoracic and lower lumbar ensuring that 6 cm was rostrally in the epidural space. Autologous graft in addition to 1 g of Vancomycin powder was applied to the decorticated spine. Wound drains inserted on suction and wounds closure were completed in layers.

Discussion

We describe the use of CF-PEEK pedicle screws in scoliosis surgery in a step wise manner utilising titanium implants first, correcting the deformity and replacing the titanium screws with CF-PEEK as described above. This resulted in a substantial reduction of MRI artefact areas on vertebral surfaces, which significantly improved the postoperative evaluation of the spinal cord soft tissue, and thus provided a substantial follow-up benefit.

Children with scoliosis and concomitant incidental intramedullary pilocytic astrocytoma is rare. The prevalence of spinal deformity on presentation of patients with intramedullary spinal cord tumours has been reported in case series between 20 and 33%. [1, 9] Usually, these patients present with symptoms and signs related to the spinal cord tumour and not incidentally. In our cases, the patients had no neurological deficits and MRIs were requested as part of the workup for scoliosis surgery. Likely the tumours and their syrinxes contributed to the worsening of the scoliosis angles. However, the patients had no neurological deficits at the time of scoliosis diagnosis, and as such we referred to the tumours as incidental. Scoliosis surgery in patients with significant intramedullary tumours can be complex and challenging. Given that the patients scoliosis were progressive and the tumours required surgical intervention and life-long follow up, two main questions have risen: which surgery to do first and what implants to use?

CF-PEEK pedicle screws have only recently become available, and PEEK and reinforced PEEK composites as a material for screw and rod constructs have been suggested to have the potential to overcome major drawbacks, such as artefacts, of standard titanium [2, 12]. In the previous studies, the authors described the use of CF-PEEK pedicle screws for stabilisation of patients with metastatic spinal tumours and those with lumbar spondylosis in comparison with standard titanium alloy implants [2, 12]. They found that postoperative CT and MRI scans showed reduced artefacts in patients who received CF-PEEK pedicle screws and allowed better assessment of the neural structures. Although methods such as Slice Encoding for Metal Artefact Correction (SEMAC) [8] and Multi-Acquisition Variable Resonance Image Combination (MAVRIC) [4] may improve image quality and decrease the extent of metal artefact, the utility of these methods as an appropriate diagnostic and follow-up tool in patients with metal implants remains to be validated [11]. The use of CF-PEEK can be used in patients that require stabilisation and long-term spine imaging for diagnostic and follow-up purposes. However, to our knowledge, the use of CF-PEEK for deformity surgery, as in our cases, has not been described before. This is perhaps due to the nature of deformity surgery; the force applied in scoliosis correction is high, and as such carbon fibre implants may fracture or fail. Therefore, we believe a hybrid approach where an initial titanium implants are applied to the concave part of the curve, correction is made and then carbon fibre implants are applied to the other side, followed by replacing the initial titanium implants with CF-PEEK, is a reasonable practical option. Indeed, this approach was performed in the two cases reported here. Both have been followed up for at least 5 years so far with a minor implant issue in case two. He had asymptomatic loss of fixation at the distal two screws due to loosening of end caps. They had serial quality MRI imaging for their pilocytic astrocytoma follow-up.

Our patients had tumour surgery first followed by scoliosis correction. Case one had both operations within the same sitting, while case two had the tumour surgery first then was followed up and later had his scoliosis correction 4 years later. The delay in performing scoliosis surgery in case two was due to unavailability of CF-PEEK implants at the time of the indexed tumour surgery. Our patients had no neurological deficits; nevertheless, the incidental intramedullary tumours with their syrinxes were large enough to warrant neurosurgical intervention. It was decided to go ahead and resect the tumours first. Performing surgical resection of the intramedullary tumours followed by scoliosis correction in the same hospital admission is perhaps the preferred option should this be possible. Our second case's curve progressed 10° after the tumour surgery. A preoperative spinal deformity has been identified as a risk factor for progressive deformity following surgery for intradural spinal tumours [13]. The underlying neuromuscular dysfunction might be part of the pathophysiology. As such, the irreversible changes in musculoskeletal function may also aggravate postoperative spine scoliosis [1]. There has been a report of two cases of long-segment intramedullary tumours complicated with scoliosis who had surgical intervention as a single-stage tumour resection followed by scoliosis correction. [14] However, in the previous report, the patients presented with neurological deficits, and CF-PEEK was not used in the scoliosis correction surgery.

In conclusion, we report a novel technique for correction of scoliosis in children with additional spinal cord tumours. Tumour resection followed by scoliosis surgery during a single-stage operation can be employed. Correction of the spine deformity utilising a combined approach by inserting titanium screws first followed by carbon fibre screws is a practical option with good outcomes. This allows satisfactory post-operative MRI evaluation of the neural structures with a reduced risk of metal artefacts.

Declarations

Ethics approval The use of carbon fibre instruments in scoliosis surgery was approved by our institution.

Consent to participate No identifiable data is presented.

Conflict of interest The authors declare no competing interests.

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