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CASE REPORT

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Early Outcomes of Staged Combined Halo-Pelvic Traction and All-Posterior Kyphectomy for Severe Kyphotic Deformity

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ABSTRACT

Severe kyphotic deformity is one of the sequelae of tuberculosis of the spine. When left untreated, patients may develop restrictive lung and heart disease and even neurologic deficits. Surgery is complex and risky, especially in young children. Halo-pelvic traction is a technique reported to decrease complexity, blood loss, operative times, and complication rates of definitive fixation of severe deformities; however, the technique has not been used locally.

This is a case report on a 6-year-old with severe kyphotic deformity secondary to tuberculosis of the spine. The aim was to provide novel insights into the design and application of the halo-pelvic traction construct, combined with an all-posterior surgical technique to achieve deformity correction.

The halo-pelvic traction was able to achieve 26 degrees (35.13%) correction over 35 days with an average daily angular correction of 0.72 degrees per day and daily lengthening at 1.52 mm per day. The patient was able to ambulate with assistance at two weeks and ambulate without assistance at three weeks on the traction construct. At six weeks, vertebral column resection and definitive fixation through an all-posterior approach were done with final angular correction of 49 degrees (66.21%). The halo-pelvic construct was maintained as an adjunct to fixation and will be maintained until fusion.

The combined two-staged approach of halo-pelvic traction and vertebral column resection through an all-posterior approach has proven to be effective in this pediatric patient with severe kyphotic deformity.

Keywords. kyphosis, spine, tuberculosis, halo-pelvic traction, traction, external fixators, child

INTRODUCTION

The spine is the most commonly affected site in skeletal tuberculosis, accounting for approximately 50% of cases.[1] When left untreated, tuberculosis eventually destroys anterior vertebral bodies, leading to kyphosis. As many as 40% of kyphotic deformities in children worsen over time. In children, growth potential also increases the risk for progression of the deformity due to the crankshaft phenomenon.[2]

Severe kyphotic deformity in very young patients presents a significant challenge. When neglected, the deformity may limit thoracic cavity volume and diaphragmatic excursion, resulting in compromised ventilation. Patients may also develop right ventricular hypertrophy and failure as a consequence of long-standing hypoxemia and pulmonary hypertension.[3] Neurologic deficits can present in up to 41% of patients with tuberculosis of the spine in severe deformities.[4] Symptoms may manifest initially as pain, numbness, and a subtle change in gait, and later progress to quadriplegia and loss of bowel and bladder control.[2]

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A multi-drug treatment regimen under direct supervision remains the standard of care in treating tuberculosis. Surgery is performed on patients with kyphosis more than 60 degrees and in pediatric patients with "spine-at-risk signs."[2,5]

Management of severe kyphotic deformities can be complex and risky, especially in young children. In children, instrumentation is possible but challenging. Vertebral bodies remain mostly cartilaginous until secondary ossification begins at puberty. The pedicles are small, and the potential length of screws may be short, limiting purchase.[6] Cases that require long posterior fusion are also at risk of the crank-shaft phenomenon due to the remaining growth potential.[7]

Recent techniques focus on a single-staged approach for acute correction. However, this approach entails complex osteotomies and acute deformity correction while working around an exposed spinal cord. This is accompanied by the risk of neurological, vascular, and pulmonary complications in up to 40% of patients.[8] Several traction techniques have been developed to promote gradual improvement in the deformity before definitive fixation and reduce complications, complexity, blood loss, and operative time.[9-15] With gradual correction of the deformity, the spinal cord, its blood supply, and other soft tissues are able to adapt.

The halo-pelvic traction and halo-gravity traction are techniques described in the literature. While both techniques are able to correct deformities and decrease complications, a recent study by Zhou determined that halo-pelvic traction was able to achieve more deformity correction over a shorter duration and decrease the need for a three-column osteotomy while having no significant difference in complication rates compared to halo-gravity traction.[14]

There are limited studies on its use in young children. Thus, this case report aimed to describe the development of the construct, the surgical technique, and the short-term radiological and clinical outcomes of halo-pelvic traction in the management of severe kyphotic deformity from spine tuberculosis in a 6-year-old.

CASE

We present the case of a 6-year-old boy (height 89.5cm, weight 13.2 kg (Z < -3, WHO), BMI 16.5 kg/m^2) with a four-year history of gradually progressing back and chest deformity (Figure 1). One year before consultation at the orthopedic outpatient department, the patient had a cough and fever and was diagnosed as a case of presumptive tuberculosis, but he was not started on anti-Koch's therapy. He developed an

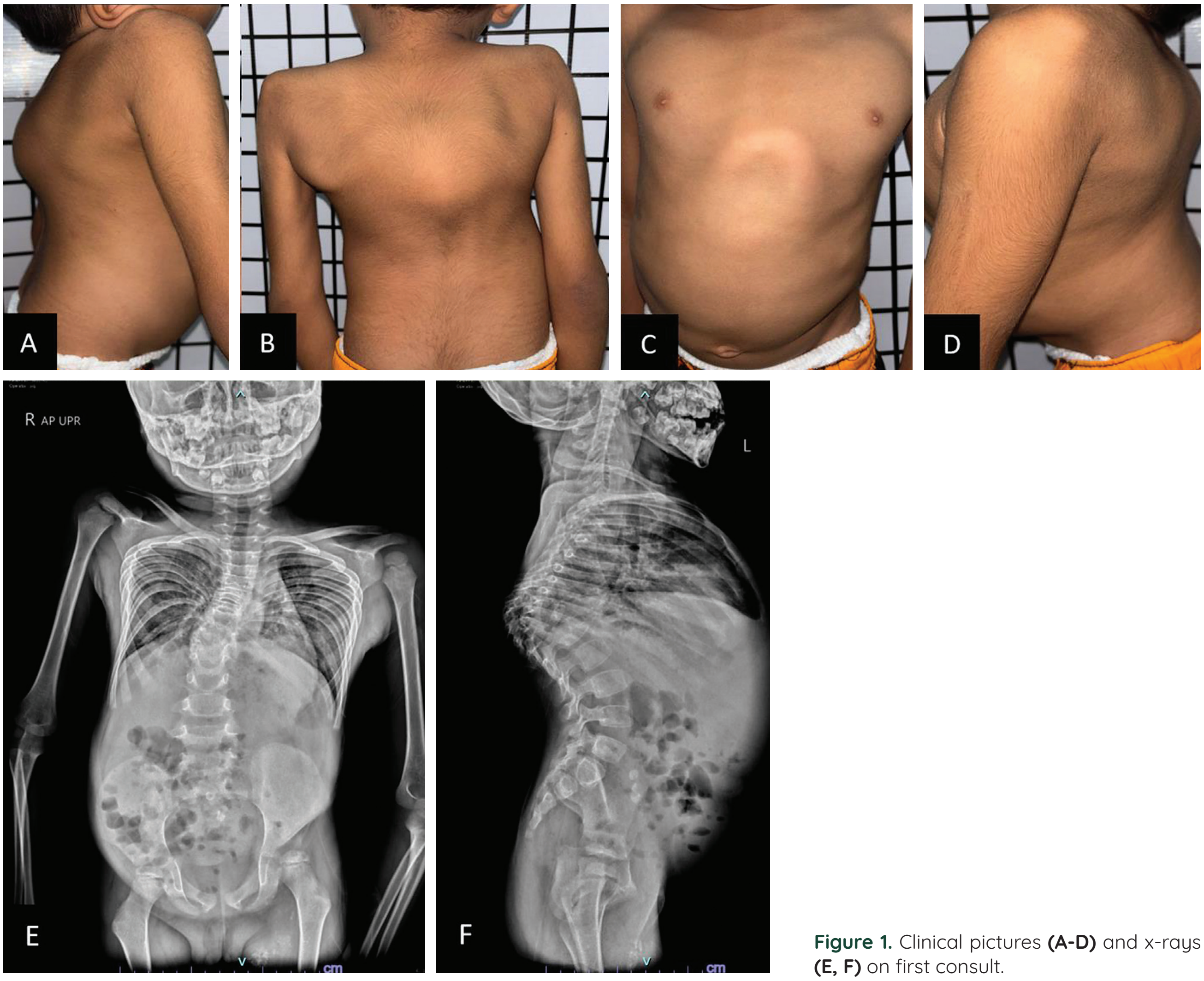

Figure 1. Clinical pictures **(A-D)** and x-rays **(E, F)** on first consult.

Figure 2. Halo-pelvic traction construct assembled prior to surgery.

abscess on the left proximal thigh and underwent incision and drainage. He was then started on anti-Koch's regimen and was referred to our service for a severe kyphotic deformity at the thoracolumbar junction. The patient had no sensory and motor deficits, was normoreflexive, and ambulatory without aid. He had 74 degrees of kyphosis at the thoracolumbar junction, which improved to 53 degrees while lying supine. He had no available MRI. Infection parameters done at three months of anti-Koch's therapy (CBC, ESR, and CRP) were within normal values. Nutritional parameters (albumin, calcium, and vitamin D) were also within normal values. During spirometry, he had difficulty sustaining breaths due to poor respiratory effort.

The halo-pelvic traction construct was designed by one of our co-authors (GCB) (Figure 2). This consisted of a halo ring measuring 18 cm in diameter, a pelvic ring and a dummy ring both measuring 26 cm in diameter, and connecting rods. Pins were used to fix the halo ring to the cranium and ilium. The dummy ring at the level of the xiphoid process was floating and served to reduce the vertical offset of the construct to provide better stability while lengthening. The construct was pre-assembled into anterior and posterior halves a few days before surgery for ease of application during the procedure. The construct weighed 2.6 kg, which was 21% of the patient's body weight.

With the patient supine under general anesthesia, the halo ring was applied to the cranium with 8 pins at 6 lbs torque. The pin configuration was adapted from Cetinkaya et al.[15] For the anterior construct, two pins were applied laterally at the supraacetabular level, and two pins were applied 30 degrees from the coronal plane at the anterior superior iliac spine (ASIS). These were attached to the halo ring with connecting rods. The patient was then flipped prone. For the posterior construct, two pins were applied 20 degrees from the midline at the posterior superior iliac spine (PSIS) and attached to the halo ring with connecting rods (Figure 3). Immediately after application of the construct, the kyphotic angle was measured at 68 degrees. No acute correction was done at this stage.

One day after application of the halo-pelvic traction, the patient reported good pain control and was able to sit up (Figure 4). Distraction was initiated on day two, initially at a rate of 3 mm per day. However, the patient was unable to

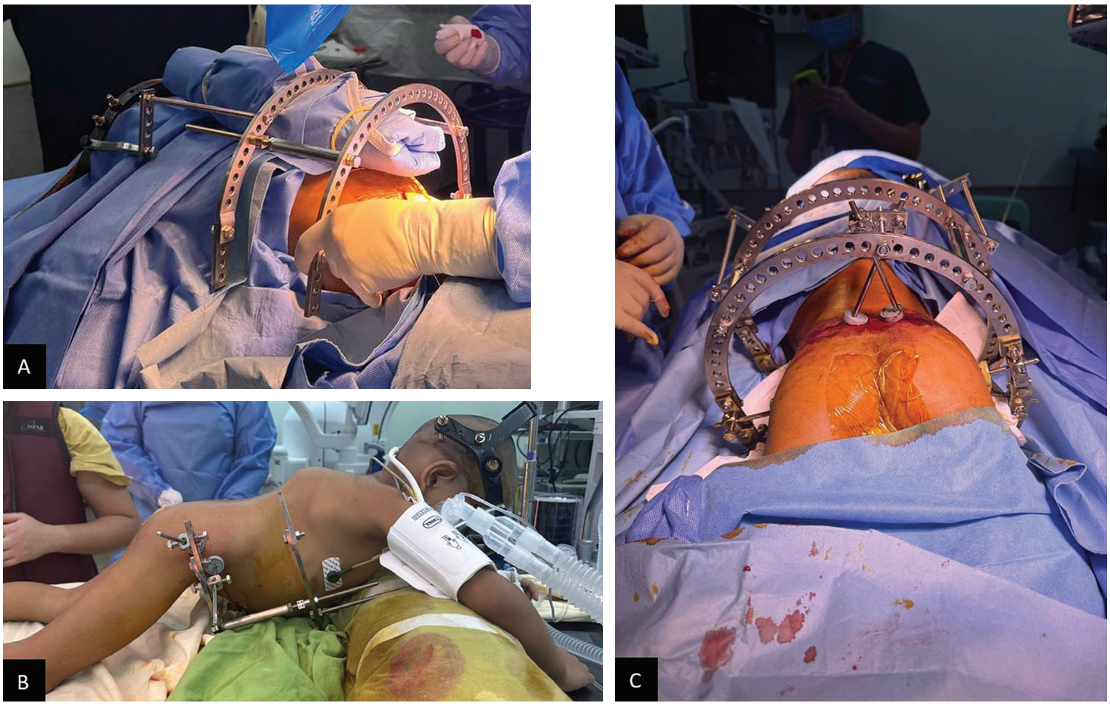

Figure 3. The anterior construct was connected to the halo ring. Pins were inserted at the supraacetabular area and anterior superior iliac spine **(A)**. The patient in prone position with multiple pillows for padding **(B)**. The posterior construct was connected to the halo ring and pins inserted at the posterior superior iliac spine **(C)**.

Figure 4. Patient was able to sit up one day after application of the halo-pelvic traction **(A-C)**. Patient lying down in bed **(D)**.

tolerate distraction due to pain in the pelvis, hence the rate of distraction was decreased to 1.5 mm per day.

The patient remained admitted throughout the course of treatment for monitoring. He received daily body baths with chlorhexidine and daily pin tract care with povidone iodine. In the second week, a superficial pin tract infection developed on the right supraacetabular pin, which resolved after taking antibiotics. He underwent physical therapy for general conditioning, strengthening, deep breathing exercises, and incentive spirometry. Nutritional upbuilding and calcium supplementation were also done. The patient was able to ambulate with minimal assistance at two weeks (Figure 5. A-D) and was able to ambulate without assistance at three weeks (Figure 5. E-G). Serum calcium, albumin, and vitamin D levels were within normal range.

Weekly radiographs were taken to monitor correction, similar to the monitoring interval of Cetinkaya et al (Figure 6). A plain thoracolumbar CT scan done three weeks post-application revealed lysis of vertebral bodies from T5 to L1, with intact posterior structures (Figure 7). At 35 days postop, we measured a kyphotic angle of 48 degrees, angular correction of 0.72 degrees per day, and lengthening of 1.52 mm per day.

Definitive fixation was done at six weeks postoperatively due to plateauing distraction. Intraoperative neuromonitoring (EMG, MEP, and SSEP) and O-arm navigation were utilized (Figures 8 to 10). Through an all-posterior approach, 4.0 mm screws were inserted at T4 and T5 pedicles bilaterally, and 5.0 mm screws were inserted at L1 and L2 pedicles bilaterally. The T6 to T12 nerve roots were sacrificed on the right side for anterior access. To avoid vascular compromise, nerve roots were identified through neuromonitoring to make sure that only nerves were cut and blood vessels were spared. Vertebral column resection was done by removing the remnants of the T6 to T12 vertebral bodies. Scanty caseous material was seen around the remnants of the vertebral bodies and sent for cultures and histopathology. An expandable cage was inserted anteriorly, and bone graft was applied generously prior to closure. There were no changes in the intraoperative neuro-monitoring signals throughout the procedure aside from the irritation after nerve root ligation. After definitive fixation, the kyphosis angle was measured at 25 degrees. The halo-pelvic construct was maintained as an adjunct to the fixation until fusion.

Postoperative pain was well-controlled with gabapentin and fentanyl patient-controlled anesthesia. He had no new onset weakness or numbness in both lower extremities. He had abdominal pain partially relieved after a bowel movement. He could tolerate high back rest for feeding and was able to tolerate ambulation on day four after definitive surgery (Figure 11). He remained admitted for two more weeks for physical therapy with the goals of general conditioning and gait retraining. Cultures showed no acid-fast bacilli while histopathology revealed fibroosseous tissues with chronic granulomatous inflammation, Langhans-type giant cells, and caseation necrosis.

The patient was seen at the clinic monthly after discharge. He was ambulatory, with no complaints of pain. He developed a superficial pin tract infection at the right hip, which improved with pin tract care and a one-week course of oral antibiotics. X-rays showed no implant loosening or subsidence (Figure 12). At 12 weeks, x-rays showed fusion at the operative site. A CT scan would have been ideal to monitor screw and cage placement. However, as the patient had extensive radiation exposure from the preoperative CT scan and intraoperative O-arm, the team decided to do x-ray monitoring instead.

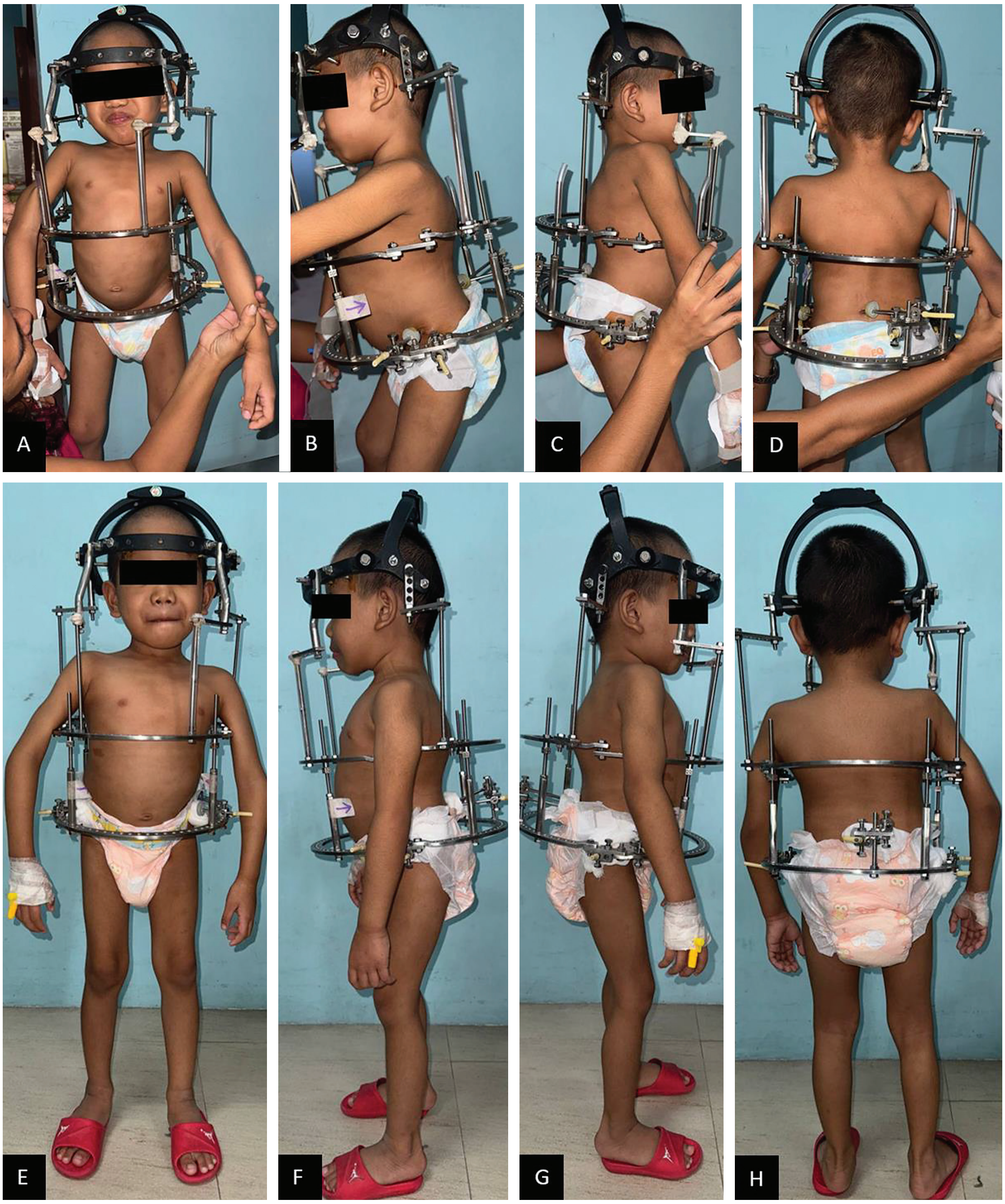

Figure 5. Patient standing on Day 14 **(A-D)** and Day 21 **(E-H)**.

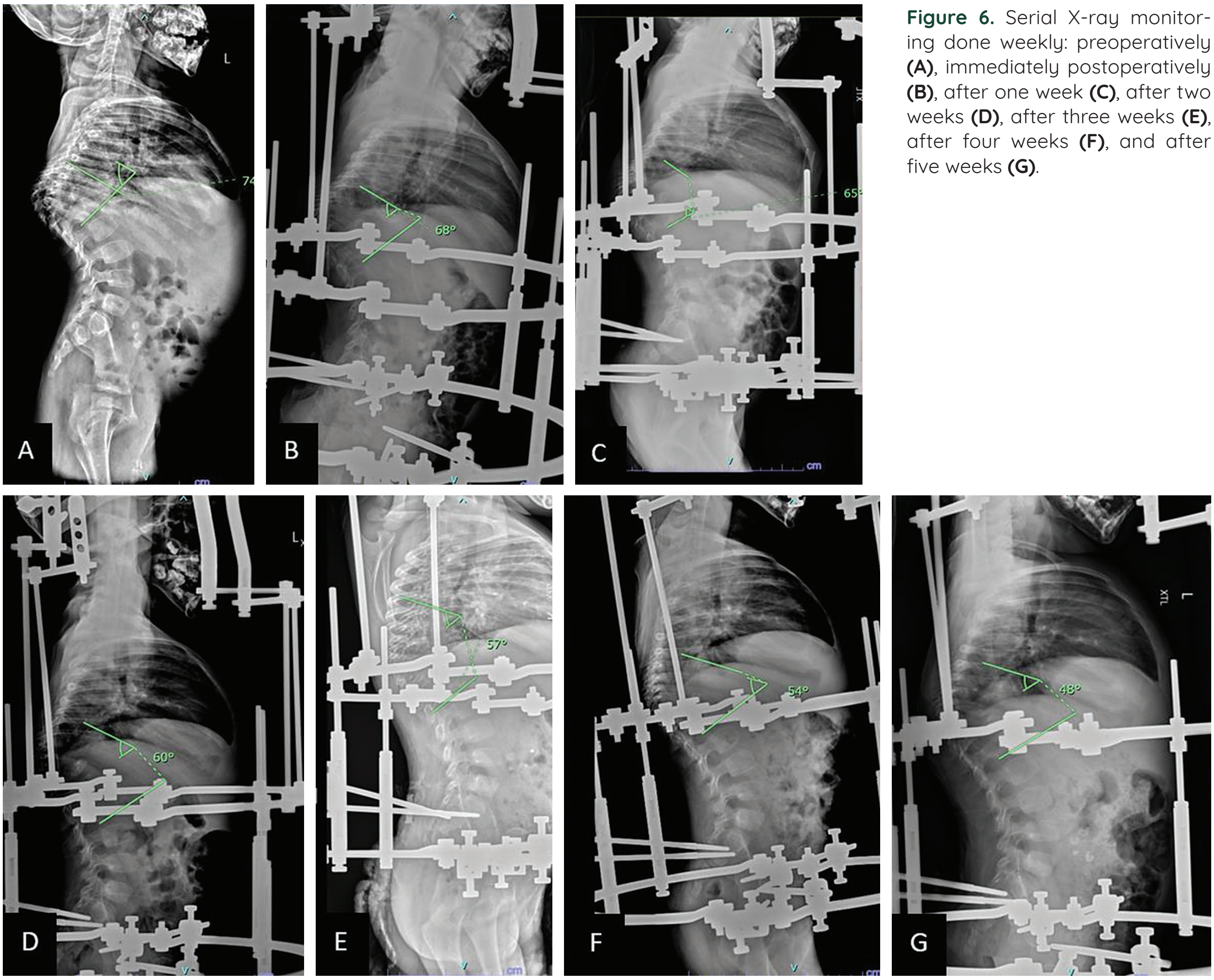

Figure 6. Serial X-ray monitoring done weekly: preoperatively **(A)**, immediately postoperatively **(B)**, after one week **(C)**, after two weeks **(D)**, after three weeks **(E)**, after four weeks **(F)**, and after five weeks **(G)**.

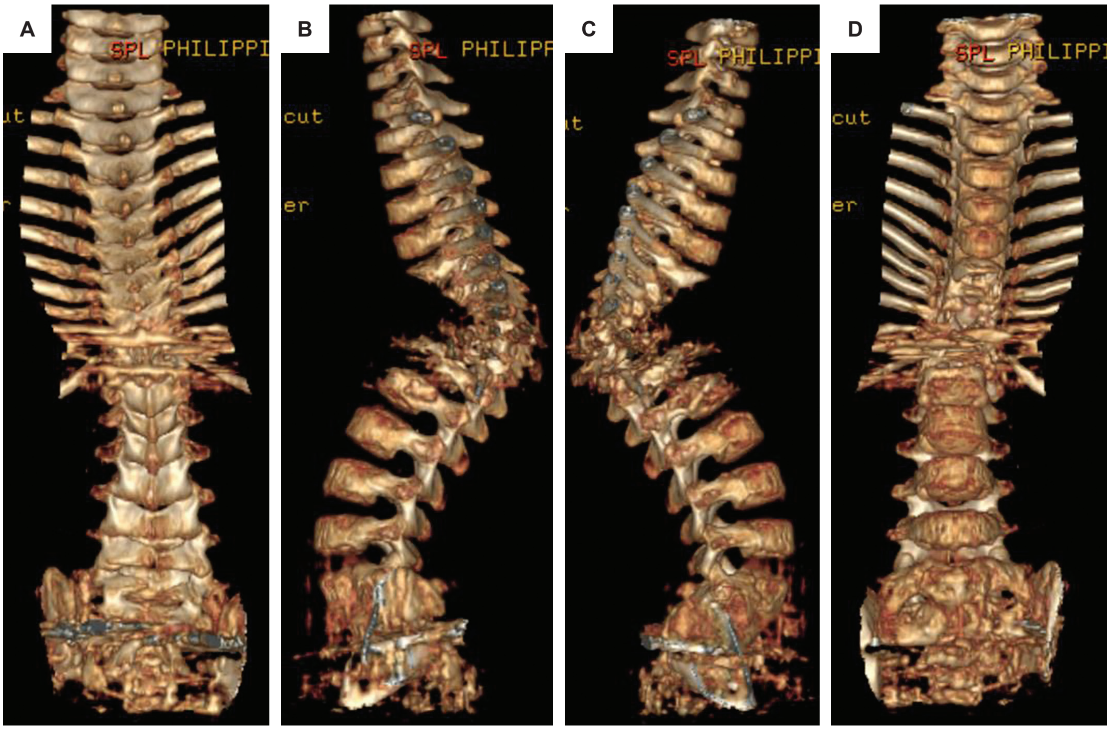

Figure 7. Thoracolumbar CT scan after three weeks **(A-D)**.

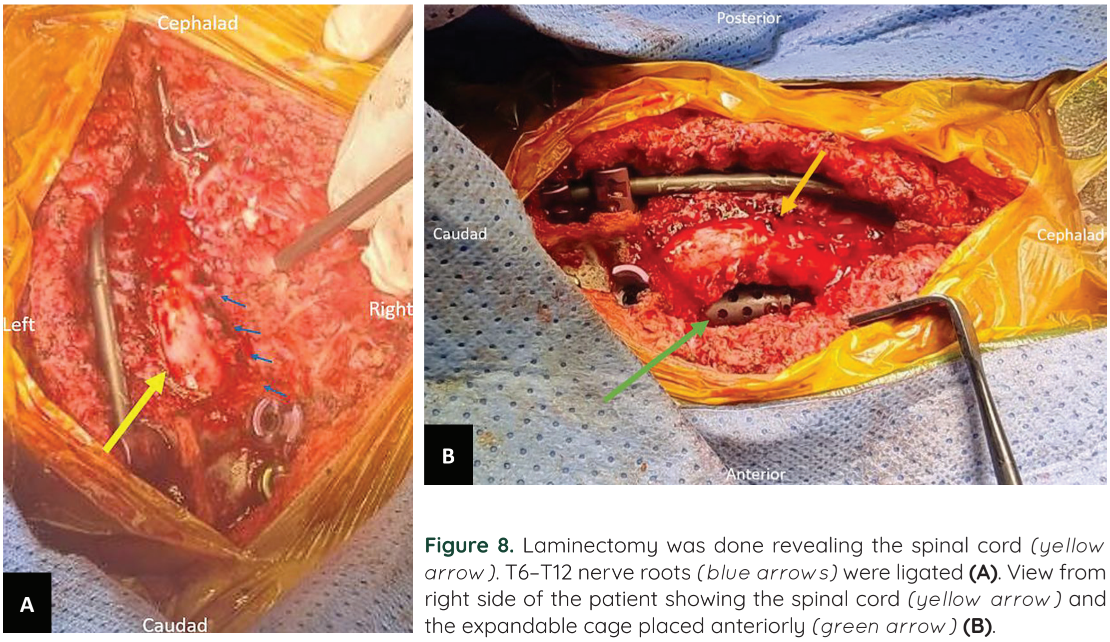

Figure 8. Laminectomy was done revealing the spinal cord *(yellow arrow)*. T6–T12 nerve roots *(blue arrows)* were ligated **(A)**. View from right side of the patient showing the spinal cord *(yellow arrow)* and the expandable cage placed anteriorly *(green arrow)* **(B)**.

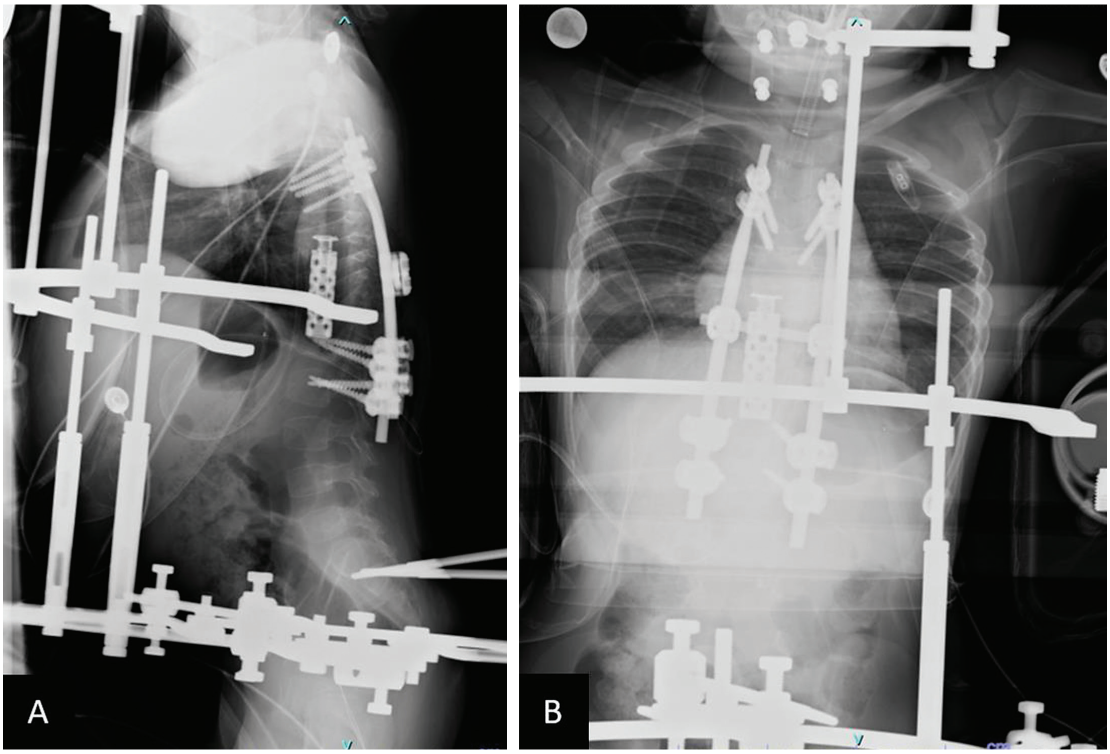

Figure 9. Anteroposterior **(A)** and lateral **(B)** x-rays after definitive fixation.

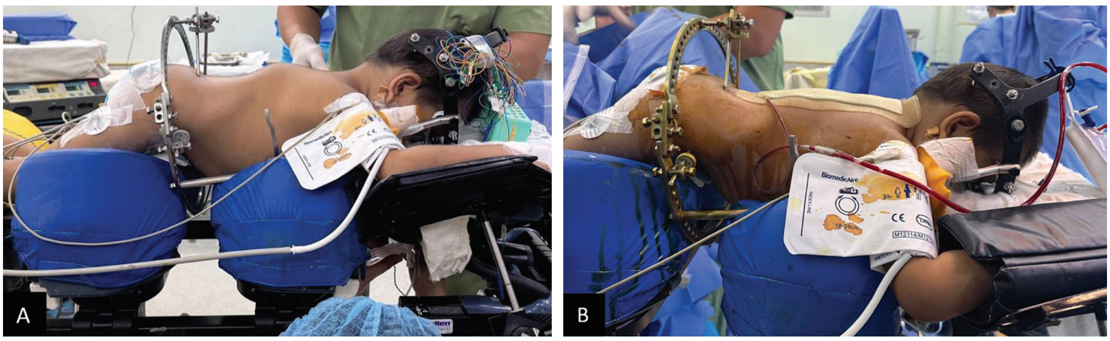

Figure 10. Patient in prone before **(A)** and after definitive fixation **(B)**.

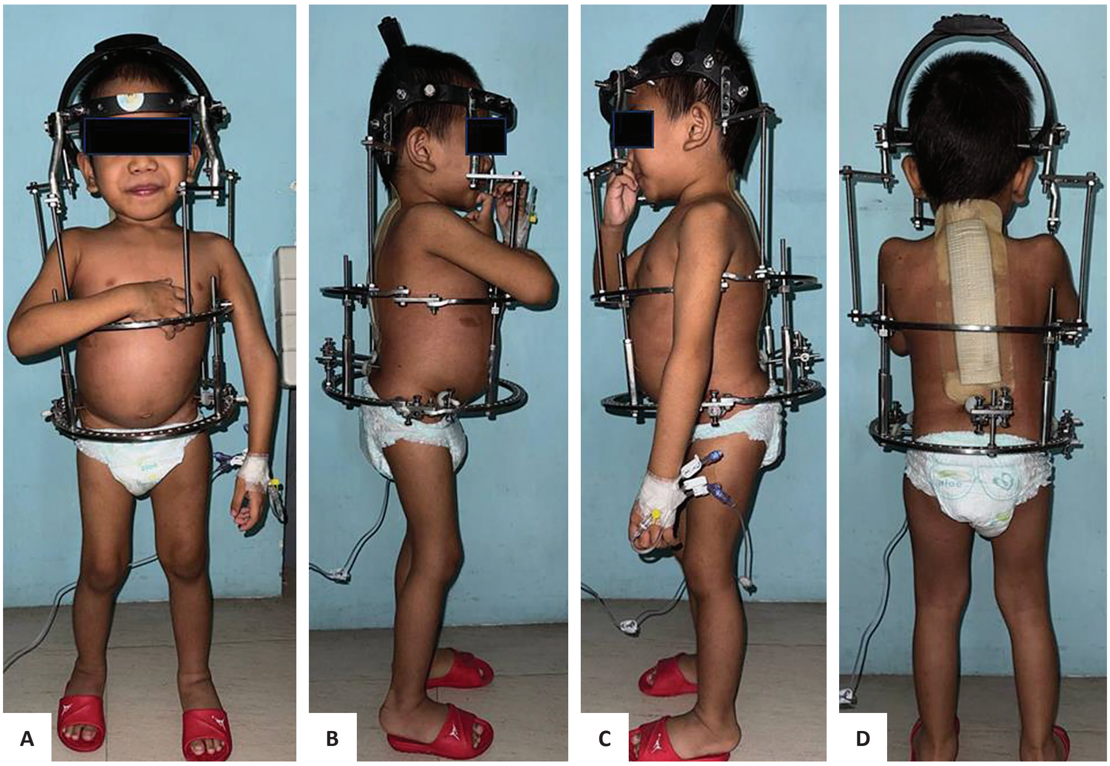

Figure 11. Patient four days after definitive surgery.

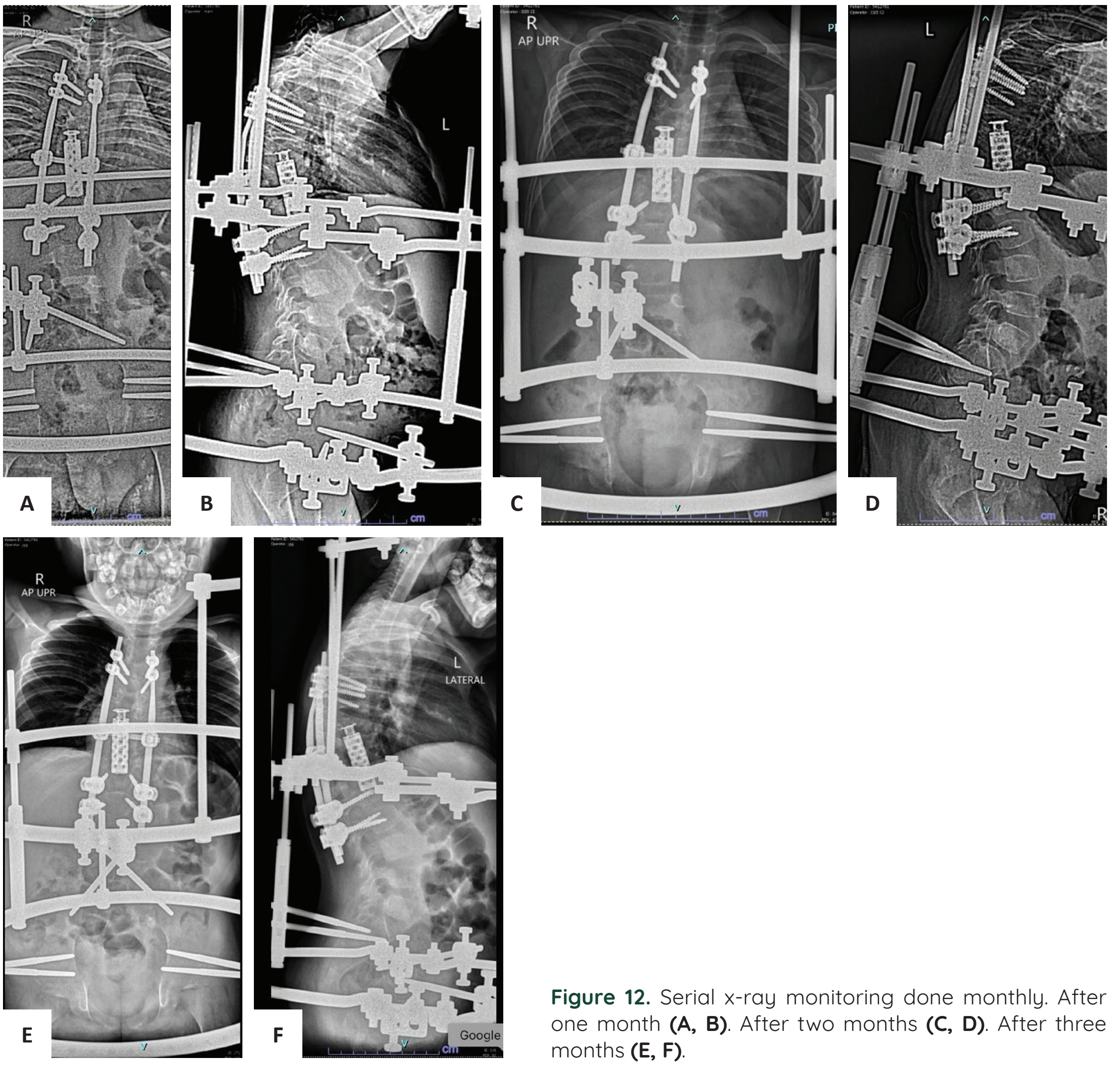

Figure 12. Serial x-ray monitoring done monthly. After one month **(A, B)**. After two months **(C, D)**. After three months **(E, F)**.

Figure 13. Removal of halo-pelvic traction and application of thermoplast brace.

Fourteen weeks after definitive surgery, the halo pelvic traction was removed in the operating room under sedation, and the patient was shifted to a total contact body jacket made of thermoplast (Figure 13). He remained ambulatory without aid, with no neurologic deficits, at six months after application of halo pelvic traction (Figures 14 and 15).

DISCUSSION

The natural history of spinal tuberculosis in children and adults varies. The pediatric spine is at greater risk for severe destruction and worse deformity due to the residual growth in the uninvolved segments of the spine. Patients present late and with more symptoms (deformity, paraplegia, incontinence, or disseminated bone and organ involvement). Indications for surgery are limited to the "at-risk signs," when ideally this disease could be identified early and treated without surgery. Multilevel involvement is also common and often pathognomonic for spinal tuberculosis, adding to the challenge of limiting fusion levels in children.

Deformity correction in children presents biomechanical and anatomical challenges. Small pedicle sizes, incomplete ossification, and poorer bone density limit fixation options, reduce screw purchase, and risk early loosening. Posterior fixation alone may not provide sufficient stability. The halo-pelvic construct afforded initial sagittal correction, stable bone purchase on the skull and pelvis, gradual distraction, and served as an external augment for the second-stage posterior instrumentation and fusion.

The halo-pelvic traction provides constant distraction at a guided rate as can be tolerated by the patient, while the halo-gravity traction involves intermittent distraction with the patient maintained on a wheelchair for at least 12 hours a day. The halo-pelvic construct has the advantages of consistent traction forces, patient mobilization, and a faster rate of correction as compared to a halo-gravity traction.

The disadvantage of the halo-pelvic construct is similar to that of any external fixation. The size and the weight of the frame may be cumbersome. Our patient was young and presented with low weight and height for age (Z < -3). The construct weighed 21% of his weight; he initially complained of its heaviness. This also placed him at risk for pin pullout, pin site infections, falls, and fractures.

The patient developed a superficial pin tract infection on the supraacetabular pin on the right side two weeks after application of the construct. Limpaphayom described that 25% of patients with a halo frame developed pin-site infections, for which oral antibiotics would usually be enough.[16] Pin tract care with sulphadiazine or hydrogen peroxide is documented to reduce the incidence of pin site

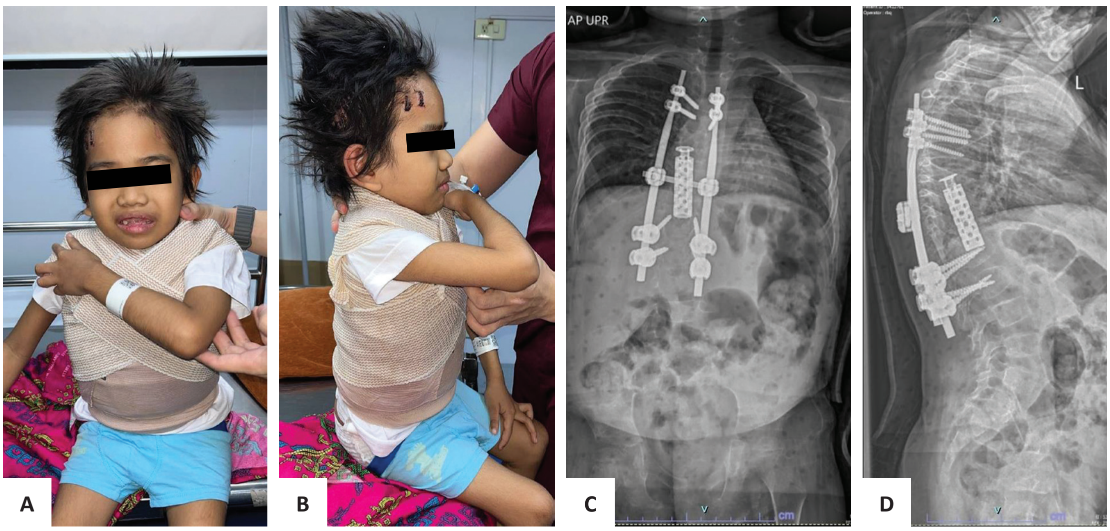

Figure 14. Patient one day after removal of halo-pelvic traction **(A, B)**. X-rays one day after removal of halo-pelvic traction **(C, D)**.

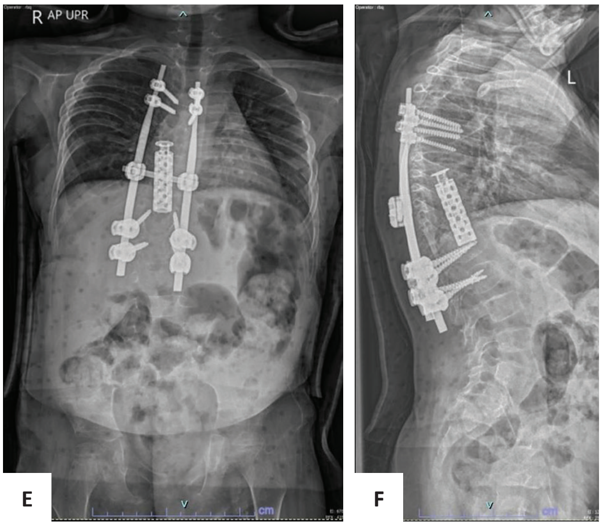

Figure 15. Patient one month after removal of halo-pelvic traction **(A-D)**. X-rays one month after removal of halo-pelvic traction **(E, F)**.

infections and may be considered in future cases.[17] This was proven to be effective in our case, and no recurrence of the pin tract infection was observed.

The initial sagittal correction achieved with the halo-pelvic traction was 26 degrees (35.13%) over six weeks. The correction with the frame seen in our patient was lower than reported by Zhou and lies closer to those in reports using halo-gravity traction in older children, which is around 30–35%.[18,19] Our slowed rate of distraction may have been too conservative because of the lack of literature in our patient's age group, and because we were guided by clinical symptoms (numbness, weakness, and pain), which children may be unable to express accurately. Objective parameters should be studied in a larger population.

The final deformity correction of 66.21% was achieved during the second-stage surgery. Kyphectomy through multilevel vertebral column resection contributed an additional correction of 23 degrees from the initial traction, which was consistent with the average correction of 50–70%.[9,14,15]

We decided to do unilateral multiple pedicle and rib resection to provide a wider fusion bed on the ribs and transverse processes of the involved levels. With this approach, multiple nerve roots were sacrificed to fully visualize and expose the anterior column. There is some evidence that ligation of multiple nerve roots may compromise the vascularity of the spinal cord, which may present as postoperative paraplegia. This may pose an even higher risk than simply ligating the artery of Adamkiewicz. A study has suggested performing temporary clamping of the nerve roots and monitoring the MEPs and SSEPs for 5–10 minutes before ligation.[20,21] However, preservation of SSEPs is still not a reliable marker of motor function postoperatively. Another study has proposed limiting the nerve root ligation on the right side, farther from the aorta.[21] This, however, does not assuredly prevent catastrophic ligation of the blood supply. A preoperative CT angiogram may be a reasonable precaution to avoid such complications.[21]

The timing of closure of the neurocentral synchondrosis varies by region; the cervical spine closes at around five years old, the lumbar at around 11 years old, and the thoracic spine later at 17 years old. While our main correction was achieved at the thoracic spine, destruction of the T7–L2 vertebral bodies and fusion of ten levels (T4–L2) will have a significant effect on the growth of this area. The growth of each thoracic vertebral body averages 0.7 mm a year in males. With around 10 years of remaining growth, the patient is already expected to be 5 cm shorter than his expected potential height.[22,23] Worsening deformity has been described in cases with scoliosis and progression of apical vertebral rotation post-fusion. In principle, posterior instrumented fusion prevents further growth of the posterior elements but may not prevent anterior growth, and vice versa for anterior fusion. In this case's mainly uniplanar deformity, the possibilities are: (1) overgrowth of the vertebral bodies anteriorly, causing further loss of thoracic kyphosis and/or increased lumbar lordosis, (2) rotational overgrowth of the unfused anterior segments of T4–5 and L1–2, or (3) a combination of the two previous possibilities. Our patient has to be followed up closely for any changes in the unfused segments.

The severity of deformity and the age of the patient were the main factors for considering a relatively tedious procedure. Careful preoperative planning necessitated repetitive radiographs and CT scans due to the construct used. However, with the limited literature, this innovative technique has proven to be effective in the short term. The risk of spontaneous fusion following stripping of the periosteum at the non-fusion levels is still possible. Growing rods or other growth-friendly techniques may be inadequate for definitive fixation.

Since this new technique carries the risk of pin tract infections, the patient had to be confined for close monitoring and observation. Furthermore, the risk of developing new deformities is still possible, and the patient would need to be monitored until adulthood. Current evidence shows no consistent association between repeated diagnostic radiation exposure and risk of developing pediatric cancers.[24]

There are a few comparative studies available on the use of the halo-pelvic traction in young children. Close monitoring of patients and sound clinical judgment helped define our distraction protocol. Our current study shows early clinical and radiographic outcomes. Constant monitoring is needed to assess long-term results and detect possible complications.

CONCLUSION

The combined two-staged approach of halo-pelvic traction and all-posterior vertebral column resection has proven effective in this pediatric patient with severe kyphotic deformity. While protocols on halo-pelvic traction were lacking and the risk of complications for both procedures individually and combined were relatively high, the patient was able to tolerate the procedures. However, while our results are promising in the short term, the patient would need constant monitoring and long-term follow-up to detect and prevent possible complications.

ETHICAL CONSIDERATION

Patient consent forms were obtained before manuscript submission.

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STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

CREDIT AUTHOR STATEMENT

PLFR: Conceptualization, Methodology, Investigation, Resources, Writing – original draft preparation, Writing – review and editing, Visualization; **MRAP:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft preparation, Writing – review and editing, Visualization, Supervision, Project administration; **GCEB:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft preparation, Writing – review and editing, Supervision, Project administration; **FPIN, SAMG:** Conceptualization, Methodology, Investigation, Resources, Writing – review and editing, Supervision, Project administration.

DATA AVAILABILITY STATEMENT

No datasets were generated or analyzed for this research.

AUTHOR DISCLOSURE

The authors declared no conflict of interest.

FUNDING SOURCE

None.

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