CASE REPORT

Robotic Precision for Severe Kyphosis in a Child with Myelomeningocele and Arnold-Chiari

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Abstract

Aim and background: Kyphoscoliosis associated with previously repaired meningocele presents significant surgical challenges due to associated anomalies, such as Chiari malformation, vertebral dysplasia, and spinal cord tethering. Surgical planning is often complicated by these factors, especially in patients with progressive deformity and functional impairment.

Case description: A 12-year-old girl with a history of thoracolumbar meningocele repair at birth presented with severe lumbosacral kyphosis and poor sitting balance. Magnetic resonance imaging (MRI) revealed Arnold-Chiari malformation type 1. A two-stage surgical approach was adopted. In the first stage, she underwent foramen magnum decompression and duraplasty to address the Chiari malformation. In the second stage, spinal deformity correction was performed using posterior spinal instrumentation, vertebral column resection (VCR), and fusion. Robotic assistance was employed for accurate placement of pedicle and iliac screws, facilitating effective correction of the deformity.

Conclusion: A staged approach addressing both neural and skeletal components enabled successful correction of severe kyphosis in a complex spinal dysraphism case. Robotic guidance enhanced the accuracy and safety of spinal instrumentation.

Clinical significance: In patients with postmeningocele kyphoscoliosis and Chiari malformation, a carefully staged surgical plan incorporating robotic-assisted instrumentation can restore spinal balance and improve functional outcomes, particularly sitting ability in children.

Keywords: Case report, Chiari malformation type 1, Kyphoscoliosis, Myelomeningocele, Robotic-assisted spine surgery, Vertebral column resection.

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Introduction

Severe kyphoscoliotic deformity associated with meningocele poses a significant surgical challenge. The pedicles in such cases are often hypoplastic, myelomatous, and steeply medially angulated, rendering planning and placement of pedicle screws exceptionally difficult.[1,2] When this deformity is combined with partial sacral agenesis, the limited bony corridor in the sacropelvic region makes placement of pelvic anchors, such as iliac wing screws or S2-alar-iliac screws, extremely challenging.[3]

Third-generation spinal robotics provide substantial advantage in addressing these difficulties. These systems facilitate preoperative planning and intraoperative robotic guidance, optimizing screw placement accuracy in anatomically distorted pedicle anatomy, including pediatric patients with small, angulated, or dysplastic pedicles.[4] Specifically, robotic platforms such as ExcelsiusGPS have demonstrated improved implant accuracy and substantially reduced surgeon radiation exposure compared to fluoroscopic or freehand techniques.[5]

Moreover, the integration of navigable high-speed burrs enables precise bone resection and decompression under real-time navigational feedback. This is especially valuable during vertebral column resection (VCR) or osteotomy procedures adjacent to meningocele or in the presence of sacral dysplasia.[4,5]

We report herein the use of robotic assistance in the deformity correction of a child with severe lumbosacral kyphoscoliosis secondary to meningocele and partial sacral agenesis. Robotic assistance enabled detailed trajectory planning for pedicle and pelvic screws in diminutive, dysplastic, and steeply angled bony anatomy, while the navigable high-speed burr facilitated controlled resection and visualization of critical structures during VCR.

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Conflict of interest: None

Patient consent statement: Written informed consent was obtained from the patients' parents for participation in the study, and due care was taken to maintain patient confidentiality and privacy.

Case Description

A 12-year-old girl who was wheelchair-bound presented with deformity of her lower back and difficulty in sitting for prolonged periods of time. She was the first-born child of a nonconsanguineous marriage and was diagnosed with spinal dysraphism antenatally. She underwent closure of a thoracolumbar meningocele immediately after birth. She had nonfunctional lower extremities and bowel

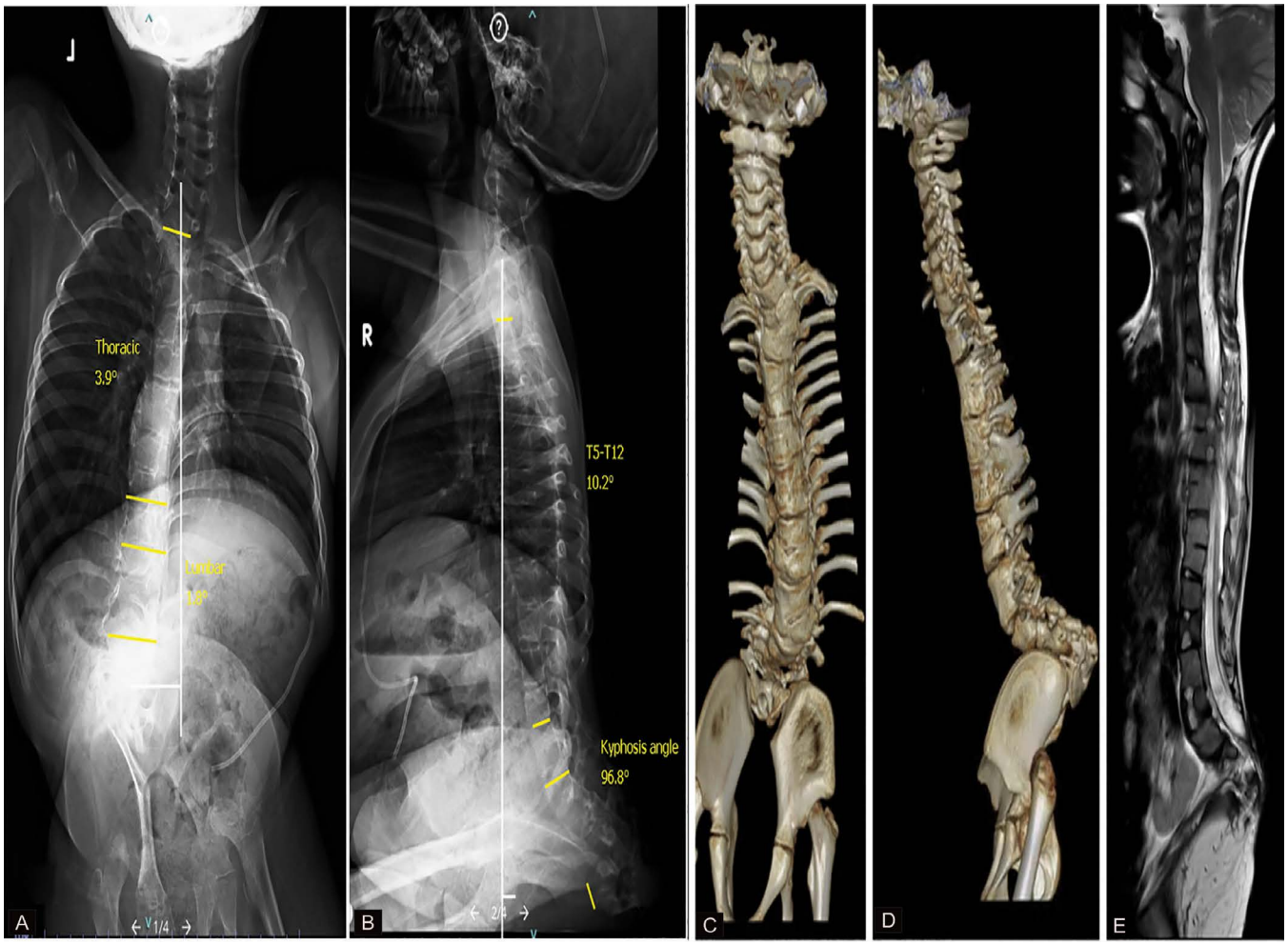
and bladder incontinence. She underwent ventriculoperitoneal shunt placement at the age of 7 years and presented to us at the age of 12 years with poor sitting balance and deformity in the lower back. The scar of the meningocele repair had healed by secondary intention. Radiographs and computed tomographic scans of the spine and pelvis revealed severe lumbosacral kyphosis, partial sacral agenesis Renshaw type III, and multiple vertebral anomalies. Magnetic resonance imaging (MRI) of the whole spine with the craniovertebral junction revealed Arnold-Chiari malformation type 1 (Fig. 1). With the goal of improving sitting balance, a decision was made to correct the deformity in two stages. Written informed consent was obtained prior to the surgery.

In the first stage, the child underwent foramen magnum decompression and duraplasty to treat Arnold-Chiari malformation type 1. In the second stage, she underwent robotic-assisted deformity correction, posterior spinal instrumentation, and fusion along with VCR using the MazorX Stealth Edition and intraoperative O-arm scan (Medtronic Ltd, Dublin, Ireland). The "scan and plan" workflow was used, wherein robot registration and image acquisition were done intraoperatively. Two sets of O-arm scans, one for placing pedicle screws from T3 to T11 and the second for placing four iliac screws in the pelvis, were needed. The dural sac was ligated and transected at the level of L1, and the navigable high-speed burr was used for VCR. The spine was stabilized with four rods, and the wound was closed in layers over a drain (Fig. 2). The child tolerated the staged surgery well and was allowed to sit 2 weeks following the procedure. Sitting radiographs of the spine at 2-month follow-up revealed a well-balanced spine (Figs 3 and 4).

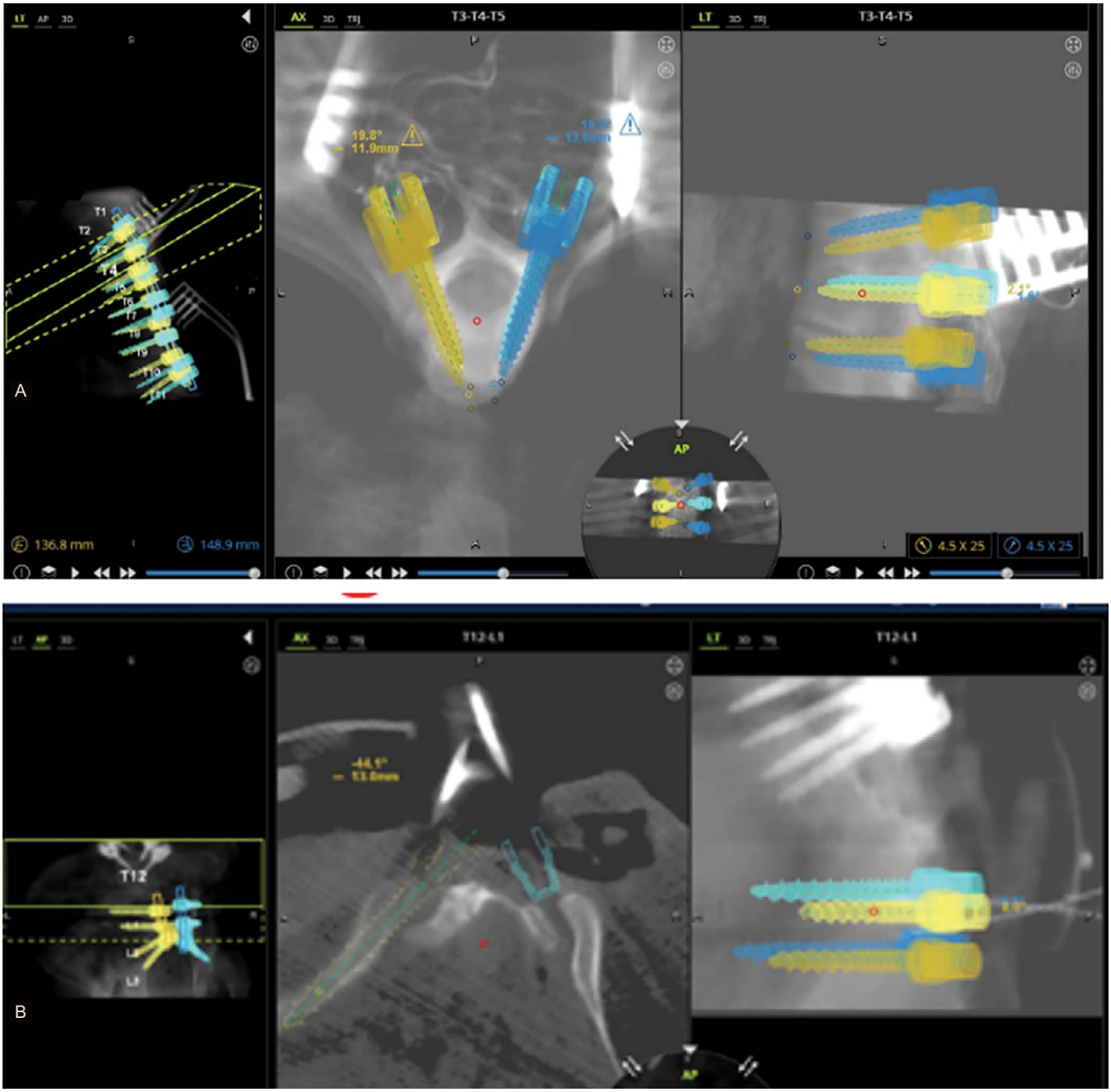
Discussion

Spinal dysraphism can lead to deformity of the spine secondary to muscle imbalance and concomitant vertebral anomalies. When associated with conditions like Arnold-Chiari malformation type 1 and tethered cord syndrome, it requires staged procedures, first treating the neuraxial abnormalities prior to treatment of spinal deformity.[2] The goal of treatment in cases where the patient is not ambulatory is to achieve good sitting balance. This frees the upper extremities, which dramatically improves daily activities. Osteoporosis, poor bone stock, and abnormal anatomy make accurate placement of pedicle screws of paramount importance to achieve deformity correction and bony fusion.[6]

The third-generation spine robot is useful in drilling trajectories in challenging situations like spinal deformity, in which there is three-dimensional distortion of the vertebral anatomy.[7,8] The presence of sacral agenesis makes placement of the pelvic anchors difficult, as there is abnormal angulation and hypoplasia of the innominate bones.[9] During the segmentation phase of



Figs 1A to E: Preoperative radiographs (A and B) and computed tomographic scans (C and D), showing severe lumbosacral kyphosis, partial sacral agenesis, and multiple vertebral anomalies. MRI (E) showing associated Arnold-Chiari malformation type 1



Figs 2A and B: Screenshots from the robot console showing planning of thoracic screws (A) and pelvic screws (B)

planning on the robot console, greater attention must be given to the anteroposterior view while making sure both pedicles are adequately visualized in each segment.[10] The vertebrae must be virtually "derotated" in all planes (axial, coronal, and sagittal) by aligning the axes prior to screw planning. While planning screws, the software allows visualization of adjacent segments in case the craniocaudal visualization of the pedicle is insufficient. Severe deformity warrants three-column osteotomies for restoration of global spinal alignment. The navigable burr is useful, as it allows visualization of critical structures while performing the osteotomy.

Conventionally, the spine robot is mounted to the patient in a semirigid manner, and this was not possible in the child due to her small size. The patient was secured to the table, and minimal movement was ensured during the whole procedure to prevent loss of navigation accuracy. In the thoracic spine, the transverse processes were flattened with the help of rongeurs to prevent skiving of the drill during entry.

The robot is a useful tool in the armamentarium of the spine surgeon by allowing accurate placement of pedicle screws in challenging scenarios. This allows challenging cases to be tackled in a safe and effective manner.

Conclusion

In this report, robotic-assisted deformity correction using the Mazor X Stealth Edition and intraoperative O-arm navigation

Fig. 3: Intraoperative clinical photograph following final rod placement and bone grafting

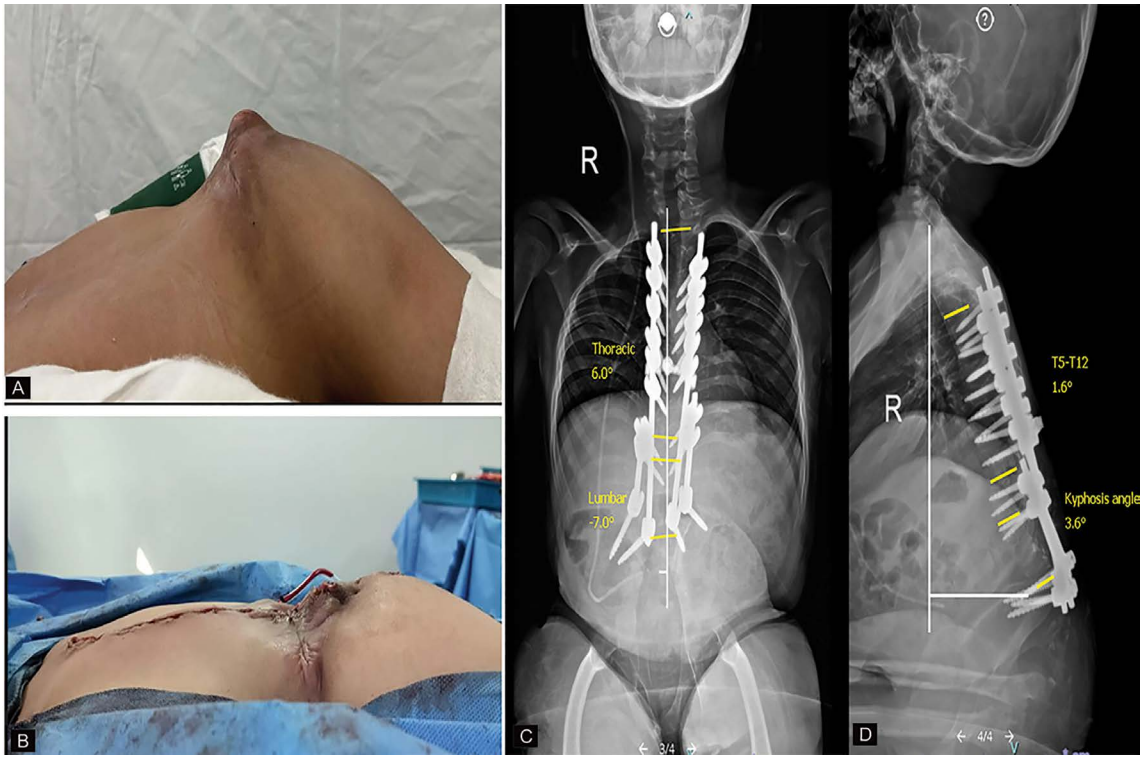
proved to be a highly effective and safe strategy for treating severe lumbosacral kyphoscoliosis in a pediatric patient with meningocele and partial sacral agenesis. Detailed preoperative planning and robotic trajectory guidance enabled accurate placement of pedicle screws in hypoplastic, steeply angulated, and dysplastic vertebrae, while navigable high-speed burr-assisted VCR was performed under real-time navigational visualization. The two-stage surgical approach—addressing the Chiari malformation followed by corrective instrumentation—resulted in excellent postoperative sitting balance and spinal alignment, with the patient tolerating early mobilization at 2 weeks and displaying a well-balanced sitting spine at 2-month follow-up.

Clinical Significance

Robotic-assisted spinal surgery offers clear clinical advantages in complex pediatric deformities, enhancing pedicle and pelvic screw placement accuracy and significantly reducing intraoperative blood loss, fluoroscopy time, and surgeon radiation exposure. These benefits translate into safer, more reliable procedures, fewer screw-related revisions, and faster recovery—even in anatomically distorted or dysplastic bone—making robot-assisted systems particularly valuable for challenging cases like severe kyphoscoliosis with sacral agenesis.

Author Contributions

Conceptualization: Vidyadhara S.
Methodology: Vidyadhara S, Balamurugan T.
Formal analysis: Balamurugan T, Abhishek Soni, Dinesh Iyer.
Surgical procedures and investigation: Vidyadhara S, Madhava Pai Kanhangad, Abhishek Soni.



Figs 4A to D: Clinical photographs showing severe lumbosacral kyphosis preoperatively (A), which was corrected following surgery (B). Postoperative anteroposterior (C) and lateral (D) radiographs

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All authors have read and approved the final manuscript.

AI Disclosure

No artificial intelligence (AI) tools were used in the writing, preparation, or editing of this manuscript.

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