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ORIGINAL ARTICLE

Posterior-only approach cervical hemivertebrectomy and short fusion with pedicle screws in young children with cervical scoliosis: case report and technical note

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Abstract

Purpose Cervical hemivertebrae (C3-6) causing significant osseous torticollis, head tilt and facial asymmetry are rare and complicated. Cervical hemivertebrectomy (CHVE) by a posterior-only approach was never reported because it is highly risky and its efficacy remains controversial. This study is to evaluate the feasibility and preliminary clinical outcomes of posterior-only approach for CHVE and torticollis correction in young children.

Methods Four young children aged 5–9 years old with significant torticollis caused by cervical hemivertebrae underwent deformity correction consisting of cervical pedicle screw (CPS) placement with O-arm-based intraoperative navigation, CHVE using ultrasonic bone scalpel and short-segmental posterior instrumentation and fusion. Details of this novel technique were presented. The preliminary short-term clinical and radiographic outcomes were assessed.

Results On average, the operative time was 312.5 ± 49.9 min, and the surgical blood loss was 375.0 ± 150.0 ml. The structural cervical scoliosis was corrected from 31.5 ± 7.3° to 11.0 ± 4.1°, and the average correction rate was 64.9%. Head tilt was favorably corrected from 11.0 ± 4.2° to 3.5 ± 2.6°. The shoulder balance improved from 6.3 ± 1.3° to 1.5 ± 1.9°. One case with C6 CHVE had convex side radiating nerve root pain but no sign of muscle power weakness. Full recovery was achieved one month after surgery. No other complication occurred.

Conclusions CHVE by a posterior-only approach was a feasible alternative option for the treatment of congenital cervical scoliosis. It could resect the CHV effectively and achieve satisfactory torticollis correction without additional anterior access surgery. Successful CPS placement in this child population was essentially important to enable reliable osteotomy closure and firm posterior instrumentation.

Keywords Cervical hemivertebra · Torticollis · Posterior-only approach · Hemivertebrectomy · Head tilt

Introduction

Congenital cervical hemivertebra (CHV) is a very rare clinical entity, it can be either isolated or combined with additional cervical anomalies (for example, Klippel-Feil syndrome or complex craniovertebral junction malformation) [1–3]. Early osseous torticollis and head tilt are common cosmetic consequences during childhood if this major osseous malformation is left untreated [4, 5]. Despite usually being painless and neurologically intact, the parents will eventually seek medical consultation when the child's face and neck becomes visibly dysmorphic. Particularly, the undesired secondary facial asymmetry is termed facial scoliosis, being characterized by a loss of parallel alignment between the eyes and the mouth [6].

To halt the progressive natural history, early cervical hemivertebrectomy (CHVE) remains to be the most effective option. Despite being enticing, this procedure is technical demanding and highly risky for catastrophic neurological complications. Deburge et al. first reported using combined anteroposterior approach, staged osteotomy surgery and awake closed reduction to correct cervical scoliosis in

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1981[7]. In the two decades thereafter, Ruf et al. modified the CHVE procedure to adopt a posterior-anterior-(posterior) (PAP) approach and anterior open reduction and fixation assisted by bending the head manually to the convex side [5]. Good correction of both cervical scoliosis and head tilt were achieved with acceptable neurological risk. In 2018, Wang et al. reported two adolescent cases of C3 cervical hemivertebra resection and torticollis correction using an anterior-posterior-anterior (APA) approach, posterior open reduction and fixation, and supplemental anterior interbody autogenous bone grafting and fixation [4]. In their reported technique, the unique improvement lied in that intentional exposure and dissection the vertebral artery (VA) was not necessary, reducing the risk of artery injury. These limited case-series studies led to a preliminary consensus that combined anteroposterior approach was the classical standard of care for CHV nowadays and worked effectively.

Unlike the treatment of hemivertebrae in thoracic/lumbar spine, posterior only treatment of CHV gained no popularity because of two major reasons: firstly, the strength of lateral mass screws in young children was limited and likely unable to withstand the correction forces needed for posterior-only closure of wedge osteotomy and short fusion. Secondly, posterior-only CHVE in the petite and flexible cervical spine of young children was associated with less surgical field visualization, big difficulty in osteotomy manipulation and high risk of spinal cord injury. In recent years, the vast improvements of osteotomy safety and efficiency using ultrasonic bone scalpel and O-arm-based intraoperative navigation for cervical pedicle screw (CPS) placement have made us reconsidering the feasibility of CHVE by a posterior-only approach [7–9]. This would be beneficial for avoiding the risks associated with additional anterior surgery and negating the need for change of operative posture during combined anteroposterior surgery, thus reducing the operative time and operative invasiveness.

This study was designed to evaluate the feasibility and preliminary therapeutic outcomes of posterior-only approach for CHVE and torticollis correction in a case series of young children. Details of this novel technique are presented, involving cervical pedicle screw (CPS) placement with O-arm-based intraoperative navigation and posterior-only ultrasonic bone scalpel assisted CHVE without dissecting the vertebral artery.

Materials and methods

In this study, four consecutive child patients with CHV (C3-6) and secondary osseous torticollis, who were operated with posterior-only CHVE, were evaluated by reviewing the medical chart and imaging scans. The surgical indications were progression of the disfiguring cervical deformity causing clinically apparent cosmetic problems in the head-neck area. The selection of range of fusion was similar to that of the thoracic and lumbar spine, being usually 1 or 2 levels above and below the hemivertebra. The hemivertebrae were one C3 hemivertebra, one C4 hemivertebra and two C6 hemivertebrae, all of which were well segmented anteriorly. Before correction surgery, radiographic evaluations involving standing whole-spine radiographs and computed tomography with 3-dimensional reconstructions were performed to evaluate the anatomical details of CHV, as well as to identify whether or not there existed additional cervical anomalies. Magnetic resonance imaging (MRI) was used for the detection of any underlying spinal cord abnormality. Computed tomographic angiography (CTA) was also performed to show the course and symmetry of the bilateral vertebral arteries and to exclude any potential vascular malformation. Personalized 3D printed model of the deformed cervical spine was created to facilitate patient's pre-surgical understanding of their congenital deformity and how surgery was performed to correct the bony torticollis. This model was also routinely sterilized and used during surgery to guide surgeon's intra-operative manipulation. The changes of morphological and radiographic deformity parameters after surgery were recorded involving Cobb angle of cervical scoliosis on 3D-CT scans, radiographic and morphological head tilt and shoulder balance, all of which were defined as follows: (1) Cobb angle of cervical scoliosis: the angle formed between proximal upper and distal lower endplates of the cervical vertebrae neighbouring CHV (Fig. 1D); (2) Radiographic head tilt (RHT): defined by the angle formed between the nasal septum-mandibular central incisor line and the vertical line (Fig. 1C) [10]; (3) Morphological head tilt (MHT): On clinical photos of frontal view captured at a relaxed standing position, the angle was measured between the axes bisecting the head and trunk (Fig. 1A); 4.Shoulder balance: the angle measured between the outer clavicle and the horizontal line (Fig. 1C) [10]. All measurements were performed independently by 2 surgeons using the Surgimap spine software (Version 2.3.1.5; Spine Software, New York, NY). The average of each measurement was used for analysis.

Surgical technique

After given general endotracheal anesthesia, the patient was applied with the Mayfield skull clamp and was subsequently positioned prone on a Jackson table for a posterior approach. The cranial reference frame was then fixed tightly to the Mayfield skull clamp. After draping and a standard posterior midline incision, sub-periosteal exposure of the laminar and lateral masses at the planned levels were

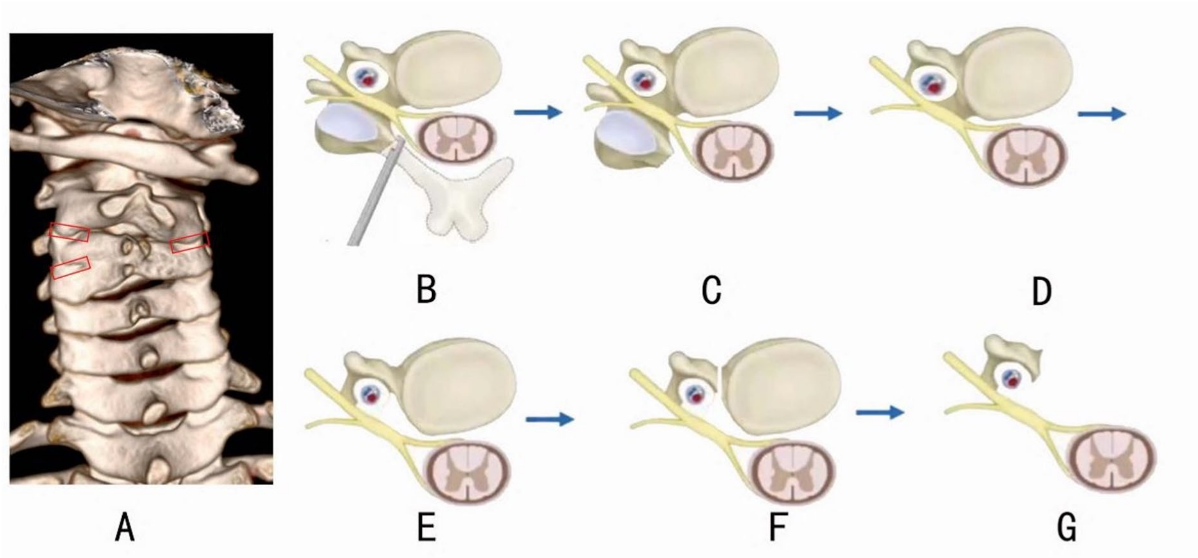

Fig. 1 Schematic diagram of sequential correction steps for posterior-only CHVE. **A**. Location of Ponte osteotomy (red box); **B** & **C**. Resection of the hemilamina; **D**. Excision of lateral mass; **E**. Excision of the cervical pedicle; **F**. disconnection of the residual transverse process with the body of hemivertebra; **G**. Excision of the residual body of the hemivertebra, the adjacent discs and the cartilage endplates

carefully performed. The sterilized 3-D printed model could assist in judging whether the desired levels of fusion were adequately exposed. Then the O-arm scan was performed, and the obtained images were uploaded to a Stealth Station S8 Navigation System. CPS, which had higher biomechanical strength, was then inserted under a 3D navigation system using the synergy spine software (Medtronic). Firstly, the ideal entry point and screw trajectory were identified with a navigated probe. A small pilot hole was then made with a high-speed drill to anchor the following probing, tapping, and screw insertion. Pedicle probing was performed using the navigated hand drill with small pushing power to minimize the discrepancy between the O-arm screen-displayed trajectory and the real trajectory [8]. Once the accuracy and integrity of trajectory was confirmed by the navigated probe both on O-arm images and from the tactile feedback, navigated tapping and screw insertion were performed. When all the planned screws were inserted, a second intraoperative O-arm scan was routinely performed to evaluate the screw accuracy. If there was screw malposition, conversion of the screw was required. One important tip that should be kept in mind was that, despite the completed preparation of screw trajectory, the first CPS being caudal to CHV should not be inserted until the CHVE was finished. Otherwise, the tail of the screw would hinder the visualization and manipulation of osteotomy because of the limited operating space in the petite neck of young children.

Posterior-only CHVE (Fig. 1) should begin with resection of the hemilamina and Ponte osteotomy at both the cranial and caudal cervical facet joints neighbouring CHV, as well as the facet joint at the concave side. If there exists congenital segmentation failure of the laminar and facet joints, we would transect and separate the synostosis using an ultrasonic bone scalpel to release the posterior cervical column. The spinal cord and the nerve roots above and below the pedicle were then exposed and protected after removal of the intraspinal fat. A temporary rod was placed on the concave side to prevent any abrupt subluxation during osteotomy. After careful prophylactic hemostasis of the epidural venous plexus, the lateral mass and the pedicle of CHV, which constructed the posterior and medial wall of the the transverse foramen, were excised and removed using an ultrasonic bone scalpel and a Kerrison rongeur. The remnants of the convex transverse process of the hemivertebra were then cut adrift from the spinal column. This disconnection made the vertebral artery within the transverse foramen not being intentionally dissected, reducing the risk of vertebral artery injury. By carefully retracting the dura sac and nerve root, the residual body of the hemivertebra, the adjacent discs and the cartilage endplates were resected and removed, and the excision should involve the concave disc material to achieve a complete 360° release. After removing the temporary rod, a convex precontoured permanent rod was then inserted, and gradual convex compression maneuver would be done subsequently trying to close the osteotomy gap. An adequate resection was the premise of easy osteotomy closure. It would be noticed that the screw heads on the convex side came together signifying closure of the resection. Further distraction on the concave side was essential after the second permanent rod insertion and could enhance the outcome of regional scoliosis correction. It was important not to impinge on the exiting nerve roots and dura during this procedure. If necessary, further compensatory decompression could be performed. By this time point, TCeMEPs and SSEPs would be performed to confirmed the integrity of neurological function. Before bone grafting, cortical bone of the adjacent laminar would be carefully roughened with high speed burr. Besides from autogenous bone grafting using the resected bone retained during osteotomy, allograft using long bone chips across the osteotomy gap were applied. Close neurophysiological monitoring with transcranial electrical motor evoked potentials (TCeMEPs) and somatosensory evoked potentials (SSEPs) would be performed throughout the surgery for every case. After surgery, all the patients were applied with a head-neck-chest orthosis for 12 weeks.

Results

The operative time was 312.5 ± 49.9 min on average, and the average surgical blood loss was 375.0 ± 150.0 ml. Mean follow-up was 15 ± 3.5 months. The structural cervical scoliosis was corrected from 31.5 ± 7.3° to 11.0 ± 4.1°, and and the average correction rate was 64.9%. The radiographic head tilt was favorably corrected from 11.0 ± 4.2° to 3.5 ± 2.6°, while the morphological head tilt was corrected from 14.8 ± 4.7° to 3.3 ± 3.0°. The shoulder balance improved from 6.3 ± 1.3° preoperatively to 1.5 ± 1.9° postoperatively. One case with C6 CHVE had post-operative convex side radiating nerve root pain but no sign of muscle power weakness. Full recovery was achieved one month after surgery without sequelae. No other complications involving screw misplacement or VA injury occurred.

Case descriptions

Case 1

Parents and their 6-year-old girl visited our outpatient clinic counselling for treatment of torticollis and head tilt. The parents were anxious, and their main concern focused on the progressive cosmetic problems. The patient's neck motion was not restricted. Neither neck pain nor neurological deficits were noticed. Compensatory elevation of the right shoulder (6°) following torticollis and head tilt was also unsightly. The CT scans revealed a hemivertebra between C2 and C4 on the left side (Fig. 2D), and magnetic resonance image (MRI) scan showed no malformations of the cervical spinal cord. CT angiography also showed no variation in the course and diameter of vertebral artery. The cervical scoliosis was measured to be 22°, and the RHT and MHT were 8° and 15°, respectively. A correction surgery was indicated to correct the torticollis by resecting the C3 hemivertebra using a posterior-only approach. CPS at C2 and C4 were inserted bilaterally using surgical synergy navigated workflow techniques (Fig. 2F, G). CHVE was performed following the aforementioned standard procedure. Sufficient closure of the osteotomy gap between C2 and C4 was confirmed when the tails of the cranial and caudal CPS neighbouring CHV contacted closely after convex compression (Fig. 2J). The operation was free of vascular and

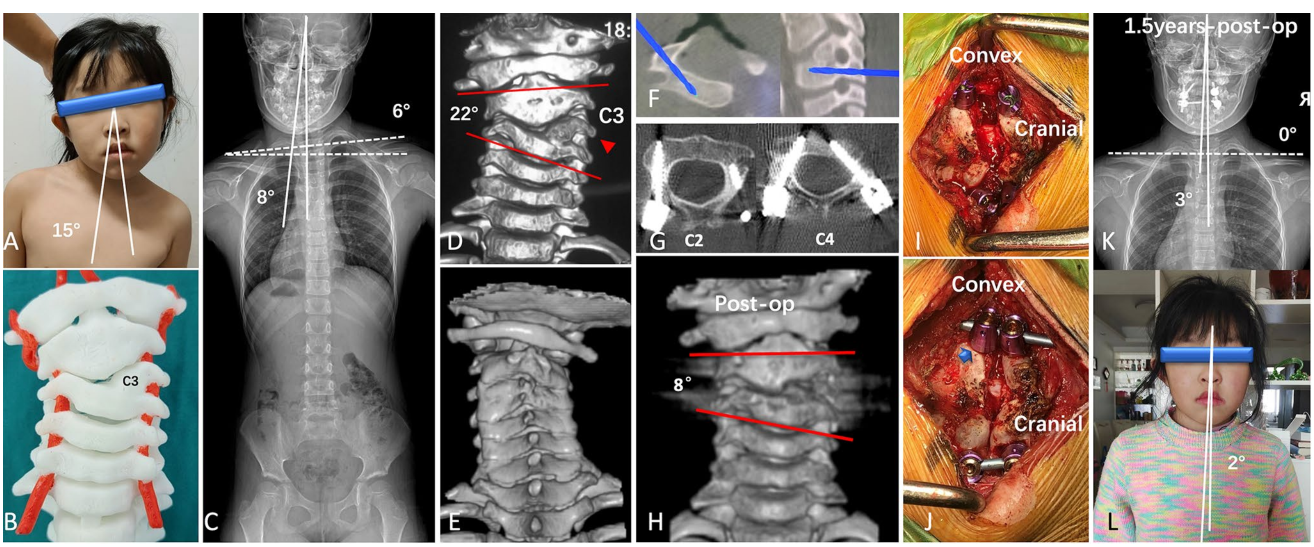

Fig. 2 A 6-year-old girl (Case 1) with osseous torticollis caused by a C3 hemivertebra (Figs. **A**, **C**, **D**, and **E**). Personalized 3D printed model of the deformed cervical spine was created to show the bony deformity and course of vertebral artery (Fig. **B**). CPS at C2 and C4 were inserted bilaterally using surgical synergy navigated workflow techniques (Fig. **F** and **G**). Sufficient closure of the osteotomy gap between C2 and C4 was confirmed when the tails of the cranial and caudal CPS neighbouring CHV contacted closely after convex compression (Fig. **I** and **J**). After surgery, the cervical scoliosis improved to 8° (Fig. **H**), and the RHT, MHT and shoulder imbalance improved to 3°, 2° and 0° by 1.5 years follow-up (Fig. **K** and **L**)

neurological complications. After surgery, the cervical scoliosis improved to 8°, and the RHT, MHT and and shoulder imbalance improved to 3°, 2° and 0° by 1.5 years follow-up, respectively (Fig. 2H, K, L).

Case 2

A 5-year-old girl presented with torticollis since birth. She exhibited the clinical triad of a short neck, a low posterior hairline, and a limited cervical range of motion, and was thus diagnosed as Klippel–Feil syndrome (KFS). The torticollis was progressive with growth, and was liable to cause secondary chin rotation, facial asymmetry and shoulder imbalance during early childhood (Fig. 3A, C). There was no symptom of neurologic deficits. Since the appearance were getting more and more visibly dysmorphic, the girl's parents were eager to seek surgical treatment. The CT scans revealed a left dominant asymmetrical congenitally unsegmented bony conglomerate consisting of a hemi-atlas with a fusion between the C1 to C4 vertebrae and an additional left-sided well segmented C6 hemivertebra (Fig. 3D). The cervical scoliosis was 35°, and the RHT, MHT and shoulder imbalance were 17°, 18° and 8°, respectively. No developmental malformation of the spinal cord was found in MRI scans. Since C6 hemivertebra was well segmented and contributed significantly to severity of torticollis, a surgical plan involving posterior-only C6 hemivertebra resection and short fusion from C5-T2 was then designed and conducted. The treatment process was uneventful. The post-operative CT scan showed complete resection of C6 hemivertebra with the cervical scoliosis being corrected to 15°, and the RHT, MHT and and shoulder imbalance improved to 6°, 7° and 2° by 1.5 years follow-up, respectively (Fig. 3J, L).

Case 3

An 8-year-old girl and her mother referred to the outpatient clinic of spinal deformity complaining about poor appearance consisting of torticollis, inner shoulder imbalance and inclined biocular line (Fig. 4A). The osseous torticollis was known since early childhood, yet was recalcitrant to physical therapy maneuvers. The deformed appearance was progressive, while the sensory and motor function were intact. The preoperative CT scans showed ipsilateral skipping two level hemivertebrae locating at C6 and T1, respectively (Fig. 4C, D). The C6 hemivertebra was relatively well segmented, which synostosed partially with the C7 vertebral body in the median portion; while the T1 hemivertebra was semisegmented. The corresponding concave intervertebral space was open and flexible at C6 level, yet was synostosed at T1 level. The cervical scoliosis was 39°, and the RHT and MHT were both 8°. Based on these anatomical characteristics, the C6 hemivertebra was selected to be the target of excision, with the fusion levels ranging from C4-T1. After navigated CPS insertion, a meticulous osteotomy was performed with sufficient osteotomy closure and utmost C5 tilt correction. After surgery, the patient developed minor convex side radiating nerve root pain but no sign of muscle power weakness. Full recovery was achieved one month after surgery. The Cobb angle was corrected to 7°, and subsequently the shoulders rebalanced very well. The head posture changed to be neutral with RHT and MHT being both improved to 0° by 1 year follow-up (Fig. 4F, G). The operative change of cosmetic appearance was dramatically satisfying (Fig. 4B).

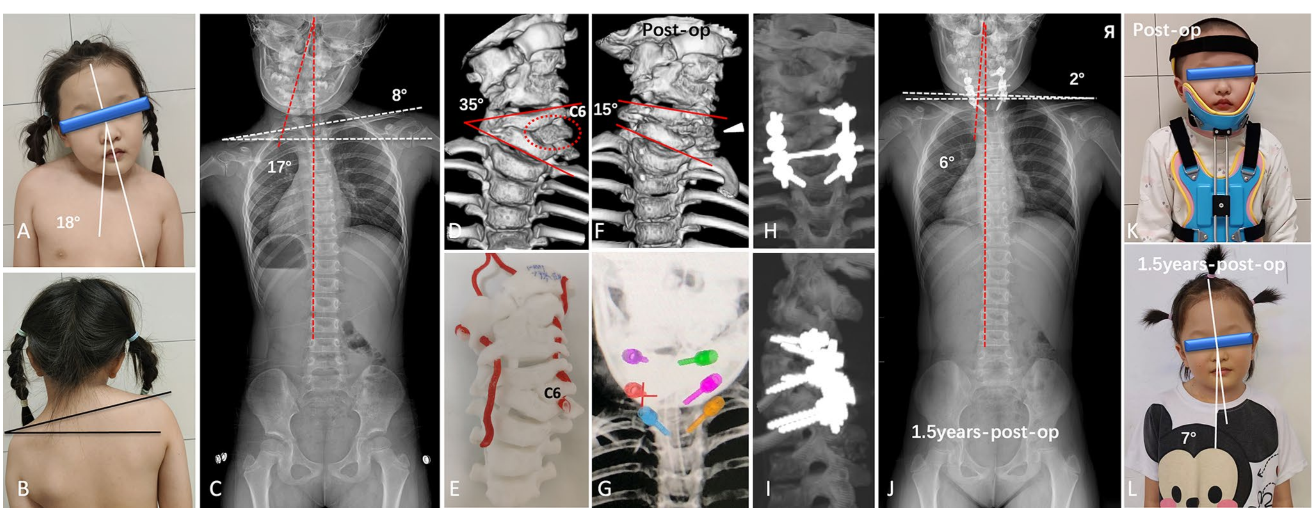

Fig. 3 A 5-year-old girl (Case 2) with Klippel–Feil syndrome, osseous torticollis and shoulder imbalance (Figs. **A**, **B**, **C**, **D**, and **E**). We performed posterior-only C6 hemivertebra resection and short fusion from C5-T2. The post-operative CT scan showed complete resection of C6 hemivertebra with the cervical scoliosis being corrected to 15° (Figs. **F**, **G**, **H**, **I**, and **K**), and the RHT, MHT and shoulder imbalance improved to 6°, 7° and 2° by 1.5 years follow-up (Fig. **J** and **L**)

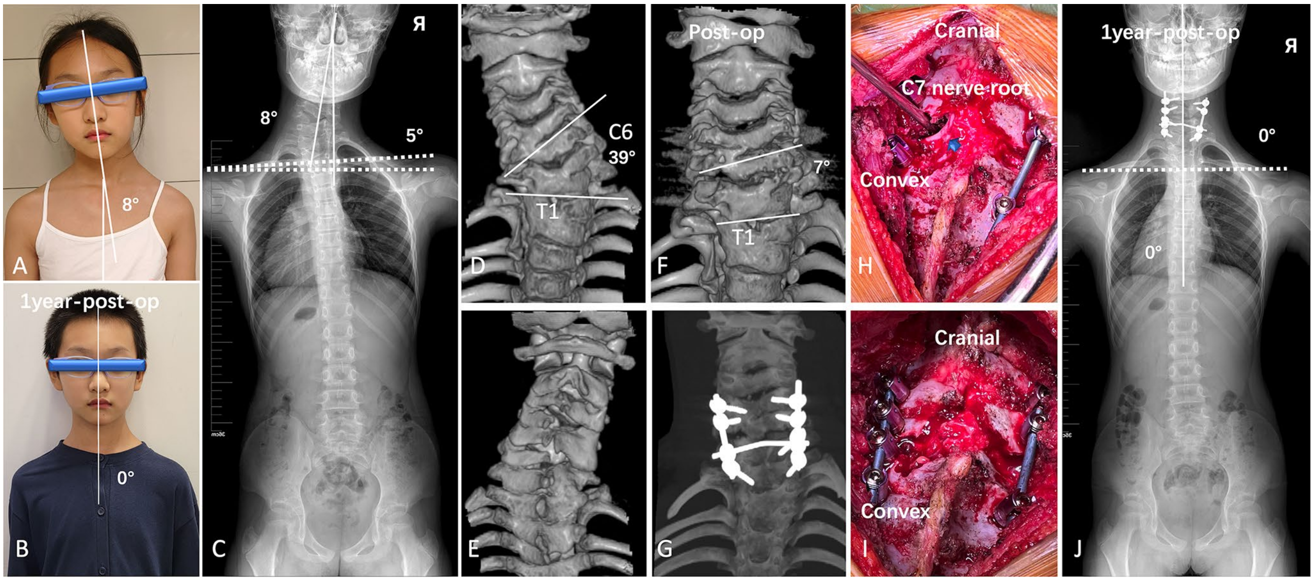

Fig. 4 An 8-year-old girl (Case 3) with osseous torticollis and inner shoulder imbalance caused by ipsilateral skipping two level hemivertebrae locating at C6 and T1. The cervical scoliosis was 39°, and the RHT and MHT were both 8° (Figs. **A**, **C**, **D**, and **E**). We performed posterior-only C6 hemivertebra resection and short fusion from C4-T1 (Fig. **H** and **I**). The post-operative CT scan showed complete resection of C6 hemivertebra with the Cobb angle being corrected to 7° (Fig. **F** and **G**). The head posture changed to be neutral with RHT and MHT being both improved to 0° by 1 year follow-up (Fig. **B** and **J**)

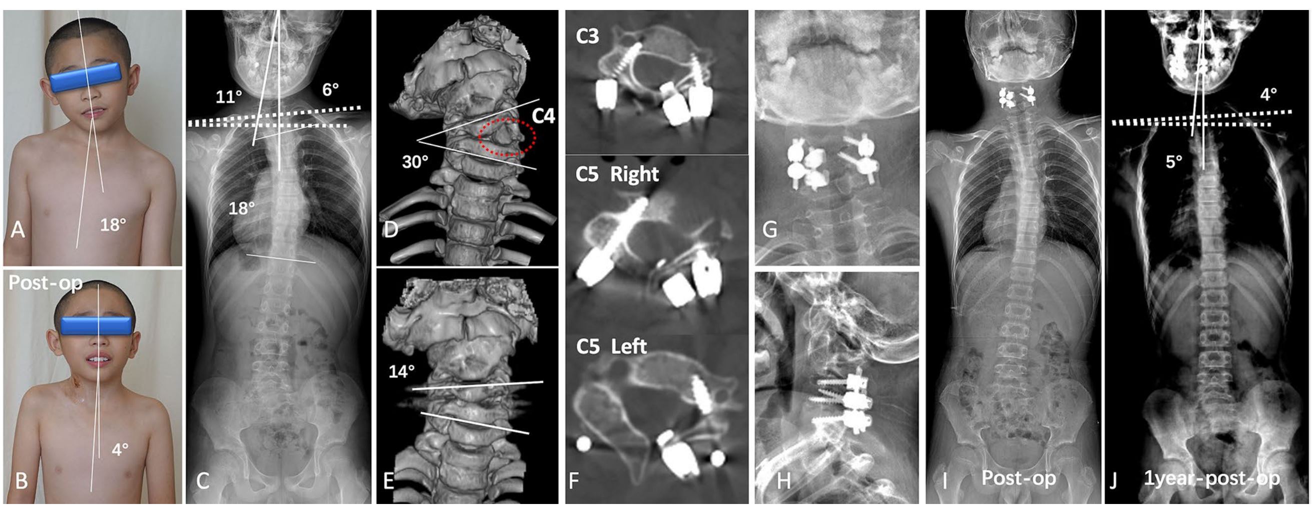

Fig. 5 An 8-year-old boy (Case 4) with progressive right torticollis and a compensatory thoracic scoliosis (Fig. **A** and **C**). The CT scans revealed multiple, contiguous congenital bony malformation: a synostosis occiput to C2, and an additional left-sided C4 hemivertebra (Fig. **D**). We performed resection of the C4 hemivertebra with short fusion of the adjacent vertebrae (C3-C5). An additional satellite rod being fixed to laminar hooks was inserted to enhance the strength of fixation (Figs. **F**, **G**, **H**, and **I**). The cosmetic appearance improved (Fig. **B**), and the cervical curve was reduced to 14° (Fig. **E**), and the RHT was improved to 5° by 1 year follow-up with spontaneous correction of the compensatory thoracic scoliosis (Fig. **J**)

Case 4

An 8-year-old boy presented with progressive right torticollis and restricted neck motion since infant age. The shoulders became increasing uneven, and the head tilted to the right side. These aesthetic problems convinced the parents to refer their son directly to our hospital. The CT scans revealed multiple, contiguous congenital bony malformation: a synostosis occiput to C2, and an additional left-sided C4 hemivertebra (Fig. 5D). The cervical scoliosis was 30°, and the RHT, MHT and shoulder imbalance were 11°, 18° and 6°, respectively (Fig. 5A, C). A compensatory thoracic scoliosis measured 18° was also observed. Obviously, the C4 hemivertebra was the major deformity driver being responsible for the disfiguring appearance, and thus was selected as the target of osteotomy correction.

Resection of the cervical hemivertebra was performed by a posterior-only approach with short fusion of the adjacent vertebrae (C3-C5). We additionally placed a supralaminar downgoing hook and an infralaminar upgoing hook on the adjacent levels above and below at the convex side (Fig. 5F, G,H). Placement of this satellite rod into these laminar hooks with gradual compression was beneficial for enhancing the strength of fixation. After surgery, the cervical curve was reduced to 14°, and the RHT was improved to 5° by 1 year follow-up with spontaneous correction of the compensatory thoracic scoliosis (Fig. 5J).

Discussion

Congenital cervical hemivertebra resulting in early torticollis phenotype is one of the rare causes of pediatric consultation. It is a neglected disfiguring disease for children with limited public awareness that this osseous torticollis is conservatively uncorrectable, and early surgical treatment should be done before irreversible cranial and facial aesthetic deformities occur [10]. The first-line treatment option to palliate or control the disfiguring symptoms is to resect the CHV totally [5]. In this way and by means of early intervention, the growth asymmetry of cervical spine could be largely corrected, and logically, secondary distortion of craniofacial soft tissue and skeletal structures can be well avoided. However, excision of a cervical hemivertebra in young children remains highly challenging given the tiny anatomy, technical complexity and high risk of unacceptable neurological and vascular injuries, thus mandating a careful assessment of the risk/benefit ratio. As a result, the related surgical outcome and experience for this complex pediatric disease are rarely reported. Moreover, the optimal age for surgical intervention is controversial and inconclusive. An individualized timing of surgical intervention and design of surgical strategy for this particular patient cohort should be considered.

In the literature, from the beginning to the present, excision of CHV preferred being done using a combined cervical approach, either separate or simultaneous [4, 5, 10–12]. The first case report detailing the presentation and treatment of CHV showed a four-stage anterior-posterior-anterior cervical surgery lasting four months in total [11]. A manual closed reduction was performed with the patient awake after both anterior and posterior osseous structures of CHV were resected. Immobilization in a halo cast continued throughout the treatment until the anterior cervical fixation using intersomatic plate was done. The whole treatment procedure was long lasting, complex and highly risky, yet still be a great first attempt. Afterwards, Ruf et al. attempted to resect CHV using a posterior-anterior-(posterior) approach [5]. The osteotomy gap after CHV resection was closed using anterior open reduction assisted by bending the head manually to the convex side. If the gap closure was insufficient, additional posterior compression instrumentation was applied to further increase the correction and enhance fusion.

In the limited literature thereafter, an anteroposterior-anterior (APA) combined approach was adopted and reported universally [4, 10, 12]. This was because the anterior open reduction of osteotomy gap performed in PAP approach was associated with less operating space as compared to posterior cervical manipulation, and the sophisticated device and delicate instrumentation for direct anterior closure and compression fixation of cervical osteotomy was unavailable. Thus manual assistance to bend the head slowly to the convex side under Mayfield traction was routinely required to realize the indirect osteotomy closure, which was the premise of subsequent anterior instrumentation. For APA approach, the superiority lied in that following sequential anterior hemivertebrectomy, release and posterior resection of the residual transverse process and lateral mass, direct posterior open reduction of cervical osteotomy could be obtained more easily using the screw-rod fixation system. Additional anterior access instrumentation could provide additional support and help obtaining a complete 360° fusion using three cortical iliac bone or a polyetheretherketone cage [4]. Recently, aside from the convex-side resection technique, a concave-side distraction technique was proposed to correct cervical scoliosis by concave distraction and lateral opening using an APA combined approach [13]. In their technique, multiple 3D-printed customized titanium alloy spacer were grafted into the intervertebral space on concave side anteriorly and between the upper and lower facet joints posteriorly for concave lengthening [13]. The outcome was favourable, yet the application of this technique was restricted to those few hospitals with access to obtain 3D-printed customized titanium prosthesis.

Despite all the modifications and improvements in the recent four decades, there were still several aspects that warrants further reformation. The combined approach was associated with more operative time and operative invasiveness, potential injury of superior laryngeal nerve, recurrent laryngeal nerve, autonomic nerves and esophagus during anterior access surgery, and a high risk of spinal cord injury during the process of change of operative posture [14]. Currently, posterior-only approach have been well applied for the treatment of thoracolumbar hemivertebra in children [15], and if possible, it should be a potential effective method that could avoid all these aforementioned problems related to anterior access surgery.

The advent of ultrasonic bone scalpel and O-arm-based intraoperative navigation for cervical pedicle screw placement were two key factors that made us reconsidering the feasibility of a clinical trial of CHVE by a posterior-only approach [7–9]. Compared to lateral mass screw, the CPS in children had much higher biomechanical strength, and was able to withstand the correction forces for posterior osteotomy closure and short fusion. In addition, spinal osteotomy using ultrasonic bone scalpel was highly efficient yet much less invasive, enabling 3-column osteotomy in children's petite and flexible neck. In this report, we described our evolution to posterior-only CHVE. Our practice of this new technique proved that the cervical hemivertebra can be effectively and totally resected using a posterior-only approach. As long as a circumferential 360° release and reliable CPS insertion were obtained, satisfactory osteotomy closure and torticollis correction with firm posterior instrumentation was not that difficult to achieve. The cosmetic appearance were all ameliorated greatly after surgery. Meticulous manipulation of the spinal cord and nerve roots, and control of epidural bleeding were essential for reducing the risk of complications. Sometimes, in order to protect against implant failure, a 3-rod technique using additional satellite rod with convex lamina hooks could enhance the rigidity of fixation and deformity correction.

The close proximity of vertebral artery with CHV was another critical factor that render the surgery of CHVE risky and difficult. Previously, the VA should be fully dissected and exposed when performing CHVE, so as to help excising the transverse foramen of the hemivertebra [5]. Wang et al. reported that, instead of dissecting the VA, they disconnected the transverse process as a whole, and freed it away from the body of CHV [4]. Logically, this technical modification could significantly reduce the risk of VA injury, and thus was much safer. In our practice, the CHV's anterolateral part of the transverse process were also cut adrift from the spinal column rather than being fully resected, and we encountered no significant bleeding caused by injury of VA. We also noticed that this residual small bony structure wouldn't obstruct the closure of osteotomy gap.

Limitation of new technique should be mentioned. Firstly, for those with non or incomplete segmentation of the upper and lower adjacent cervical vertebrae on the concave side, a posterior-only approach may not be capable of transect and separate the concave synostosis effectively. For better osteotomy closure, this anteriorly fused cervical malformation should better be operated with combined approach. Secondary, the latest follow-up was far before reaching skeletal maturity. Since the main purpose was to show the feasibility of this novel technique, this issue has no relevance but may be not sufficient to show the true long-term outcome. Thirdly, congenital deformities at the cranio-cervical junction, as well as existence of dominant vertebral artery on the side of hemivertebra, are contraindicated for application of this technique.

Conclusion

Presented herein is the initial clinical trial of posterior-only approach for excision of lower cervical hemivertebra in young children. Excellent short-term surgical outcome with low incidence of complication demonstrated that CHVE by a posterior-only approach was a feasible alternative option and an important supplement for the treatment of congenital cervical scoliosis with acceptable neurological risk and shorter recovery period. It could resect the CHV effectively and achieve satisfactory improvement of head-neck aesthetic appearance without additional anterior access surgery. Successful CPS placement and thorough wedge osteotomy in this child population were quite important to enable reliable osteotomy closure and firm posterior instrumentation. Surgeon skillset and expertise were essential for precise and safe execution of this novel technique. Considering the complexity of cervical hemivertebra deformity, employment of posterior-only CHVE should only be one alternative option, and the ultimate choice of surgical technique and approach for correction of congenital cervical scoliosis was likely surgeon and case-dependent.

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