ANTERIOR CORRECTION OF ANGULAR KYPHOSIS IN CHILDREN: DESCRIPTION OF THE TECHNIQUE AND ANALYSIS OF CLINICAL SERIES

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Objective. To describe the original technical surgical procedure simplifying the correction of kyphosis in children due to instrumental distraction of the anterior column of the spine, to analyze its effectiveness in the setting of clinical series. Level of evidence — IV.
Material and Methods. The study included 9 patients aged 7 months to 14 years (median age: 4 years 8 months) with angular kyphosis (median magnitude 53°, min — 38°, max — 80°) associated with tuberculous (n = 4) and non-specific (n = 4) spondylitis and with a sequelae of spinal cord injury (n = 1). Deformity correction was achieved using temporary instrumental interbody distraction followed by anterior fusion with titanium mesh cage filled with autologous bone graft during a single-step two-stage reconstruction and stabilization surgery.
Results. The duration of surgery was 3 hours 2 min ± 44 min, the volume of blood loss — 190 ml ± 39 ml. In all cases, the deformity was corrected by 75—85 % with restoration of physiological thoracic kyphosis and spinal profile.
Conclusion. A safe and effective technique for intraoperative anterior instrumental distraction can be used to correct angular kyphosis in children, including infants.
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Posterior vertebrectomies (spinal osteotomies) at the deformity apex, which correspond to Schwab grade 4–6 osteotomies [1], are most often used to correct angular kyphosis of various etiologies [2]. Various vertebrectomy techniques enable effective deformity correction from 30–40° (PSO) to 49–80° (VCR) [3, 4], but the following factors limit their use in pediatric patients [5, 6]:

1) large amount of blood loss reaching 45% of the total blood volume (TBV) (or 1.5 L in absolute values);

2) surgery duration of 180 to 450 min;

3) risk of neurological complications, which amounts to 30 % due to invasiveness of the procedure and injury to the spinal nerve roots, including their planned transection for full access to the anterior column;

4) significant reduction in the spine length due to multilevel resection of the posterior column (at least throughout the pathologically changed vertebrae);

5) long-term extended posterior instrumental fixation necessary for formation of adequate anterior and posterior fusion.

One of the ways to reduce these risks and complications is the so-called 360° spine reconstruction through combined approaches. The advantages of this surgery include reduced blood loss, a reduced risk of injury to the spinal nerve roots, and no need for extensive resection of the posterior column due to better visualization of the reconstruction area and interbody fusion with a combined primary-stable non-biological implant – titanium mesh cage with osteoinductive material (bone auto- or allograft) [7]. In this surgery, kyphosis correction is carried out before placement of an interbody implant by means of combination of manual reclination and a posterior instrumental maneuver to increase post-resection diastasis. At the same time, reclination requires coordinated technical manipulations (axial distraction, posterior-anterior compression over the kyphosis apex and anterior posterior compression over the shoulder girdle and pelvis) of members of the operating team (surgeons, anaesthesiologists), and the implant is inserted under certain tension to be impacted at maximally held correction.

The study objective is to describe the original surgical technique that simplifies kyphosis correction in children due to instrumental distraction of the anterior spinal column and to analyze its effectiveness in a clinical series.

In this publication, we describe the technique and analyze its immediate, short-term, and long-term outcomes.

Material and Methods

In 2015–2018, 9 patients aged 7 months to 14 years (M = 4 years and 8 months) with angular kyphotic deformity of the spine caused by infectious destructive disease (4 patients with tuberculous spondylitis and 4 patients with non-specific spondylitis and its sequelae) and consequences of spinal cord injury (SCI, 1 patient) underwent reconstructive surgery using anterior instrumental distraction at the Pediatric

Surgery and Orthopedics Clinic of the Saint-Petersburg Research Institute of Phthisiopulmonology (SPRIP). The indications for surgery were as follows: destruction of the anterior spinal column complicated by angular kyphosis with a Cobb angle of ⩾35°; post-traumatic kyphotic deformity of the thoracolumbar spine with a magnitude of 46°. The neurological status of patients at the time of surgery was assessed as Frankel type E in eight cases; the patient with SCI sequelae had paresthesias from the L1 segment, without motor disorders.

The design and objective of this publication (analysis of a clinical series) did not assume comparing the effectiveness of this technique with that of others used previously in similar patients.

Perioperative (pre- and postoperative) antibiotic therapy was performed in regimens consistent with current guidelines for treatment of specific and non-specific spondylitis [8, 9]. Immediate outcomes were evaluated in all patients, while long-term outcomes were assessed in seven patients (4 patients with tuberculous spondylitis and 3 patients with non-specific spondylitis and its sequelae) followed-up for more than 6 months after surgery (max, 36 months); follow-up examinations were carried out at 6 months (X-ray) and 12 months (CT). The postoperative follow-up period in two children was less than 4 months.

During examination, the following parameters were evaluated:

1) surgery duration (min);

2) amount of operative blood loss in absolute (mL, with allowance for losses in the aspirator and wipes) and relative (% of TBV as a ratio of the absolute value to the estimated age-weight TBV) values;

3) value and degree of kyphosis correction (as Cobb angle and % of the baseline value);

4) rate of intra- and postoperative complications.

Statistical data processing was performed using the Statistical Package for the Social Sciences (version 22.0). Mean values of the studied parameters were calculated using the descriptive statistics method. Numerical values are presented as M ± m, (min; max), where M is the mean value, m is the standard deviation, min is the minimum value, and max is the maximum value.

Results

One-narcosis reconstruction of destructive diseases accompanied by thoracic and thoracolumbar spine deformities by means of the described technique includes 4 main stages:

1) resection of destroyed vertebral bodies and pathological tissues;

2) instrumental interbody distraction;

3) placement of titanium mesh cage with autologous bone graft;

4) posterior instrumental fixation of the spine.

The first and fourth surgical stages are described in detail in papers devoted to surgical treatment of spondylitis in children [10]. In our opinion, the most important aspect is a technical solution that combines the second and third stages.

Removal of the destroyed vertebral bodies, decompression of the spinal canal, and treatment of paravertebral abscesses through the anterolateral approach (1st stage of surgery) were followed by insertion of distractor screws into the lateral surfaces of the cranial and caudal bodies of the blocked vertebrae; the screw length was preliminarily calculated using the CT data with allowance for the vertebral body transverse diameter (a Caspar cervical distractor was used in younger children, and transpedicular screws were used in older children). Deformity correction (2nd stage) was performed by gradual distraction; in this case, there was a visual increase in interbody diastasis into which titanium mesh cage filled with autograft (a fragment of the rib or iliac crest) was inserted at the end of distraction (3rd stage). Upon reducing the distractor tension due to soft tissue retraction, the mesh cage was clamped between the blocked vertebrae without reducing the distraction diastasis, while the axial stiffness and the shape of titanium mesh cage ends provided stable anterior fixation, which enabled distractor removal. At the last stage, final stabilization was performed through the posterior approach by means of posterior instrumental fixation; in the case of residual deformity, limited laminectomy was performed at its apex. Posterior spinal fusion was carried out throughout the area corresponding to anterior spinal reconstruction.

A schematic of the technique is presented in Fig. 1.

Intraoperative photographs (Fig. 2–4) illustrate the reconstruction stages.

The results obtained in analysis of the surgery duration, amount of blood loss, and deformity changes are presented in Tables 1 and 2.

After completion of the anterior stage of surgery, 3 (33.3 %) patients underwent single-level laminectomy at the kyphosis apex, followed by posterior instrumental fixation in order to increase correction. In 5 (55.5 %) patients, laminectomy was completely avoided. In one case (SCI sequelae), laminectomy was performed at the time of primary surgery.

There were no intraoperative and any postoperative complications in patients of the analyzed series.

Discussion

The trend to use posterior spinal vertebrectomies for correction of deformities of various etiologies in children is seen in a large number of recent publications. However, the need for reconstructive interventions in young children with infectious spondylitis is associated with the fact that targeted antibiotic therapy does not prevent kyphosis, and orthosis does not prevent kyphosis progression during child growth. In turn, early restoration of the spine profile and support ability retains the potential for further growth and development of the child [4].

According to Jeszenszky and coauthors [11], VCR is effective for restoration of the sagittal balance in early-onset spinal deformities and provides correction of initial kyphotic deformity from 126 to 55° (56 %). Given the age of patients (not older than 5 years), of particular interest are the reported values of reduced blood loss (M = 762 mL) and surgery duration (M = 500 min). In addition, complications were revealed in two cases (proximal contact kyphosis and peri-implant infection), which required revision interventions. Helenius and coworkers [12] performed 4 VCR operations in children with congenital angular kyphosis, along with deformity correction (from 57 to 70 %), and had one case of postoperative complication – L5 nerve root paresis. In this case, the mean blood loss was 1,680 mL (min = 500, max = 3,500), which, according to the authors, required mandatory replacement with whole blood or its components.

Angular kyphosis of 60° or more occurs during the natural course of tuberculous spondylitis in 3–5 % of cases [13]. A retrospective analysis of 17 VCR surgeries for this pathology indicates both deformity correction by 68.7 ± 6.5%, on average, and high mean values of blood loss (M = 2,218 mL) and surgery duration (6 h 4 min) [14]. A modified version of posterior vertebrectomy through the vertebral arch in children with post-tubercular angular kyphosis aged 11 ± 5 years enabled a reduction in the surgery duration to 4 h and 16 min and blood loss to 870 mL, on average [15], which remains a very significant indicator and reaches 40% in terms of TBV. Without denying the effectiveness of VCR surgery, especially in cases of severe angular kyphosis, we believe that the proposed technique for correction of kyphotic deformity has certain advantages:

– temporary instrumental anterior distraction seems to be more technological and controllable;

– preserved posterior spinal column prevents bayonet displacement of the vertebrae, the risk of which is always present in the case of iatrogenic destabilization of the posterior column;

– anterior fusion with titanium mesh cage filled with autologous bone, which is inserted into the interbody diastasis and wedged between the vertebral bodies by means of terminal pins, ensures sufficient stability and greater safety during subsequent manipulations on the posterior spinal column.

Conclusion

The developed technique for correction of angular kyphosis is a technical solution enabling controlled correction of deformity in children in the setting of stable spine, ensuring a reduction in blood loss and surgery duration. The technique has demonstrated its effectiveness and safety in patients of different ages, including children of the first years of life, which suggests that it may be used not only for infectious and destructive and post-traumatic lesions but also for other, in particular congenital, deformities.

Limitations of the significance of the findings. The significance of the presented results is limited by the publication design (retrospective clinical series), a small number of patients preventing statistically correct comparison with other types of corrective surgery for kyphosis in children, and a lack of experience in applying the technique for deformities exceeding 90°.

The study did not have sponsorship. The authors declare no conflict of interest.

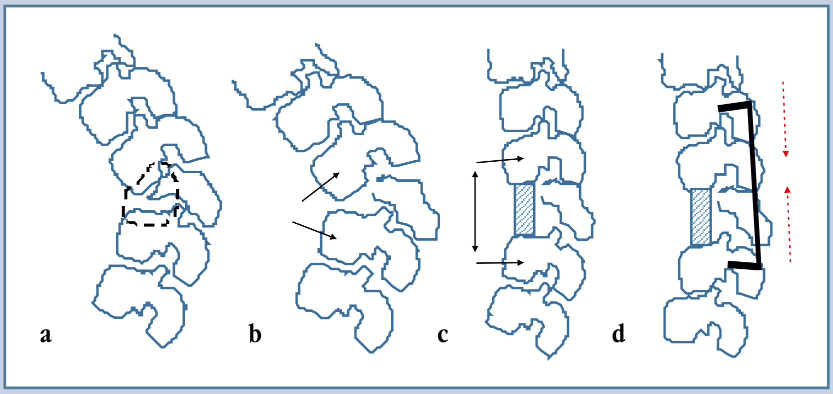
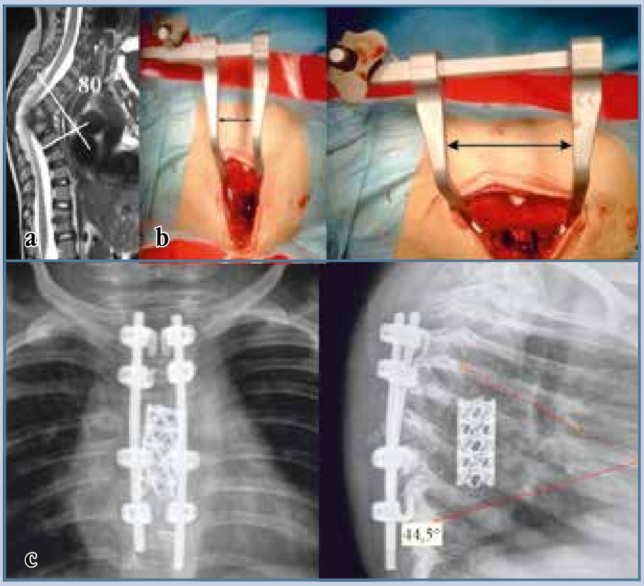


Fig. 1
Principles of kyphosis correction: **a** – initial condition: kyphotic deformity in the setting of a destroyed or hypoplastic anterior spinal column; the dashed line indicates the resection area that provides anterior mobilization of the spine; **b** – screws of an interbody distractor (arrows), which are inserted into the lateral surfaces of the vertebral bodies; **c** – anterior instrumental fixation (double-headed arrow) and anterior interbody spinal fusion; **d** – posterior instrumental fixation (dashed arrows indicate the direction of instrumentation tension in the compression mode)



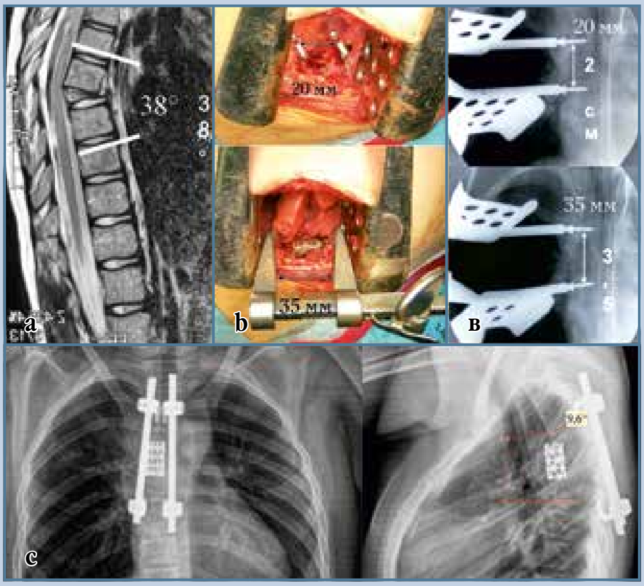


Fig. 2
A 18-month-old male patient K. with neonatal sepsis sequelae involving the C5–C7, T4–T7, and T12–L1 vertebrae: **a** – a preoperative MRI scan: angular thoracic T2–T12 kyphosis of 80°; **b** – intraoperative extension of diastasis from 10 to 24 mm with a Caspar distractor after resection of the T4–T7 bodies; **c** – postoperative radiographs: anterior spinal fusion of T3–T8 is performed with titanium mesh cage filled with an autologous rib graft, with restoration of a physiological profile of the thoracic spine to 44°; total kyphosis correction is 36°

Fig. 3
An 11-year-old male patient Z. with a pathological fracture of the T7 vertebra (according to examination of the surgical material – chronic nonspecific spondylitis) and angular thoracic T6–T8 kyphosis of 38°: **a** – a preoperative MRI scan; **b** – intraoperative photographs of the correction stages by means of a Caspar distractor: insertion of screws into the vertebral bodies; placement of titanium mesh cage; **c** – X-ray control of distraction; **d** – radiographs of the spine after surgery: residual kyphosis is 9°; deformity correction is 29°

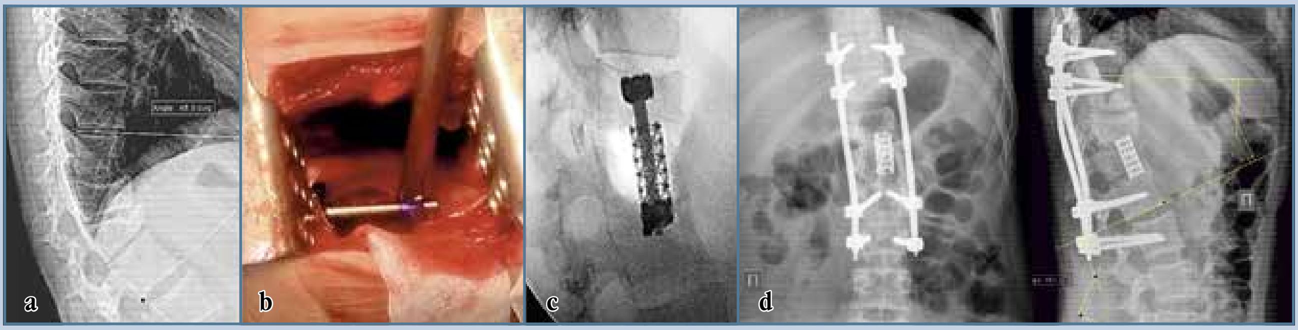


Fig. 4
A 14-year-old female patient S. with sequelae of a T12 (type A1) and L1 (type A3 according to the AO classification) fracture; condition after repeated surgery: anterior reconstruction with posterior instrumental fixation through an isolated posterior approach, which is complicated by deep infection of the surgical site; removal of anterior and posterior implants; late complications: spinal instability, post-traumatic thoracolumbar kyphosis of 47°, and chronic pain; surgery at our clinic 12 months after injury: resection of the L1 body, deformity correction, anterior spinal fusion of T12–L2 (mesh cage + autologous bone); posterior transpedicular fixation of T10–L3: **a** – preoperative spondylogram in the lateral projection; **b** – view of the surgical wound after resection of the L1 body and the distraction maneuver on screws inserted in the T12 and L2 bodies; **c** – intraoperative radiograph (lateral projection) after placement of titanium mesh cage with autologous bone; **d** – postoperative radiographs: the sagittal spine profile is restored; total kyphosis correction is 21°

Table 1

Surgery duration and amount of blood loss in operated patients

Parameter	M ± m	Min	Max
Surgery duration, (h + min)	3 + 2 ± 0 + 44	3 + 10	4 + 30
Blood loss, mL	190 ± 39	150	250
Blood loss, % of TBV	13.1 ± 2.7	10.4	17.3

Table 2

Changes in kyphotic deformity at surgical stages (Cobb angle, degree)

Before surgery			After surgery			Correction, n (%)	Loss of correction*
M ± m	min	max	M ± m	min	max		
53.0 ± 14.2	38	80	28.5 ± 12.9	9	44	24.5 ± 1.3 (54)	3.7 ± 1.4

*12 months after surgery (calculated on seven patients).

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