Genij Ortopedii. 2021. Vol. 27, no. 6. P. 717-726.

Original article

https://doi.org/10.18019/1028-4427-2021-27-6-717-726

Algorithm for the treatment of congenital anomalies of the spine

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Abstract

Introduction The treatment of congenital spinal anomalies poses a formidable task. Although many classifications of congenital malformations of the spine and the spinal cord have been developed and a variety of surgical options offered, none of the existing classifications can be used to identify appropriate treatment guidelines and surgical practices. **Design** Expert consensus level. Evidence level: 5 (UK Oxford, version 2011). Objective of the study was to offer an algorithm of surgical treatment strategy for patients with congenital malformations of the spine based on identification of a leading syndrome. **Material and methods** The algorithm was developed through the clinical experience and consensus opinion of the authors based on the management and follow-up of 284 patients with different patterns of congenital spinal deformity treated between 2008 and 2018. **Results** The algorithm offered to identify an appropriate treatment strategy for congenital anomalies of the spine included a stepwise protocol for sequential assessment of the criteria selected and considered as components of the leading syndrome of multiplanar deformity allowing well-argued surgical options and succession of treatment stages. Sequential evaluation is essential for patients with multilevel congenital anomalies and several main arcs. The algorithm is presented as a checklist with a table and comments to the main syndromes and decision-making process. **Conclusion** The algorithm offered is a stepwise checklist providing a step-by-step process for making decisions on the approach and practice for treating congenital anomalies of the spinal column. It is designed to consider main pathological syndromes being typical of congenital pathology and reduce tactical and methodological flaws. The algorithm is of purely advisory nature. The consensus opinion of experienced surgeons has been shown to be essential for timely management facilitating appropriate treatment strategy for the rare and diverse nosological group.

Keywords: hemivertebra, spinal anomaly, congenital spinal deformity, congenital scoliosis, congenital kyphosis, congenital lordosis, treatment algorithm

For citation: Filatov E.Iu., Ryabykh S.O., Savin D.M. Algorithm for the treatment of congenital anomalies of the spine. *Genij Ortopedii*, 2021, vol. 27, no 6, pp. 717-726. https://doi.org/10.18019/1028-4427-2021-27-6-717-726.

INTRODUCTION

The treatment of congenital spinal anomalies poses a formidable task due to multiple criteria used to assess "vertebral status" and determine the prognosis of the pathology including complicated cases. Although at least five classifications of congenital malformations of the spine and the spinal cord have been developed and a variety of surgical options offered, none of the existing classifications can be used to identify appropriate treatment guidelines and surgical practices. Among a sufficient number of publications available the majority are case reports describing short-segment fixation or evaluating the effectiveness of growing systems that restrict the evidence for the choice of treatment modalities based on long-term results. There are many works representing retrospective analyses of local cohorts (evidence level: 3-4 UK Oxford, version 2011) without comparison of the results with uniform evaluation criteria.We could not find evidence of the treatment strategy for a congenital anomaly based on a syndromal approach. The approach is widely used when choosing treatment options for trauma and degenerative pathology of the spine.

Design: expert consensus level.

Evidence level: 5 (UK Oxford, version 2011).

Objective of the study was to offer an algorithm of surgical treatment strategy for patients with congenital malformations of the spine based on identification of a leading syndrome.

MATERIAL AND METHODS

The algorithm was developed through the clinical experience and consensus opinion of the authors based on the management and follow-up of 284 patients with different patterns of congenital spinal deformity treated between 2008 and 2018.

Concept: the algorithm was based on five key principles:

– the principle of the "syndromal approach" in assessment of malformation;

– the principle of "sequence of correction starting with the most aggressive component of malformation";

– the principle of "priority of short-segment fixation" with the use of vertebrectomy and local fixation to facilitate realignment of the main, cranial and caudal curves through the leading component of the deformity or reduce the rate of its progression;

– the principle of reducing the number of staged operations;

– the principle of "base-to-top timely reconstruction": the anatomy and reliability of fixation points in the caudal vertebrae facilitate staged caudal-to-cranial correction. This is essential for patients aged 2-3 years who can undergo early radical local correction at several levels and approach the final correction at older age with a minimum angle of the curve.

RESULTS

Justification of the algorithm The algorithm (Fig. 1) offered to identify an appropriate treatment strategy for congenital anomalies of the spine included a stepwise protocol for sequential assessment of the criteria selected and considered as components of the leading syndrome of multiplanar deformity allowing well-argued surgical options and succession of treatment stages. Sequential evaluation is essential for patients with multilevel congenital anomalies and several main curves. The algorithm is presented as a checklist with a table and comments to the main syndromes and decision-making process.

Initial clinical evaluation is performed to identify instability, scoliotic, kyphotic and lordotic angles at each level of spinal involvement (Table 1, stage 1–4). Examination is the platform for identifying key syndromes in a particular patient. The basic examination protocol includes an assessment of the somatic, local and neurological status of the patient. Whole spine MRI screening may be required in neurological dysfunction or signs (stigmas) of intraspinal formations. Standing anteroposterior whole spine-pelvic, standing lateral whole spine-pelvic radiographs are the standard first-line examination. Pediatric CT spine imaging is limited to regions of radiographic concern and acquired using the lowest possible radiation exposure. Functional radiography, CT or MRI should be considered as an option if mechanical instability is suspected.

The first stage: consists in the initial clinical evaluation to identify instability, scoliotic, kyphotic and lordotic angles at each level of spinal involvement.

The second stage: with instability detected surgical treatment is planned (Table 2, stage 5) using techniques that would be appropriate for specific type and cause of instability. Neurological instability can be caused by different factors including diastematomyelia, thickened filum terminale, spinal canal stenosis due to bone or soft tissue abnormalities, etc. with binding presence of progressive neurological symptoms. Mechanical instability is always caused by a variant of malformation with the presence of pathological mobility or deficiency of the vertebral columns and can be represented by type I Winter kyphosis, dentoid bone, sacral aplasia, etc. Treatment methods are described in the diagram and can be used in combination with other treatment options.

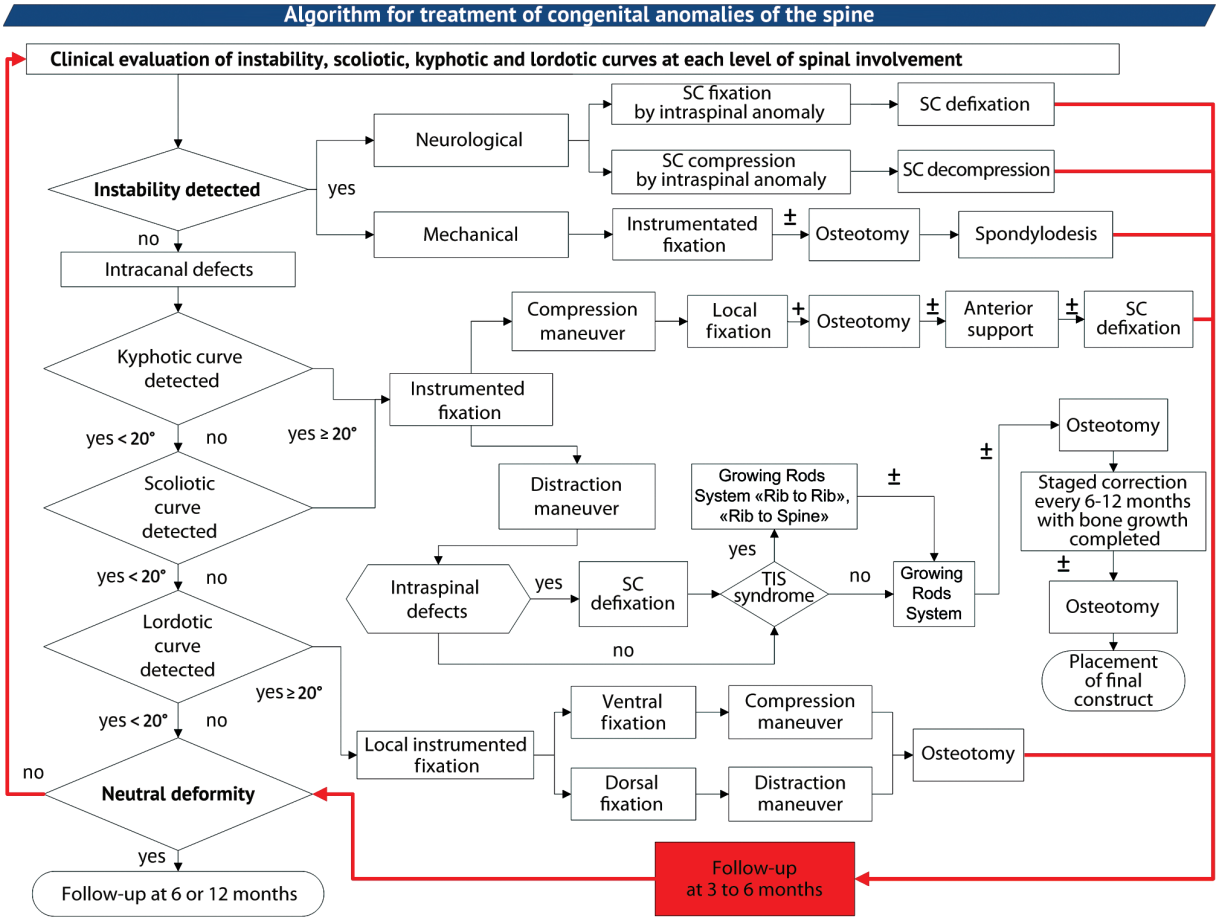

Fig. 1 Algorithm for identifying an appropriate treatment strategy for congenital anomalies of the spine

Table 1

Stages 1–4. Clinical and radiological assessment of instability, scoliotic and kyphotic curves at each level of anomaly (evaluation criteria and options for surgical treatment)

Syndrome		Evaluation criteria	Description
1	Instability	Mechanical	Loss or absence of the ability of the vertebral motor segment(s) to maintain the average physiological position of the vertebrae relative to each other at rest and ambulation
		Neurological	This is a pathological condition of the spine and spinal cord, accompanied by progressive neurological symptoms caused by spinal cord injury or progression of deformity with foci of myelopathy seen in many cases
2	Kyphotic curve	Local curve evaluated at levels of involvement (angular kyphosis)	Measured with vertebrae adjacent to the anomaly in degrees according to Cobb
3	Lordotic curve	Local curve evaluated at levels of involvement	Measured with vertebrae adjacent to the anomaly in degrees according to Cobb
4	Scoliotic curve	Local curve evaluated at levels of involvement	Measured with vertebrae adjacent to the anomaly in degrees according to Cobb
		General curve evaluated at levels of involvement	Cobb angle measured

Table 2

Stage 5. Surgical treatment of instability (methods and options of surgical treatment)

Type of instability	Cause of instability	Method of treatment	Comments
Neurological	SC fixation by intracanal anomaly	Spinal cord defixation	Phantom screws can be used if needed to fix them at this level, including vertebrectomy and curve correction
	SC compression by intracanal anomaly	Spinal cord decompression	
Mechanical	Disturbed formation	Anterior or posterior instrumentation fixation and spinal fusion	Vertebrectomy and curve correction can be applied

The second stage: with instability detected surgical treatment is planned (Table 2, stage 5) using techniques that would be appropriate for specific type and cause of instability. Neurological instability can be caused by different factors including diastematomyelia, thickened filum terminale, spinal canal stenosis due to bone or soft tissue abnormalities, etc. with binding presence of progressive neurological symptoms. Mechanical instability is always caused by a variant of malformation with the presence of pathological mobility or deficiency of the vertebral columns and can be represented by type I Winter kyphosis, dentoid bone, sacral aplasia, etc. Treatment methods are described in the diagram and can be used in combination with other treatment options.

The third stage (Table 3, stage 6) allows consideration of intracanal anomalies that are not manifested as neurological dysfunction but are risk factors for neurological instability in the future (associated/unassociated with surgical treatment). The anomalies may not affect stages of treatment but adjust surgical strategy depending on the type of the main correction maneuver (compression or distraction). When using a compression maneuver, spinal cord defixation or decompression can be performed in one surgical session or in the next stage if needed. If the surgeon focuses on distraction maneuver spinal cord defixation must be scheduled with the first stage.

The fourth stage involves consideration of multicomponent scoliotic, kyphotic and lordotic curves with several main curves (Table 4, stage 7). Correction is first produced at the level of the largest curve. If the leading curve (all arcs ± 5°) cannot be identified the most caudal defect is to be addressed first (Fig. 2). Number of operations recommended and the principle of using the growing construct are also described. A growing construct is ineffective for kyphotic curve and its use can be considered for scoliosis with hyperrotational kyphosis, small angular kyphosis and with hyperrotational lordosis.

The fifth stage is the correction of the kyphotic curve of the deformity if any (Table 5, stage 8). The major compression maneuver during instrumented correction and the mandatory use an osteotomy (multilevel with extended kyphotic curve, a local deformity of 30° or local osteotomy at the apex of the curvature for pronounced angular kyphosis) are essential. The minimum dorsal fixation recommended should include at least 4 vertebrae (4 fixation points cranially and caudally from the expected level of vertebrotomy). For older children, the fixation zone can be increased to restore balance in all planes and acute correction of the curve. The length of fixation is determined individually with anterolateral or combined access.

Table 3

Stage 6. Presence of intraspinal anomalies without neurological deficit (methods and options of surgical treatment)

Type of maneuver	Методика лечения
Compression	Local fixation and shortening vertebrectomy Schwab type 3-6, defixation can be used in the second stage or in one surgical session if indicated
Distraction	Defixation and use of growing rods in one surgical session or in two stages with defixation performed first

Table 4

Stage 7. Succession of surgical treatment

Identification of the level	Number of surgeries	Comments
The level with the largest local and general curves	No more than 4 staged operations for scoliosis and 2 for kyphosis with an overall fixation of no more than 8 vertebrae or a growing system (extra-focal correction for scoliosis, small angular kyphosis and lordosis)	Fixation zone can be increased in children older than 10-12 years with low growth potential for one-stage correction of the curve in all planes
All arcs are the same (± 5 °), surgical treatment begins with a caudal defect		

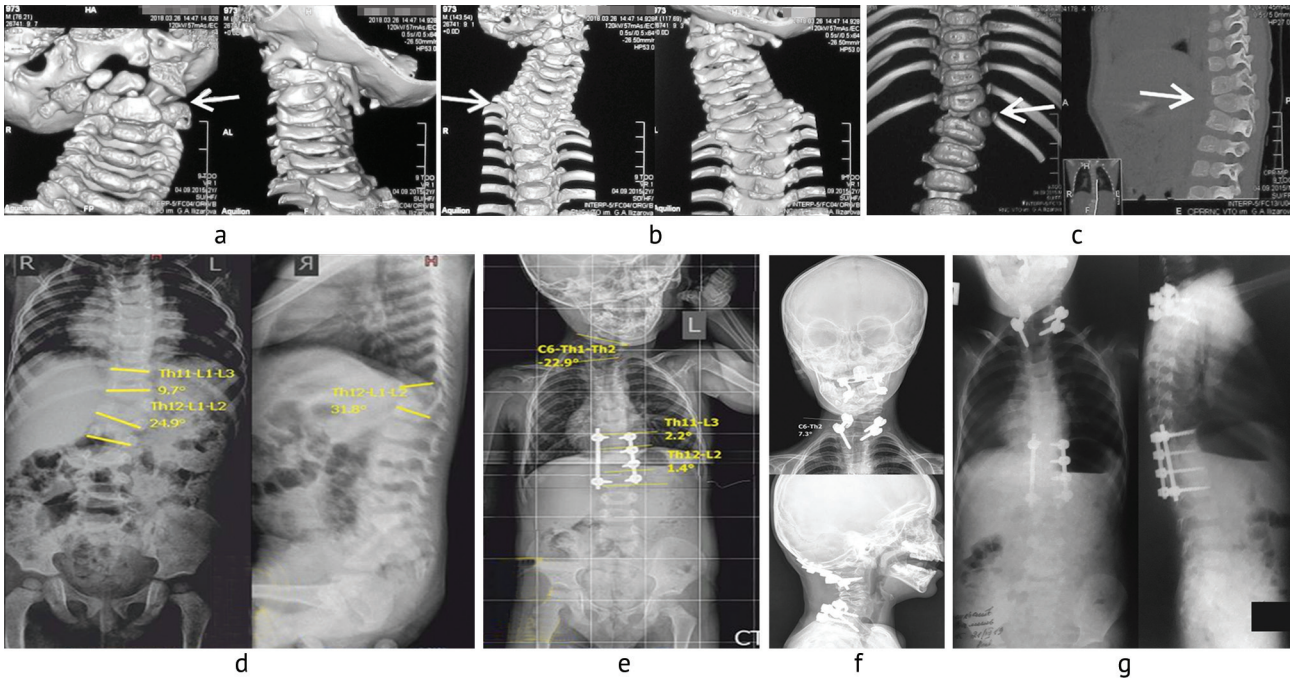

Fig. 2 Radiographs and CT scans of a patient aged 1 year 11 months with multiple anomalies and segmentation of the cervical and thoracic spine

The sixth stage is the correction of the scoliotic curve (Table 5, stage 9) and the choice of treatment methods. Principles of local correction are similar to those used for kyphotic curve, and extra-apical osteotomy is performed to osteotomize a vertebra adjacent to the apex to allow use of the abnormal vertebrae as reference points in transition zones [7, 8]. Assessment of the leading syndrome should involve the presence of intraspinal defects and thoracic insufficiency syndrome (TIS) as major modifiers. This is important in children with high axial growth potency. Thus, tethered spinal cord syndrome is recommended to treat with defixation at the primary stage, and the presence of TIS syndrome can impact the type and design of the construct to be used. Staged corrections with growing distraction systems as classified by Skaggs (2014) should be performed once every 6-12 months on average depending on age and degree of the curve progression. We emphasize that osteotomy can be used at any stage of treatment (Fig. 3) [9]. The final stage of correction and fixation using multi-support system is indicated at skeletal maturity.

Stage seven involves the correction of the lordotic curve (Table 5, stage 10) and the choice of treatment methods. Variants of anomalies with a lordotic curve are extremely rare and are represented in the literature by single "neglected" cases [10–13]. Major correction maneuver is performed from the dorsal access using pre-bent rods after vertebrectomy performed from a combined or anterolateral approach, With the use of an isolated anterior (ventral) fixation, the major compression maneuver is performed after discapophysectomy at several levels or local osteotomy Schwab type 3–6 at the apex of lordosis.

Table 5

Stages 8–10. Surgical treatment of the deformity component (methods and options of surgical treatment)

Type of treatment	Method of treatment	Comments
Stage 8. Kyphotic component of the curve		
Osteotomy	At the apex of the curve	Schwab type 3–6 common
	Multilevel	Schwab type 1–2 rare
Instrumentation fixation	Reconstruction of the anterior column	For the defect developed in the anterior column (mesh and autograft)
	Posterior instrumental fixation: – minimum 4 vertebrae (4 fixation points above and 4 fixation points below the proposed vertebrotomy), – maximum 6 vertebrae (in children with high growth potential)	Fixation zone can be increased in children older than 10-12 years with low growth potential for one-stage correction of the curve in all planes
	Anterior instrumentation fixation	Vertebrectomy performed from anterolateral or combined approaches
Stage 9. Scoliotic component of the curve		
Osteotomy	At the apex of the curve	Schwab type 3–6 common; 1–2 rare and only with extended curves in children with minimal growth potency and extended fixation
	Outside the apical zone	Schwab type 3–4 common; 5–6 not common (for rigid curves and mobility of < 40%)
	Multilevel	Schwab type 1, 2, 3 common in children > 10–12 years with low growth potential and more extensive curve
Instrumentation fixation	Local posterior instrumented fixation (in children with high growth potential < 12 years): – minimum 2 vertebrae (2 fixation points above and 2 fixation points below the area of the proposed vertebrectomy); – maximum 6 vertebrae	In children > 10–12 years old with low growth potential, the fixation zone can be in children > 10–12 years old with low growth potential increased for one-stage correction of the curve in all planes
	Anterior instrumented fixation	Vertebrotomy performed from anterolateral or combined approaches
	Anterior support	For the defect developed in the anterior column
	GrowingRodsSystem (GRS) can be used in ineffective short-segment fixation (no more than 8 vertebrae) including staged treatment	GRS «RibtoRib», «RibtoSpine» recommended to include 2–3 vertebrae in the fixation bases, use of distractors "RibtoRib", "RibtoSpine" for TIS
		Osteotomies can be used in a single session or with staged treatment
Stage 10. Lordotic component of the curve		
Osteotomy	At the apex of the curve	Schwab type 3–6 using ventral or combined approaches
	Multilevel	Multilevel discapophysectomy from ventral access + Schwab 2 osteotomy from dorsal access with costal head resection to improve chest rigidity. Multilevel Schwab 4 vertebrectomy from dorsal access with costal head resection can also be performed
Instrumentation fixation	Anterior instrumentation fixation	Vertebrectomy performed from ventral, anterolateral or combined approaches
	Posterior instrumented fixation: the volume of dorsal fixation is determined individually due to rare cases, the volume of vertebrectomy and the need to correct the sagittal balance, but not less than 4 vertebrae (4 fixation points above and 4 fixation points below the level of the proposed vertebrotomy)	Fixation zone can be increased in children older than 10–12 years with low growth potential for one-stage correction of the curve in all planes

If the second and subsequent stages of surgical treatment are needed procedures in one surgical session or hospitalization can be considered. Follow-up visits are recommended every 6 months. The ultimate goal of treatment is to transform the curve into a neutral form. When this goal is achieved, follow-up visits can be scheduled once a year. If the goal is not achieved, follow-up is needed more often to evaluate the spine pathology according to the algorithm.

We will present the *practical application of the algorithm* using clinical examples.

Case 1 A step-by-step algorithm was used for a patient aged 1 year 11 months who had multiple anomalies and segmentation of the cervical and thoracic spine treated with short-segment fixation at three levels (Fig. 2).

Stage 1: assessment of instability that was seen with dystrophic changes in the os odontoideum. Functional radiography with flexion and extension showed no instability with the volume of movements within 2 mm. The curve was the major finding at this level (Fig. 2a).

Stage 2: assessment of the kyphotic component of the curve showed local kyphosis at the Th12-L2 level of 31.8° (Fig. 2c).

Stage 3: assessment of the lordotic component of curve demonstrated no local lordosis detected.

Stage 4: assessment of the scoliotic component of the curve showed three local scoliotic curves at Th12-L2 measuring 24.9° sin; C6-Th2, 22.9° dex; C0-C2, 19° sin (Fig. 2a-c).

Stage 5: ruling out intracanal defects: none was detected on MRI scan of the spine.

Stage 6: assessment of the leading component of the curve showed kyphoscoliosis at one level (31.8°/24.9° sin) and scoliosis at two levels (Fig. 2a-d).

Stage 7: surgical treatment of kyphotic component of the curve included extirpation of hemivertebrae L1 and correction of the curve and fixation of 4 vertebrae Th11-L3 (Fig. 2e).

Stage 8: surgical treatment of scoliotic component of the curve: the patient was seen at 3 months and scoliosis was radiologically detected at the level of C6-Th2 as the leading component. Extirpation of the hemivertebra was performed and posterior instrumentation and correction of the curve produced 2 weeks after the follow-up visit.

Stage 9: surgical treatment of the scoliotic component of the curve at another level: the patient was seen at 2 weeks of wound healing, the Schwab 2 type osteotomy, posterior instrumented fixation C0-C2 and correction of the curve produced (Fig. 2f).

Two-year follow-up (Fig. 2g).

Case 2 A girl aged 3 years 2 months was diagnosed with scoliosis of the thoracic spine due to multiple anomalies and segmentation of the vertebrae (Fig. 3).

Stage 1: instability assessment: not detected.

Stage 2: assessment of the kyphotic component of the curve: not detected.

Stage 3: assessment of the lordotic component of the curve: not detected.

Stage 4: assessment of the scoliotic component of the curve: three local scoliotic curves detected at Th8-L1, 49.1° sin; C6-Th7, 31° dex; L1-L4, 2.3° dex (Fig. 3a).

Stage 5: ruling out intracanal defects: ruled out with MRI screening of the spine.

Stage 6: assessment of the leading component of the curve: scoliosis due to multiple anomalies at the level of C6-Th7, 31° dex with major structural curve at Th8-L1, 49.1° sin (Fig. 3a).

Stage 7: surgical treatment of the scoliotic component of the deformity: instrumented fixation with the dynamic DGR (Dual Growing Rods) system Ø 4.5 was performed (Fig. 3b). Pathological torticollis was detected after the initial correction that was compensated for 3 months. Then 4 staged operations were performed using the DGR system at an interval of 6-8 months. Each subsequent operation also resulted in torticollis that was corrected within the same time interval (Fig. 3b, c, d).

Stage 8: surgical treatment of the scoliotic component of the deformity at another level: radical correction of scoliotic deformity was performed at the apex of the congenital bone block with three-column Schwab 5 vertebrectomy produced at the apex of the bone block (Th3 conditionally), the Ø 4.5 system reassembled and the curve corrected, local 360° fusion produced 3 years after the DGR placement for the 6-year-old. The operation was performed with intraoperative motor and somatosensory evoked potential monitoring (MSP, MEP and SSEP).

A good correction of the curve and well realigned head could be seen after the surgery (Fig. 3e, f).

This clinical example demonstrates a primarily inadequate surgical strategy since the curve could not have been converted to neutral without treatment of the leading curve at C6-Th7 (congenital malformation). Correction at the level of the leading curve must be performed first even if the counter-curve is clinically greater. Two-year follow-up (Fig. 3f).

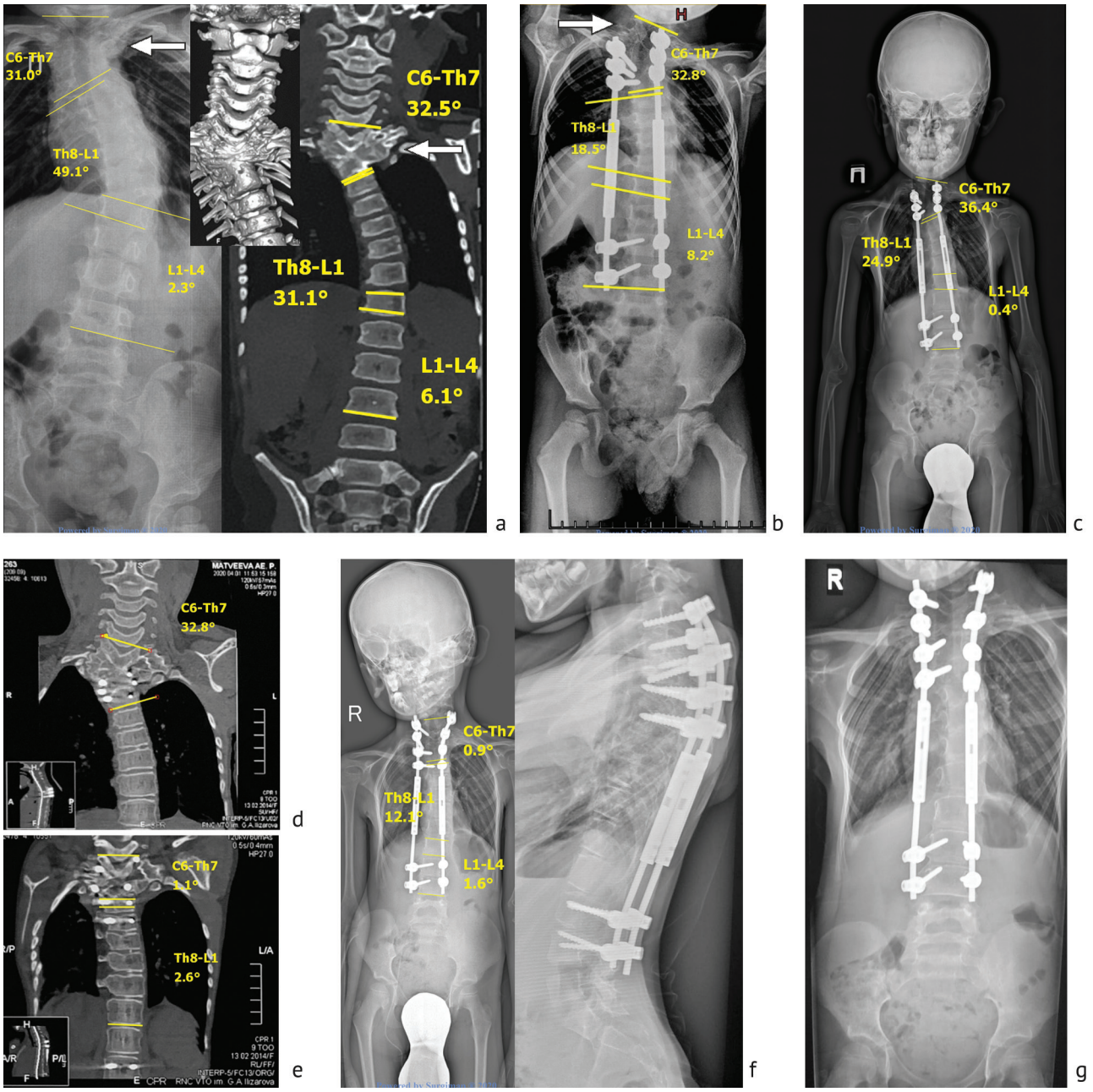

Fig. 3 Radiographs and CT scans of a girl aged 3 years 2 months diagnosed with scoliosis of the thoracic spine due to multiple anomalies and segmentation of the vertebrae

DISCUSSION

The discussion was based on the comments to the tables and the answer to the following questions:

What are the treatment algorithms for congenital spinal deformity?

A search through various databases revealed 2 publications with a treatment algorithm for multiple congenital anomalies. Tikoo at al. suggested to perform insitu fixation or vertebrectomy for less than 3 segments and DGR or VEPTR can be recommended for more than 3 segments [14]. Vitale et al. reported a serious respiratory dysfunction in children younger than 8 years compared to healthy children with in situ fixation of 4 or more segments of the thoracic spine [15].

TIS syndrome (Thoracic Insufficiency Syndrome) can develop in patients with congenital scoliosis of the thoracic spine and decreased hemithorax (hemithoraxes) and lead to a reduction in SAL (Space Available Lung) and respiratory dysfunction [16]. Children younger than 8 years are likely to maintain pulmonary hyperplasia that is associated with the effective thoracoplasty up to 8 years [17]. The curve correction is associated with decreased height of the chest in shortening vertebrotomy, spinal fusion and conditions for the normal development of the chest in other planes.

A growing construct is offered for children younger than 10 years of age with a vertebrectomy and fixation being practical for children older than 10 years [18]. There are publications describing a classification and treatment of anomalies of the craniovertebral junction [19] and cervical spine [20] offering an algorithm for this small group of patients. A.V. Burtsev [21] reported a syndromic approach to the treatment of spinal pathology with a general insight into the problem and an approach to treatment strategy for instability, imbalance or compression syndromes including patients with anomalies.

What length of fixation should be considered local?

Matsumoto et al. reported that short fusion of 3 segments is preferred for children up to 6 years (1.8–6.9) and 6 level fusion is useful for children older than 12 years (7.1-18.1). The authors suggested that the use of 6-segmental fixation in young children may provide better long-term results compared to short fixation [22]. The length of fixation and its effect on further growth and the implant related complication rate are rarely accurately reported [23]. We can assume that the maximum fixation can be 6-8 vertebrae in children with high growth potential in multiple anomalies located in different parts of the spine and requiring surgical treatment. Fixation of 8 vertebrae was used in clinical example No. 1 (Fig. 2) including 2 craniovertebral C0–C2, 2 cervical-thoracic C7–Th1 and 4 thoracolumbar junction Th11-L2 vertebrae. Fixation of asymmetric alternating vertebrae at several levels would also average to 6-7 vertebrae. We normally use fixation of 6 vertebrae (2 references of 3 vertebrae each) mounting DGR. If distraction is not performed at the reference level and fixation restrains segmental growth it can also be assumed that two vertebrae will not significantly increase the loss in growth (Fig. 3).

What are the consequences of spine fixation?

According to Dimeglio, we can expect a growth deficit after the fusion of five vertebrae up to 22 mm, if the operation is performed at the age of 10 years. With ten segments (18 growth plates) fused, the expected growth deficit can be 49 mm (10 years after surgery) [24]. In a study of Zhou et al. the average age of patients at the time of surgery was 9.8 years, and the average fusion length was 7.4 segments. The estimated growth deficit in the study was 22–49 mm [25]. According to J. Lonstein, early fixation does not stop potential growth, because the anomaly zone cannot grow like normal segments due to undeveloped growth plates [26]. Ruf et al. reported residual endosteal growth persisting in most cases after hemivertebral resection despite instrumented fixation [27]. Winter at al. presented an interesting report on the formation of T2–L3 fusion without complications [28]. Kaspiris and Angelos reported that the risk-benefit ratio approved of surgical treatment compared to the natural course of the disease, and the rate of spinal fusion complications in patients with congenital scoliosis was not higher than that with other treatment options [29]. The actual growth deficit is difficult to assess and further observations are needed. Given the pronounced progression in unbalanced multiple disorders of segmentation and vertebral formation at a rate from 1° to 33° per year (on average 4°) [30-31], it is extremely difficult to assess the long-term result depending on the length of fixation or the natural course. The answer to this question can be provided only with long-term results of at least 10–12 years.

How do intraspinal anomalies affect the strategy of correction of congenital deformity?

The choice of treatment strategy in patients with congenital deformities associated with intraspinal anomalies is difficult due to a paucity of publications and based on experts' own experience. A retrospective study performed by Jamil at al. included 12 patients with diastematomyelia treated conservatively. The children were followed up for between 2 and 10 years. During the period of observation, no one developed new symptoms or signs, and there was no progression of existing neurological deficits. [32]. This suggests that observation is required for patients with asymptomatic or non-progressive diastematomyelia [33–34]. Some patients with baseline neurological symptoms can develop progressive neurological symptoms caused by diastematomyelia [33] with the anomaly being neurologically unstable and to be treated first. Liu et al. reported treatment of diastematomyelia before the correction of scoliotic curve [35]. Gavriliu et al. suggested either simultaneous correction of the curve and septum removal or septum resection first to be followed by correction of the curve at the second stage [36]. Xing at al. reported 15 cases of simultaneous removal of the diastema and resection of the hemivertebra with a good primary result [37]. Yu B. et al. reported 31 patients with congenital deformity and diastomatomyelia. Septum was removed in one case, and others underwent vertebrectomy and correction of the curve at primary stage [38]. There are publications reporting clinical cases of simultaneous resection of the hemivertebra and removal of diastematomyelia [39–40] or vertebrectomy without resection of the septum [41–42]. With compression as the major maneuver during the resection of the hemivertebra, we support either removal of diastematomyelia [43] when practicing at the site or removal of the septum at the second stage in another surgical session after 3–6 months. Similar strategy is described in single publications for other intraspinal anomalies of tethered spinal cord, such as lipoma or

thickened filum terminale. The primary stage included the correction of the curve and vertebrectomy, and the neurosurgical procedure was performed if indicated [44]. Some authors report that intraspinal anomalies (diastematomyelia, thickened filum terminale or syringomyelia) in patients with congenital scoliosis with normal or stable neurological status do not increase the risk of neurological complications of correction surgery. These patients may not require preventive neurosurgical intervention [45].

CONCLUSION

The choice of treatment methods and their sequence for congenital malformations of the spine is a formidable task in pediatric spinal surgery due to the variety of spinal anomalies and concomitant segmental defects of the spinal canal and the chest. In our opinion, none of the existing classifications can be used to identify appropriate treatment guidelines and surgical practices and the algorithm can be very helpful. The algorithm offered is a stepwise checklist providing a step-by-step process for making decisions on the approach and practice for treating congenital anomalies of the spinal column. It is designed to consider main pathological syndromes being typical of congenital pathology and reduce tactical and methodological flaws. The algorithm is of purely advisory nature. The consensus opinion of experienced surgeons has been shown to be essential for timely management facilitating appropriate treatment strategy for the rare and diverse nosological group.

Limitations to the significance of the results The effectiveness and limitations of this protocol can be evaluated with sunbstantial database of long-term outcomes in multicenter settings.

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The article was submitted 25.02.2021; approved after reviewing 18.05.2021; accepted for publication 19.10.2021.

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