INFLUENCE OF DESTRUCTIVE CHANGES AND SURGICAL CORRECTION ON THE PARAMETERS OF SAGITTAL BALANCE OF THE CERVICAL SPINE IN CHILDREN

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Objective. To analyze dynamics of changes in the parameters of the sagittal balance of the cervical spine against the background of surgical treatment of destructive tumor and infectious inflammatory pathology of the cervical vertebrae in children.

Material and Methods. Design: retrospective-prospective monocentric cohort. A total of 81 radiographs of the cervical spine in a standing position before and after surgery in children operated on for vertebral tumors and cervical spondylitis were selected. The 10 most common parameters were measured: angular values of Oc–C2, C2–C7, C7S, T1S, TIA, NT, CeT, CrT, SCA, as well as the cSVA distance measured in mm. The material was statistically processed using nonparametric analysis methods.

Results. In case of suboccipital lesions, the most significant changes were in the Oc–C2 and CrT parameters, in case of subaxial lesions — Oc–C2, C2–C7, and in case of cervicothoracic junction lesions — C2–C7, C7S, T1S, TIA, NT, CeT, and CrT. Significant difference between the groups was noted only for NT parameter between the norm and the group of cervicothoracic junction pathology after surgery ($p = 0.0190$). In case of tuberculous spondylitis, the greatest changes were noted in TIA, NT, CeT, SCA and cSVA parameters. Significant differences were also revealed only for NT parameter between the postoperative groups of tuberculous spondylitis and tumors ($p = 0.0016$), as well as between the group of tuberculous spondylitis after surgery and the norm group ($p = 0.0013$). In case of extensive (3 or more vertebrae) destruction, the NT parameter differed from the norm both before ($p = 0.0174$) and after ($p = 0.0059$) surgical treatment. The cSVA parameter differed from the norm in case of short destructions only before surgical correction ($p = 0.0195$), while in case of extensive destructions it differed from the norm only after surgical reconstruction ($p = 0.0212$).

Conclusion. Studying the issues of spine biomechanics in pathological conditions allows for better understanding the changes that occur and propose effective methods for correcting and restoring the normal anatomy of the segment.

Key Words: sagittal balance; cervical spine; children; tumor; spondylitis; osteomyelitis; surgical treatment.

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The normal values of sagittal balance parameters in children provided in the recent specialized literature allowed re-evaluating spinal changes occurring during various disease processes [1–5]. Considering that many of them lead to spinal deformity, the objective was to objectify changes in the cervical spine in children by analyzing the sagittal balance parameters with underlying tumors and infectious inflammatory lesions of the cervical vertebrae.

Study design: retrospective-prospective monocentric cohort.

The main study item included the sagittal balance parameters of the cervical spine with underlying destructive changes in the vertebrae and the possibility of surgical correction.

Inclusion criteria were the following:

- one treatment center: Pediatric Surgery and Orthopedics Clinic, Saint Petersburg Research Institute of Phthisiopulmonology;
- determined etiology of the disease: vertebral tumors and spondylitis;
- localization: cervical vertebrae, including Oc/C1–C7;
- available lateral radiological images of cervical spine in a standing position, including before and after surgery;
- age of patients under 18 years at the time of surgery.

Exclusion criteria included the following:

- any congenital malformations of the cervical vertebrae or signs of traumatic injuries found during a complete physical examination of a child;
- underlying neurosurgical abnormality: tumors and congenital malformations of the spinal cord or skull base, including any type of myelodysplasia;
- neurological disorders and inability for a child to maintain a standing position.

Material and Methods

To analyze balance changes, 81 lateral cervical spinal radiological images were selected from the clinic's radiological archive; all images were performed in a standing position before and after surgical treatment in children with tumors and infectious and inflammatory lesions of the vertebrae.

The 10 most common parameters were measured using the selected radiological images: angular values Oc–C2, C2–C7, C7S, T1S, TIA, NT, CeT, CrT, SCA, as well as the cSVA distance in mm (Fig. 1). These parameters are described in the literature, as well as a detailed measurement technique [1]. To eliminate potential errors because of various software when working with DICOM files, all measurements were performed in the licensed version of RadiAnt DICOM Viewer software (version 2021.2, Copyright © 2009–2022 Medixant).

The data were statistically processed using non-parametric analysis methods. The sample parameters are provided as Me (Q1–Q3), since the Shapiro-Wilk and Lilliefors (Kolmogorov-Smirnov test with Lilliefors correction) tests revealed statistically significant deviations of the analyzed parameter groups from the normal distribution. The source data was accumulated, adjusted and systematized in LibreOffice Calc spreadsheets (version 3.7.2, MPL v.2). Statistical analysis and visualization of the obtained results were carried out using the R language (version 3.5.1, GNU GPL v.2) in the RStudio Desktop integrated development environment (version 2022.02, GNU AGPL v.3).

Results

All parameters were firstly divided into groups according to the main level of lesion, regardless of the etiology (suboccipital Oc-C2, subaxial C3–C7, and cervicothoracic C7–T1), as well as concerning the surgical treatment: before and after surgery (Table 1).

In case of suboccipital lesions, the most significant changes were found in the Oc–C2 and CrT parameters, in case of subaxial lesions – in Oc–C2, C2–C7, and in case of lesions of the cervicothoracic junction – in the C2–C7, C7S, T1S, TIA, NT, CeT, and CrT.

Moreover, a statistically significant difference between groups was found only for the NT parameter (Kruskal–Wallis test: $\chi^2 = 20.8029$; df = 6; $p = 0.0020$). Dunn's test with Holm adjustment of the critical significance value for multiple comparisons revealed a difference between the normal parameters and the cervicothoracic junction group after surgery ($p = 0.0190$; Fig. 2; Table 2).

To assess the changes in the sagittal balance depending on the disease etiology and in regard to the surgical treatment (before/after) without considering the lesion level, the data was divided into nosological groups. The results are provided in Table 3.

According to the obtained results, the greatest changes in the parameters, especially TIA, NT, CeT, SCA and cSVA, were registered in case of tuberculous spondylitis and indicated by the deviated median and a wide interquartile range. This corresponds to a greater extent of the lesion and the most common involvement of the cervicothoracic junction (base of the neck) in the disease of this etiology [6].

However, statistically significant differences were registered only for the NT parameter (Kruskal–Wallis test: $\chi^2 = 22.935$; df = 6; $p = 8e\text{-}0.4$). To assess the difference between groups, a pairwise comparison of the groups was performed using Dunn's post hoc test with Holm adjustment (Fig. 3, Table 4).

This post hoc test revealed differences in the NT parameter between the postoperative groups with tuberculous spondylitis and tumors ($p = 0.0016$), as well as between the group with tuberculous spondylitis after surgery and the control group ($p = 0.0013$). The difference between the NT parameter in patients with tuberculous spondylitis after surgery and the one in the control group may be associated with the extended reconstruction in the cervicothoracic junction.

Because of the presence of patients with extensive vertebral destruction in the cohort, it was decided to divide the children into 2 groups: with short destruction (2 or less vertebrae) and extensive destruction (3 or more). This dividing was based on the information on the impact of damage to three or more vertebrae on the surgical treatment outcome [7–10]. The results are provided in Table 5.

Statistically significant differences were registered for the NT parameter (Kruskal–Wallis test: $\chi^2 = 17.856$; df = 4; $p = 0.0013$) and for the cSVA parameter (Kruskal–Wallis test: $\chi^2 = 11.6$; df = 4; $p = 0.0206$; Fig. 4, 5).

The between-group difference for the NT parameter was revealed by pairwise comparison of groups using Dunn's post hoc test with Holm adjustment (Table 6).

It was revealed that the NT parameter differs from the normal value in case of extensive destruction both before and after surgical treatment. Short destruction does not result in a significant change in the parameter.

This test revealed no significant differences for cSVA parameter, despite the Kruskal-Wallis test, so it was decided to perform a pairwise comparison using the Mann-Whitney test (Table 7).

The Mann-Whitney test indicated significant differences from the normal values for short destructions, which were eliminated after surgical correction. At that, the cSVA parameter for extensive destructions differs from the normal value only after surgical reconstruction; this was possibly associated with the difficulty of restoring normal anatomy with many affected vertebrae.

Discussion

The obtained results can be explained both by the relatively small number of cases in each group and, consequently, the impossibility of detecting deviations from the normal condition, as well as by the high adaptation options of the cervical spine, with its unique mobility features compensating for these deviations.

The analysis of changes in the sagittal balance parameters is of great interest from the point of view of an unbiased evaluation of abnormalities in spi-

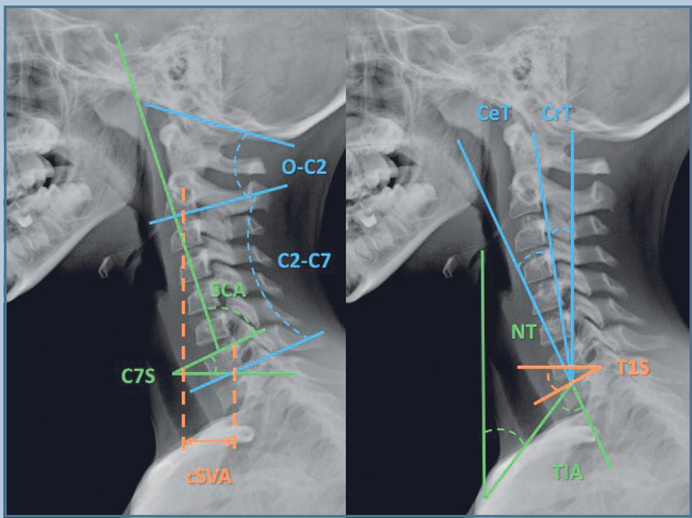

Fig. 1
Sagittal balance parameters of the cervical spine

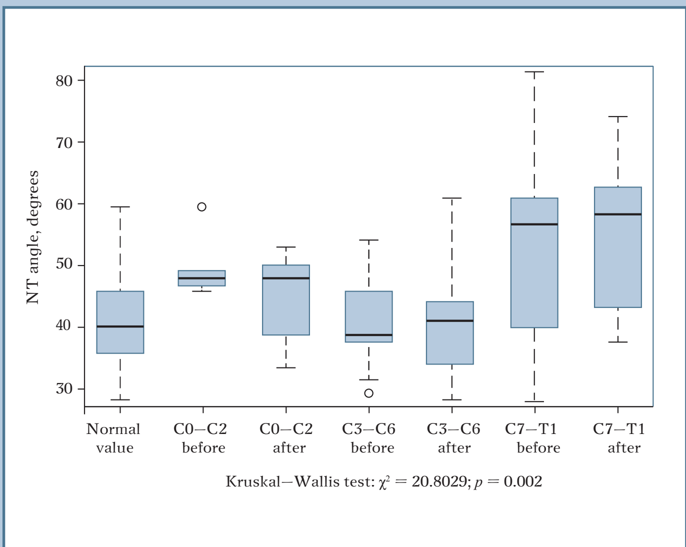

Fig. 2
Change in the NT parameter depending on the level of lesion before and after surgical correction

nal deformities of various origin, as well as the subsequent assessment of postoperative correction.

A literature search reveals a complete lack of information on abnormal changes in the sagittal profile of the cervical spine in the case of vertebral destruction. Meanwhile, extremely few studies describe the analysis of the sagittal balance in children with congenital defect of the cervical spine, as well as compensatory changes in the neck with deformities of the subjacent departments.

Table 1
Changes in the parameters of the cervical spine sagittal balance depending on the level of destruction before and after surgical correction, Me (Q1–Q3)

Parameters	Normal value	Suboccipital (Oc–C2)		Subaxial (C3–C6)		Cervicothoracic junction (C7–T1)	
		before correction	after correction	before correction	after correction	before correction	after correction
Oc–C2, degrees	−23.0 (−37.00 to −18.,00)	−23.0 (−26.00 to −13.00)	−24.0 (−34.50 to −16.00)	−22.5 (−29.00 to −17.75)	−21.0 (−28.25 to −18.50)	−21.0 (−26.50 to −18.00)	−21.0 (−26.50 to −18.00)
C2–C7, degrees	−7.0 (−18.00–2.00)	−5.0 (−13.00–0.00)	−7.5 (−22.50–1.00)	−6.0 (−10.00–1.50)	−10.0 (−17.50 to −2.75)	−10.5 (−28.00–0.75)	−20.0 (−23.50 to −6.00)
C7S, degrees	24.0 (18.00–30.00)	27.0 (27.00–31.00)	18.5 (11.75–25.75)	19.0 (16.50–28.00)	24.0 (14.75–28.25)	25.0 (16.25–37.25)	35.0 (20.50–37.00)
T1S, degrees	28.0 (22.00–35.25)	33.0 (31.00–33.00)	22.0 (17.75–27.25)	24.0 (21.50–32.00)	28.0 (20.75–33.00)	25.0 (16.50–39.00)	34.0 (12.50–36.50)
TIA, degrees	69.5 (61.25–78.00)	80.0 (78.00–81.00)	66.0 (60.00–69.50)	66.0 (60.25–73.50)	66.5 (61.25–75.75)	77.5 (66.00–95.50)	76.0 (70.00–95.5)
NT, degrees	41.0 (36.00–46.00)	48.0 (46.00–50.00)	48.0 (39.50–51.00)	40.0 (38.00–45.75)	41.5 (33.25–44.00)	55.0 (41.25–60.50)	57.0 (43.00–63.50)
CeT, degrees	21.0 (14.00–24.00)	17.0 (11.00–19.00)	14.5 (11.75–17.25)	18.0 (12.00–22.00)	18.0 (14.25–25.00)	15.0 (11.50–27.25)	18.0 (−2.50–24.00)
CrT, degrees	9.0 (6.00–12.00)	17.0 (11.00–17.00)	4.5 (−0.50–10.00)	9.0 (6.00–13.00)	8.5 (3.00–13.00)	5.0 (2.25–19.50)	11.0 (7.00–18.50)
SCA, degrees	80.0 (74.00–86.00)	81.0 (75.00–90.00)	82.5 (79.50–88.25)	86.0 (75.00–89.00)	84.5 (76.75–90.00)	82.5 (77.00–87.25)	80.0 (72.00–94.25)
cSVA, mm	24.0 (17.00–32.00)	24.5 (18.00–29.00)	13.0 (2.25–27.25)	19.0 (15.00–23.25)	20.0 (14.00–23.00)	18.0 (11.50–32.00)	24.0 (8.50–29.50)

Table 2

Significance of differences in the NT parameter between lesion levels before and after surgical treatment (Dunn's test with Holm adjustment $p \le 0.025$)

Levels	Normal value	Oc–C2 before surgery	Oc–C2 after surgery	C2–C6 before surgery	C2–C6 after surgery	C7–T1 before surgery
C7–T1 after surgery	Z = –3.1192 p = 0.0190	Z = 0.0092 p = 0.4963	Z = –1.1567 p = 1.0000	Z = –2.7781 p = 0.0519	Z = –2.9999 p = 0.0270	Z = –0.3755 p = 1.0000
C7–T1 before surgery	Z = –2.5132 p = 0.1077	Z = 0.3086 p = 1.0000	Z = –0.8020 p = 1.0000	Z = –2.2597 p = 0.1907	Z = –2.4745 p = 0.1134	–
C2–C6 after surgery	Z = 0.3517 p = 1.0000	Z = 2.2460 p = 0.1853	Z = 1.2640 p = 1.0000	Z = 0.2717 p = 1.0000	–	–
C2–C6 before surgery	Z = 0.0217 p = 0.9827	Z = 2.0807 p = 0.2435	Z = 1.0753 p = 1.0000	–	–	–
Oc–C2 after surgery	Z = –1.1568 p = 1.0000	Z = 0.9636 p = 1.0000	–	–	–	–
Oc–C2 before surgery	Z = –2.2058 p = 0.1918	–	–	–	–	–

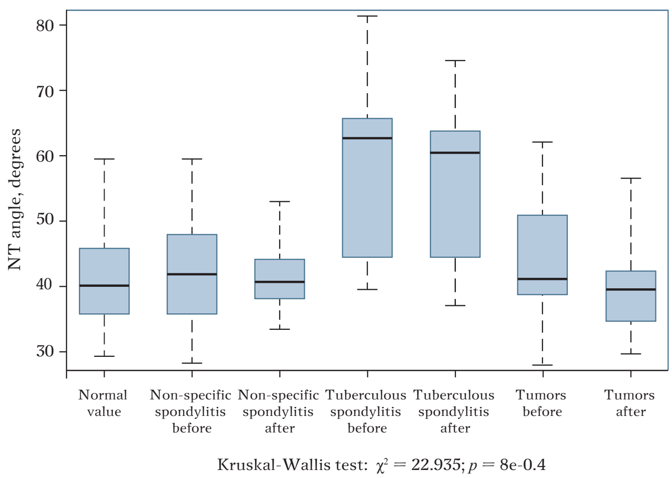

Fig. 3
Changes in the NT parameter in destructive disease of various origin before and after surgical correction

A.A. Kuleshov et al. [4] revealed an increase in the C7S, T1S, and TIA in children with Down syndrome, as well as a decrease in the atlantoaxial parameters (ADI, SAC-C1, SAC-C1/SAC-C4) compared to the normal values, which may be the cause of the C1–C2 instability, even in the absence of the odontoid bone.

When comparing the cervical sagittal balance parameters in healthy children and children with confirmed short stature, Wu et al. [5] found a significant increase in cervical lordosis, T1S, thoracic kyphosis, and a trend to stooped posture.

In adolescents with Scheuermann's disease and the kyphosis apex located in the thoracic spine, researchers revealed an increase in the C2–C7, CeT and TIA compared to the normal values and kyphosis located in the thoracolumbar junction [11, 12]; moreover, the increase in cervical lordosis occurs due to C4–C6 segments [12].

Several articles describe the effect of types 1 and 2 Lenke scoliotic deformity on the sagittal profile of the cervical spine. The authors unanimously take the position that the selection of the upper fixed vertebra (T2–T4) has an effect on the correction of the shoulder girdle level and that cervical lordosis is directly dependent on thoracic kyphosis at the T1–T5 level (cervical lordosis decreases with hypokyphosis at this level) and the T1S parameter [13–17]. However, Legarreta et al. [16] and Ketenci et al. [17] indicate that the selection of the upper fixed vertebra starting from the T3 and above leads to a significant decrease in cervical lordosis, while other authors mention the absence of such an effect. For type 3 and 6 Lenke scoliosis, Yanik et al. [18] revealed a dependence of cervical lordosis only on the T1S value and kyphosis at the T5–T12 level.

For surgical management of early scoliosis using growth-friendly rods, Han et al. [19] draw attention to the greatest effect on the cervical imbalance and, accordingly, on the critical changes in the C2–C7, cSVA and T1S values of the proximal adjacent kyphosis, excessive correction of thoracic kyphosis, and the T1S value, particularly.

It is significant that Lee et al. [20] in their review of many literature sources mentioned that most researchers provided comparable values of NT. Assuming the constancy of this parameter, the authors provided an algorithm for select-

Table 3
Changes in parameters depending on the origin of destruction before and after surgical correction, Me (Q1–Q3)

Parameters	Normal value	Spondylitis				Tumors	
		non-specific before surgery	non-specific after surgery	tuberculous before surgery	tuberculous after surgery	before surgery	after surgery
Oc–C2, degrees	–23.0 (–29.00 to –18.00)	–19.5 (–24.50 to –13.75)	–23.5 (–29.25 to –17.75)	–26.0 (–33.00 to –20.00)	–20.0 (–24.00 to –16.00)	–33.0 (–35.00 to –21.00)	–23.0 (–28.00 to –20.00)
C2–C7, degrees	–7.0 (–18.00–2.00)	–4.0 (–11.00–1.50)	–10.5 (–12.50–1.00)	–10.0 (–31.00–1.00)	–22.0 (–31.00 to –3.00)	–6.0 (–14.00–0.50)	–8.5 (–22.25 to –3.00)
C7S, degrees	24.0 (18.00–30.00)	21.0 (16.50–30.00)	22.5 (15.75–26.25)	35.0 (16.00–38.00)	26.0 (19.00–35.00)	22.0 (17.00–31.00)	25.0 (14.00–31.25)
T1S, degrees	28.0 (22.00–35.25)	24.0 (16.50–31.00)	27.0 (20.75–29.00)	40.0 (22.00–44.00)	30.0 (17.00–35.00)	25.0 (20.50–33.50)	27.5 (20.50–33.75)
TIA, degrees	69.5 (61.25–78.00)	65.0 (59.75–74.75)	68.0 (63.00–73.50)	100.0 (68.00–124.00)	75.0 (69.00–94.00)	71.5 (61.25–79.75)	65.0 (58.75–75.25)
NT, degrees	41.0 (36.00–46.00)	43.5 (36.50–48.00)	42.0 (38.00–45.50)	61.0 (46.00–65.00)	57.0 (46.00–62.00)	42.5 (38.00–50.25)	39.0 (31.75–44.00)
CeT, degrees	21.0 (14.00–24.00)	15.0 (11.50–18.75)	17.0 (14.75–19.75)	20.0 (–1.00–36.00)	18.0 (4.00–25.00)	17.0 (12.00–22.50)	15.5 (11.25–21.75)
CrT, degrees	9.0 (6.00–12.00)	9.0 (3.25–12.50)	9.0 (6.75–11.25)	20.0 (2.00–22.00)	8.0 (3.00–16.00)	9.0 (6.00–16.50)	9.5 (2.25–14.75)
SCA, degrees	80.0 (74.00–86.00)	88.0 (78.75–90.25)	86.0 (82.50–93.50)	87.0 (86.00–102.00)	76.5 (69.50–90.50)	82.5 (72.50–87.00)	81.0 (79.00–87.00)
cSVA, mm	24.0 (17.00–32.00)	20.0 (13.00–23.00)	20.5 (10.00–24.25)	32.0 (7.00–38.00)	17.0 (14.00–26.00)	18.5 (15.00–28.50)	21.0 (7.00–27.00)

Table 4
Significance of differences in the NT parameter between destructive processes of different origin before and after surgical treatment (Dunn's test with Holm adjustment, $p \leq 0.025$)

Nosological groups	Normal value	Spondylitis				Tumors before surgery
		non-specific before surgery	non-specific after surgery	tuberculous before surgery	tuberculous after surgery	
Tumors after surgery	Z = 0.8593 *p* = 1.0000	Z = 1.2589 *p* = 1.0000	Z = 0.8870 *p* = 1.0000	Z = 2.8066 *p* = 0.0476	Z = 3.7803 *p* = 0.0016	Z = 1.4308 *p* = 0.8387
Tumors before surgery	Z = –0.9362 *p* = 1.0000	Z = –0.0866 *p* = 0.9310	Z = –0.3767 *p* = 1.0000	Z = 1.8720 *p* = 0.3673	Z = 2.5275 *p* = 0.0919	–
Tuberculous spondylitis after surgery	Z = –3.8375 *p* = 0.0013	Z = –2.4686 *p* = 0.1017	Z = –2.5975 *p* = 0.0845	Z = 0.0501 *p* = 0.4800	–	–
Tuberculous spondylitis before surgery	Z = –2.5747 *p* = 0.0853	Z = –1.8757 *p* = 0.3945	Z = –2.0219 *p* = 0.3023	–	–	–
Non-specific spondylitis after surgery	Z = –0.3255 *p* = 1.0000	Z = 0.2812 *p* = 1.0000	–	–	–	–
Non-specific spondylitis before surgery	Z = –0.7428 *p* = 1.0000	–	–	–	–	–

Table 5

Change in parameters depending on the extent of destruction before and after surgical correction, Me (Q1–Q3)

Parameters	Normal value	Short destruction (up two vertebrae)		Extensive destruction (three and more vertebrae)	
		before surgery	after surgery	before surgery	after surgery
Oc–C2, degrees	–23.0 (–29.00 to –18.00)	23.0 (–34.00 to –15.25)	–23.0 (–29.00 to –17.25)	–29.5 (–36.00 to –21.50)	–21.0 (–25.00 to –19.00)
C2–C7, degrees	–7.0 (–18.00–2.00)	–6.0 (–13.50–1.25)	–10.0 (–18.00–-1.50)	–2.5 (–24.50–0.75)	–21.5 (–26.50 to –2.25)
C7S, degrees	24.0 (18.00–30.00)	20.5 (16.75–31.25)	25.0 (14.50–28.50)	31.0 (18.75–37.25)	24.0 (17.50–36.00)
T1S, degrees	28.0 (22.00–35.25)	24.0 (19.75–33.00)	28.0 (20.00–32.50)	35.5 (19.75–43.00)	29.5 (12.75–36.00)
TIA, degrees	69.5 (61.25–78.00)	68.0 (60.50–77.00)	66.5 (61.75–76.00)	90.5 (68.25–118.00)	74.0 (65.75–94.75)
NT, degrees	41.0 (36.00–46.00)	42.0 (38.00–48.00)	42.5 (35.50–45.00)	55.5 (48.50–64.00)	56.5 (45.00–62.75)
CeT, degrees	21.0 (14.00–24.00)	17.5 (12.50–22.25)	16.0 (12.00–20.50)	12.0 (2.00–30.25)	19.5 (0.75–26.50)
CrT, degrees	9.0 (6.00–12.00)	8.5 (4.75–13.50)	9.0 (4.00–13.00)	19.5 (7.00–21.50)	7.0 (2.50–16.00)
SCA, degrees	80.0 (74.00–86.00)	84.0 (75.00–89.00)	85.0 (80.00–90.00)	86.5 (84.00–95.25)	75.0 (68.00–86.50)
cSVA, mm	24.0 (17.00–32.00)	19.0 (13.50–23.75)	21.0 (12.50–27.00)	35.0 (17.75–38.00)	14.0 (7.75–24.50)

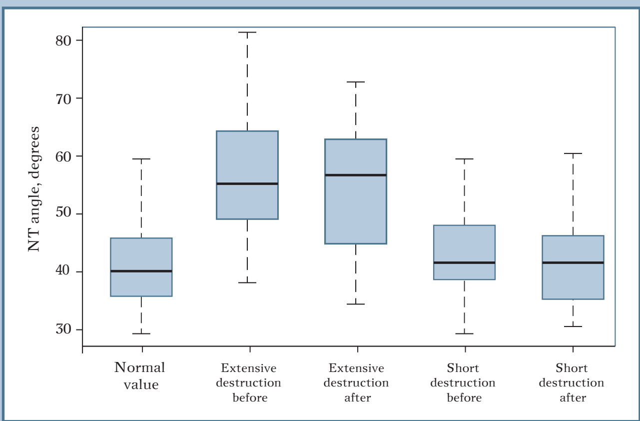

Fig. 4
Change in the NT parameter with different extent of vertebral destruction before and after surgical correction

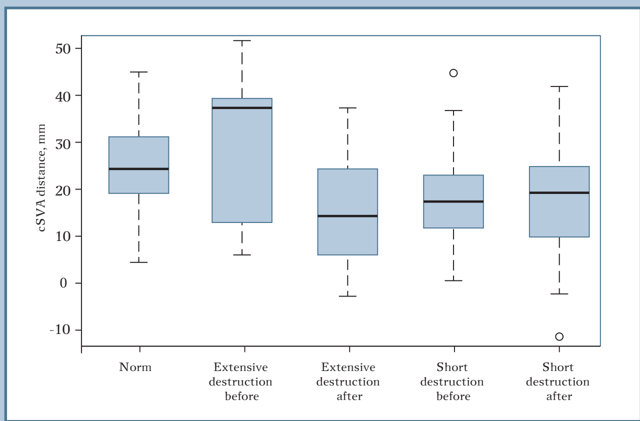

Fig. 5
Change in the cSVA parameter with different extent of vertebral destruction before and after surgical correction

ing the level of corrective vertebrotomies for cervical spine deformities depending on the T1S value and the cervicothoracic junction condition; their own results revealed a statistically significant change in the TIA and T1S before and after surgery, while maintaining the NT value at the pre-surgical state. They also specify possible options for compensation/decompensation of cervical kyphosis due to the thoracic and lumbar spine.

Thus, it can be said that the analysis of the sagittal balance of the cervical spine in children and adolescents with different diseases is one of the less studied issues in present vertebrology. Our results only provide limited information on one of the rare variants of such abnormality: destructive lesions of the cervical vertebrae.

Conclusion

Analysis of changes in the sagittal balance parameters of the cervical spine in children with destructive processes reveals a level-related dependence: the Oc-C2 and CrT parameters changed more in case of suboccipital lesions, the Oc–C2 and C2–C7 – in case of subaxial lesions, and the C2–C7, C7S, T1S, TIA, NT, CeT, and CrT – in case of lesions of the cervicothoracic junction.

Dependence of changes in parameters on the number of affected vertebrae was found, with the highest value observed in tuberculous spondylitis. At that, NT and cSVA were the most sensitive parameters demonstrating statistically significant deviations from the normal values.

Further study of the issues of spinal biomechanics in abnormal conditions is required for better understanding of the changes and offering effective tech-

Table 6

Significance of differences in the NT parameter between the normal condition and destructive processes of various extent before and after surgical treatment (Dunn's test with Holm adjustment; $p \leq 0.025$)

Extent of destruction	Normal value	Extensive destructions ($n \geq 3$) before surgery	Extensive destructions ($n \geq 3$) after surgery	Short destructions ($n < 3$) before surgery
Short destructions ($n < 3$) after surgery	Z = –0.0393 p = 0.4843	Z = 2.6906 p = 0.0250	Z = 2.94078 p = 0.0147	Z = 0.7399 p = 0.6890
Short destructions ($n < 3$) before surgery	Z = –0.9177 p = 0.7176	Z = 2.2813 p = 0.0563	Z = 2.4170 p = 0.0469	–
Extensive destructions ($n \geq 3$) after surgery	Z = –3.2457 p = 0.0059	Z = 0.3915 p = 0.6954	–	–
Extensive destructions ($n \geq 3$) before surgery	Z = –2.8520 p = 0.0174	–	–	–

Table 7

Significance of differences in the cSVA parameter between the normal value and destructive processes of various extent before and after surgical treatment (Mann–Whitney test, $p < 0.05$)

Extent of destruction	Normal value	Extensive destructions ($n \geq 3$) before surgery	Extensive destructions ($n \geq 3$) after surgery	Short destructions ($n < 3$) before surgery
Short destructions ($n < 3$) after surgery	W = 1347.5 p = 0.0672	W = 125 p = 0.1428	W = 148 p = 0.3801	W = 362 p = 0.6511
Short destructions ($n < 3$) before surgery	W = 1243 p = 0.0195	W = 109 p = 0.1401	W = 130 p = 0.4225	–
Extensive destructions ($n \geq 3$) after surgery	W = 621 p = 0.0212	W = 54 p = 0.1002	–	–
Extensive destructions ($n \geq 3$) before surgery	W = 159.5 p = 0.2745	–	–	–

niques of correction and restoration of the normal anatomy of the spinal segment.

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The study was approved by the local ethics committees of the institutions.

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References

1. **Glukhov DA, Zorin VI, Maltseva YaA, Mushkin AYu.** Sagittal balance of the cervical spine in children older than 4 years: what is the norm? Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2022;19(4):19–29. DOI: 10.14531/ss2022.4.19-29
2. **Qi H, Zhao Z, Gao X, Wang C, Zhang Z, Su D, Zu F, Xue R, Hou Z, Chen W, Zhang D.** Normal spinopelvic parameters and correlation analysis in 217 asymptomatic children. Eur Spine J. 2024;33:2569–2576. DOI: 10.1007/s00586-024-08311-9
3. **Qi H, Zhao Z, Zu F, Wang C, Wang C, Zhang Z, Ren J, Xue R, Wang Z, Hou Z, Chen W, Zhang D.** Investigation of spinopelvic sagittal alignment and its correlations in asymptomatic pediatric populations. Sci Rep. 2025;15:6847. DOI: 10.1038/s41598-025-91481-3
4. **Kuleshov AA, Nazarenko AG, Sharov VA, Vetrile MS, Ovsyankin AV, Kuzminova ES, Lisyansky IN, Makarov SN, Strunina UV.** Comparative characteristics of cervical sagittal balance parameters and atlantoaxial instability criteria in normal and Down syndrome children. N.N. Priorov Journal of Traumatology and Orthopedics. 2024;31(1):55 66. DOI: 10.17816/vto624245
5. **Wu TH, Chen LL, Wen JX, Han SM, Zhong ZW, Guo Z, Cao L, Wu HZ, Yu BH, Gao BL, Wu WJ, Liu JC.** Spinal sagittal and coronal morphology characteristics in children with short stature. Quant Imaging Med Surg. 2025;15:1383–1395. DOI: 10.21037/qims-24-992
6. **Glukhov DA, Mushkin AYu.** Structure and clinical manifestations of tumor and infectious destructive lesions of the cervical spine in children: 20-year single-center cohort data. Medical alliance. 2023;11(4):88–96. DOI: 10.36422/23076348-2023-11-4-88-96
7. **Vaccaro AR, Cirello J.** The use of allograft bone and cages in fractures of the cervical, thoracic, and lumbar spine. Clin Orthop Relat Res. 2002;(394):19–26. DOI: 10.1097/00003086-200201000-00003
8. **Daffner SD, Wang JC.** Anterior cervical fusion: the role of anterior plating. Instr Course Lect. 2009;58:689–698.
9. **Setzer M, Eleraky M, Johnson WM, Aghayev K, Tran ND, Vrionis FD.** Biomechanical comparison of anterior cervical spine instrumentation techniques with and without supplemental posterior fusion after different corpectomy and dis-

cectomy combinations: Laboratory investigation. J Neurosurg Spine. 2012;16:579–584. DOI: 10.3171/2012.2.SPINE11611
10. **Glukhov DA, Mushkin AYu.** Surgical treatment of tumors and spondylitis of the cervical spine in children: what does 20-year monocentric experience with the syndromic approach reveal? Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2025;22(1):79–87. DOI: 10.14531/ss2025.1.79-87
11. **Jiang L, Qiu Y, Xu L, Liu Z, Wang Z, Sha S, Zhu Z.** Sagittal spinopelvic alignment in adolescents associated with Scheuermann's kyphosis: a comparison with normal population. Eur Spine J. 2014;23:1420–1426. DOI: 10.1007/s00586-014-3266-2
12. **Janusz P, Tyrakowski M, Kotwicki T, Siemionow K.** Cervical sagittal alignment in Scheuermann disease. Spine. 2015;40:E1226–E1232. DOI: 10.1097/BRS.0000000000001129
13. **Hwang SW, Samdani AF, Tantorski M, Cahill P, Nydick J, Fine A, Betz RR, Antonacci MD.** Cervical sagittal plane decompensation after surgery for adolescent idiopathic scoliosis: an effect imparted by postoperative thoracic hypokyphosis. J Neurosurg Spine. 2011;15:491–496. DOI: 10.3171/2011.6.SPINE1012
14. **Zhao J, Chen Z, Yang M, Li G, Zhao Y, Li M.** Does spinal fusion to T2, T3, or T4 affects sagittal alignment of the cervical spine in Lenke 1 AIS patients: A retrospective study. Medicine (Baltimore). 2018;97:e9764. DOI: 10.1097/MD.0000000000009764
15. **Moreira Pinto E, Alves J, de Castro AM, Silva M, Miradouro J, Teixeira A, Miranda A**. High thoracic kyphosis: impact on total thoracic kyphosis and cervical alignment in patients with adolescent idiopathic scoliosis. Spine Deform. 2020;8:647–653. DOI: 10.1007/s43390-020-00069-6
16. **Legarreta CA, Barrios C, Rositto GE, Reviriego JM, Maruenda JI, Escalada MN, Piza-Vallespir G, Burgos J, Hevia E.** Cervical and thoracic sagittal misalignment after surgery for adolescent idiopathic scoliosis: a comparative study of all pedicle screws versus hybrid instrumentation. Spine. 2014;39:1330–1337. DOI: 10.1097/BRS.0000000000000403
17. **Ketenci IE, Yanik HS, Erdem S.** The effect of upper instrumented vertebra level on cervical sagittal alignment in Lenke 1 adolescent idiopathic scoliosis. Orthop Traumatol Surg Res. 2018;104:623–629. DOI: 10.1016/j.otsr.2018.06.003
18. **Yanik HS, Ketenci IE, Erdem S.** Cervical sagittal alignment in extensive fusions for Lenke 3C and 6C scoliosis: the effect of upper instrumented vertebra. Spine. 2017;42:E355–E362. DOI: 10.1097/BRS.0000000000001796
19. **Han B, Hai JJ, Pan A, Wang Y, Hai Y.** Machine learning analysis of cervical balance in early-onset scoliosis post-growing rod surgery: a case-control study. Sci Rep. 2025;15:2024. DOI: 10.1038/s41598-025-86330-2
20. **Lee SH, Hyun SJ, Jain A.** Cervical sagittal alignment: literature review and future directions. Neurospine. 2020;17:478–496. DOI: 10.14245/ns.2040392.196

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