



# SAGITTAL BALANCE OF THE CERVICAL SPINE IN ADULTS: A NON-SYSTEMATIC LITERATURE REVIEW

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The article presents a non-systematic review of 44 publications on sagittal balance of the cervical spine selected over the past 10 years. Currently, despite the abundance of parameters proposed for assessing the sagittal balance, no consensus has yet been reached regarding the mandatory use of specific criteria. Debates persist regarding both the boundaries of “normality” and the degree of clinical impact of even the most established parameters on a patient’s functional status. Data on the influence of various single- or multi-level surgical interventions on the cervical sagittal balance are inconsistent. Consequently, there is no consensus on the need and methods of correcting specific alterations in cervical sagittal profile parameters. As a result of the literature analysis, the following parameters of the cervical spine balance were identified, which are considered the main ones: cervical lordosis (CL), sagittal vertical axis (cSVA), T1 slope angle (T1S), the T1S-CL difference, and spinocranial angle (SCA). Reference ranges were defined for most of them: T1S – 18.5°–40°, cSVA – less than 40 mm, SCA – greater than 88.6°, and T1S-CL – less than 25° ± 5°. The impact of surgeries such as ACDF and laminoplasty on sagittal cervical balance is controversial: some authors report significant changes in parameters following both anterior decompression and laminoplasty, while others, on the contrary, indicate the absence of significant alterations.

**Key Words:** sagittal balance; cervical spine; spine surgery; ACDF; laminoplasty.

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The last two decades have been marked by a significant deepening of medical knowledge in the field of sagittal balance of the spine. The sagittal profile parameters described by Le Huec et al. [1] and Roussouly et al. [2] have received worldwide recognition and have become indispensable in spine surgery, especially of its lumbar department.

The first works on the sagittal balance of the cervical spine appeared in the 2010s and were devoted to changes in its sagittal profile after surgical treatment. The main subject of interest in this period was changes in the neck balance in patients with myelopathy after laminoplasty [3, 4].

At the moment, a significant list of cervical spine sagittal profile parameters has been proposed, however, a clear consensus has not been developed regarding which specific parameters need to be assessed in the preoperative period in patients with certain pathological changes [5].

In this regard, there is a large volume of scattered data on the influence of each parameter on the clinical picture and functional status of patients with various diseases of the cervical spine [5–13]. In addition, there is no unified view on the change in the sagittal profile after

a particular type of surgical treatment [14–21]. This explains the absence of a clear judgment on the need to correct certain changes in neck balance parameters. And even with the presence of such a necessity, corresponding algorithms for the surgical correction of changes in the cervical profile in its various manifestations have not been developed.

Objective of the study was to highlight the most relevant and contradictory sections on the topic of sagittal balance of the cervical spine, summarize and analyze existing approaches and assessments of each of the highlighted sections.

## Material and Methods

The literature search was conducted in four electronic databases: PubMed, Cochrane Library, Google Scholar and eLibrary using the following keywords: “sagittal balance of the cervical spine”, “parameters of the cervical sagittal profile”, “degenerative-dystrophic diseases of the cervical spine” in Russian, “sagittal balance of the cervical spine”, “parameters of the sagittal profile of the neck”, “degenerative and dystrophic diseases of the cervical spine” – in English. The established level of evidence of sources – no less than 3 on the scale for assessing levels of evidence

reliability. In the articles, the most relevant and contradictory sections concerning the sagittal balance of the cervical profile were highlighted: relevant parameters, clinical significance of parameters, autoregulation of sagittal balance of the neck and its connection with other departments, influence of various surgical interventions on the sagittal profile of the neck.

Articles detailing one or more of the above-described sections over the past 10 years were included, with the exception of those necessary for presenting fundamental terms and the basis of the work. Non-surgical orientation and duplicating articles were excluded.

## Results and Discussion

For the execution of this non-systematic review, 44 publications were selected. Of these, 25 studies were performed no earlier than the last 5 years, another 12 – no earlier than the last 10 years: PubMed – 36 publications, Google Scholar – 3 publications, eLibrary – 5 publications. Of these, 2 systematic reviews and meta-analyses, 5 prospective studies, 24 retrospective cohort studies, 11 literature reviews, two methodological works.

The conducted analysis allowed highlighting four main groups of studies: 1) 23 publications on the study of the influence of various types of surgical interventions on the sagittal profile of the cervical spine; 2) 14 publications – on the analysis of sagittal balance parameters, their normative values and correlation relationships with functional outcomes of treatment; 3) 4 publications – on the biomechanical aspects and compensatory mechanisms of the cervical spine. A separate category of three sources consisted of reference and historical publications. It should be emphasized that the problematics of many studies are of an adjacent nature, touching upon several of the indicated directions simultaneously. In this regard, the final categorization was carried out based on the dominant thematic focus of each work.

*Influence of sagittal balance parameters on clinical manifestations of various diseases of the cervical spine*

Despite the fact that lordosis is considered the most natural shape of the cervical spine profile, there are many works indicating that a significant number of people in the asymptomatic population have a sagittal profile different from lordotic. Thus, Kim et al. [22] reported 26.3% of cases of cervical spine kyphosis in a group of asymptomatic examinees. Khalil et al. [23] – about 32% of cases of cervical kyphosis. Thus, it is impossible to consider the influence of the CL (cervical lordosis) parameter in isolation from other parameters of the sagittal profile.

In addition to CL, described by Cobb et al. [24], the following parameters are also highlighted: sagittal vertical axis (cSVA), measured as the distance between the vertical plumb line drawn from the middle of the body of the C2 vertebra, and the posterosuperior edge of the body of the C7 vertebra [25]; the angle of slope of the T1 vertebra (T1 slope, T1S), measured as the angle between the line drawn along the endplate of the T1 vertebra, and the horizontal line [26]; the difference of angles of the T1 vertebra slope and cervical lordosis (T1S-CL) [27]; as well as the spino-

cranial angle (SCA), introduced by previously mentioned Le Huec et al. [1].

In 2021 meta-analysis [6], a significant increase in the indicators of the T1S, cSVA and a decrease in SCA in patients with diseases of the cervical spine compared to the control group was demonstrated [11]. A number of authors revealed a positive correlation between the cSVA indicators and the ranking of patients according to the Neck Disability Index (NDI) both in the pre- and postoperative periods. This correlation becomes most pronounced at a cSVA of more than 40 mm [7–9]. The average indicator for the asymptomatic population is  $18.7 \pm 1.76$  mm [6]. B.B. Damidinov et al. [10] demonstrated a close positive correlation between the cSVA and the intensity of pain measured by the VAS. An inverse correlation is also reported between the cSVA values and the depth of functional impairments, assessed in the pre- and postoperative periods according to the modified scale of the Japanese Orthopaedic Association (mJOA) in studies involving patients with cervical myelopathy [28, 29].

As for the T1S parameter, it was revealed that the average indicator for the asymptomatic population is  $24.5^\circ \pm 0.98^\circ$  [6], and in patients with a low T1S, particularly less than  $18.5^\circ$ , the risk of degenerative changes of the cervical spine is increased [11, 12]. However, according to other authors [5, 13], high values of T1S also correlated with worse postoperative indicators, the greatest severity of this correlation occurred at a T1S  $>40^\circ$ .

Iyer et al. [8] investigated the influence of the T1S-CL parameter on clinical data of patients before surgery. Along with the cSVA indicator, an inverse correlation was revealed between the T1S-CL and the preoperative values of the NDI of the patient. Other authors, having analyzed the connection between T1S-CL and functional outcomes in patients who underwent multilevel fixation of the cervical vertebrae, found a positive correlation of T1S-CL and postoperative indicators of the NDI [9]. Conditionally, an indicator of less than  $20\text{--}30^\circ$  can be considered a normal T1S-CL value. However,

the authors point out the need for further clarifications based on larger patient samples [8, 9]. The average indicator of the T1S-CL value in the asymptomatic population is  $16^\circ \pm 3^\circ$  [6].

In studies devoted to the investigation of the SCA parameter, average values for the asymptomatic population are indicated as  $83^\circ \pm 9^\circ$  [5]. In another study, it is assumed that a SCA equal to  $88.6^\circ$  can be considered a cut-off point, at a value below which a connection with worse Neck Disability Index at the preoperative stage, but with good dynamics according to this scale in the future, is revealed [30].

Thus, to date, the question of the influence of sagittal profile parameters on the clinical indicators of the patient remains relevant. The majority of researchers agreed that values of T1S within the limits of  $18.5\text{--}40^\circ$ , cSVA – less than 40 mm, SCA – more than  $88.6^\circ$ , T1S-CL – less than  $20\text{--}30^\circ$  are associated with a favorable clinical and functional status.

*Mechanisms of autoregulation of sagittal balance of the cervical spine*

In recent years, more and more data have begun to appear on the possibilities of compensation both inside and outside the cervical spine. It has been shown that kyphosis of one or several cervical segments can be compensated by adjacent upper or lower segments, and lordotic changes in profile in the C2–C7 segments can be compensated by hyperkyphotic changes of the C1–C2 vertebrae and *vice versa* [31, 32].

When considering the mutual influence of adjacent spinal departments on sagittal balance, it was revealed that as a result of kyphotic changes in the thoracic spine, an increase in CL occurs, which, along with changes in the pelvis, is the main physiological instrument of the body for maintaining the cone of economy of global balance [33]. These data are confirmed by Smith et al. [34], who revealed that operations aimed at correcting kyphotic imbalance in the thoracolumbar spine lead to a spontaneous correction of cervical hyperlordosis.

Of note, the counterintuitive lack of direct correlation between lumbar lordosis (LL) and CL discovered in a number of works. LL exerts only an indirect

influence on the profile of the cervical region, possessing a direct correlation with thoracic kyphosis (TK), which, in turn, through the T1S parameter directly impacts the magnitude of CL [35, 36]. These data are also confirmed by A.V. Krutko et al. [37], indicating the absence of correlation of cervical sagittal balance parameters and pelvic parameters.

An increase in CL values leads to two consequences: a decrease in the area of intervertebral foramina with an increase in the risk of compression of their contents and an increase in load on the group of neck flexor muscles. These symptoms are compensated by tilting the patient's head forward, which due to an increase in cSVA leads to an expansion of intervertebral foramina with a subsequent decrease in load on the neck extensor muscles [38, 39].

Other authors proposed parameters explaining the compensatory mechanisms of the cervical spine similar to how it occurs in the lumbar department. This is expressed by the formula:  $TIA = \text{Neck Tilt (NT)} + T1S$ . The proposed formula can be briefly described as follows: an increase in thoracic or cervical kyphosis leads to a compensatory increase in T1S and, as a consequence, an increase in CL, which are necessary to maintain NT parameter values around  $44^\circ$ . This value allows ensuring minimal energy expenditure of horizontal gaze and maximal functional adaptation [40].

Thus, the mechanisms of compensation for changes in sagittal balance are presented both at the intra- and interdepartment levels. Kyphotic changes of the thoracic region lead to an increase in CL. In turn, hyperlordotic changes in the C2–C7 vertebrae, which increase the load on the neck muscles and increase the risk of compression of the contents of the intervertebral foramina, can be compensated both by hyperkyphotic changes in the C1–C2 vertebrae, and by forced changes in the posture of the head and neck similar to how it happens in sagittal balancing of the lumbar spine.

#### *Impact of surgical treatment on sagittal balance of the cervical spine*

One of the significant issues is to what extent performing surgical operations

on a given spine department affects the parameters of the sagittal profile.

According to a number of studies, performing Anterior Cervical Discectomy and Fusion (ACDF) significantly increases the values of subaxial lordosis of the C2–C7, T1S and decreases the cSVA indicator. The impact effect described by the authors of these works on the parameters increases proportionally to the number of segments on which the intervention is performed. Such an effect seems natural due to the restoration of the disc height in its anterior part due to the interbody implant and its wedge-shaped form [14–17].

However, there are contradictory data from other authors who investigated the influence of two-level ACDF on the neck profile and showed that neither T1S nor cSVA underwent statistically significant changes in the postoperative period. Only a significant isolated increase in the lordosis of the C2–C7 vertebrae occurred [18]. In yet another work, also dedicated to ACDF on two levels and its impact on the sagittal balance of the neck, no significant changes in any of the listed parameters were revealed [19].

Thus, contradictory data are presented in modern literature on the influence of ACDF on the cervical sagittal profile. It is worth noting that the situation is aggravated by the fact that often works on the influence of ACDF on balance parameters are concentrated separately on single-, double- or three-level operations and are rarely presented together in one study, which makes it difficult to draw an unambiguous conclusion about the influence of ACDF on the balance as a whole. By the way, in the few works devoted to artificial disc replacement in the cervical spine, similar results are presented [41, 42].

Similar to the above, in studies dedicated to the influence of laminoplasty on the sagittal profile of the cervical spine, contradictions are also found. In a number of works, the results of radiographic measurements in the postoperative period point to a significant kyphotization, that is, a decrease in the indicators of subaxial lordosis of the C2–C7 vertebrae, an increase in the size of the cervical cSVA. T1S underwent no changes

[43]. It was noted that after laminoplasty in the group of patients with a high preoperative T1S, the angle of the C2–C7 vertebrae decreased more significantly than in the group with a low T1S. The authors put forward a hypothesis that patients with a high T1S may have a greater tendency to kyphotic changes in the sagittal profile of the cervical spine due to performing laminoplasty. A limit value of the C2–C7 vertebrae lordosis of  $9.3^\circ$  was proposed as a risk factor for the development of postoperative kyphosis. According to these data, after laminoplasty, the incidence of postoperative kyphosis in the group with an angle of the C2–C7 vertebrae  $\leq 9.3^\circ$  was significantly higher by 16.1% than in the control group [20, 40, 44]. In a work dedicated to the application of laminoplasty in patients with myelopathy at the cervical level, M.D. Dreval and A.O. Gushcha [44] explain such changes by damage during the operation to the posterior osteoligamentous complex of the cervical spine, which perceives the main part of the axial load at this level.

In contrast to the given data, in another work with a comparable sample of patients who underwent the laminoplasty procedure, the absence of a significant change in indicators such as cervical lordosis, as well as cSVA, T1S after laminoplasty is reported [21]. There is no unambiguous answer to the question of what the presence or absence of changes in neck balance after laminoplasty depends on, presumably, this may be associated with a difference in the technique of performing the operation, economical or excessive excision of the ligamentous apparatus when exposing the bone structures of the cervical region.

Thus, as in the case with the previous surgical method, available data on the influence of laminoplasty on neck balance do not provide an unambiguous answer about its changes, or, conversely, preserving parameters in the postoperative period.

#### **Conclusion**

At the moment, the most common and applicable parameters are CL, cSVA,

T1S, difference of angles T1S and CL, SCA. During the literature analysis, it is confirmed that they exert a significant influence on clinical manifestations and functional outcomes in patients.

Indicative ranges of parameters associated with a favorable prognosis are established: T1S within the limits of 18.5–40°, cSVA – less than 40 mm, SCA – more than 88.6°, T1S-CL – less than 25° ± 5°. Average values in a healthy population are for T1S – 24.5° ± 0.98°, for cSVA – 18.7 ± 1.76 mm, for SCA – 83° ± 9°, for T1S-CL – 16° ± 3°. How-

ever, an ideal profile does not exist, and its assessment should take into account the patient's clinical picture, including wide variability in the asymptomatic population.

Data on the influence of ACDF on sagittal balance are contradictory. Some studies demonstrate a statistically significant increase in the lordosis of the C2–C7 vertebrae and improvement of cSVA parameters after Anterior Cervical Discectomy and Fusion, with the effect intensifying proportionally to the number of operated segments. However, other works do

not confirm these changes, noting only an isolated increase in lordosis or a complete absence of dynamics of key parameters.

The results of laminoplasty in the context of sagittal balance also remain debatable: on the one hand, in some patients a postoperative deterioration in the form of kyphotization with an increase in cSVA is noted, especially at an initial value of lordosis of the C2–C7 vertebrae less than or equal to 9.3°, on the other hand – studies do not reveal significant changes in sagittal parameters after similar interventions.

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