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Clinical issues of the sagittal balance in adults

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Literature data were used to present the parameters of integral sagittal balance assessment. It is shown that the assessment of the sagittal balance should be performed taking into account the spatial position of the body and the use of the “cone of economy” concept and gravity line. Cervical spine and the pelvis are the key compensatory mechanisms in correction of the sagittal balance changes. The ratio of PI (pelvic incidence) and LL (lumbar lordosis) is the most significant as far as it correlates with the changes in the quality of life. Clinical interpretation of the changes in the sagittal balance should be conducted on the basis of their integration with a mandatory consideration of clinical manifestations and changes in the quality of life.

Keywords: spine, sagittal balance, deformities, integral evaluation, quality of life

RELEVANCE

Over the past decades, the contemporary adult vertebrology uses the term adult spinal deformity (ASD). The incidence of this condition among the elderly people in the United States, according to the literature, has reached 70 %. However, the presence of a deformity of the spine does not necessarily mean the need for surgical treatment. The fundamental factor that predetermines the deterioration in the quality of life and, as a consequence, the need for surgical correction, is a disorder in the sagittal balance. In the opinion of most vertebrologists, it is the state of the sagittal balance that strongly correlates with the quality of life [1–3]. The sagittal balance is an independent predictor of the outcome of surgical treatment in ASD. In surgical correction of the deformity, it is the effect on the sagittal balance and lumbar-pelvic parameters that significantly improves the quality of life according to HRQoL scores [4–11].

SAGITTAL BALANCE

The pioneer in studying the sagittal balance is Jean Dubousset who in his numerous works showed the need to understand the balance by its assessment. According to J. Dubousset, the sagittal balance is the relationship of all the curves of the spine (kyphosis and lordosis) in which the minimum amount of muscle energy is used in space under the action of the gravitational load to maintain the position of the body in space (posture). At the same time, the position of the eye level remains horizontal. Compliance with these two conditions is possible only if the body is in the so-called "cone of economy" (**Fig. 1**) [2, 12–14].

From the point of view of an objective evaluation of the sagittal balance, a large number of X-ray parameters are considered (**Fig. 2**), on the basis of which an integral assessment of the balance state is made. Taking into account all radiographic parameters, it is possible to determine the so-called global alignment [15, 16]. However, measuring these parameters allows us to estimate only the static component of the balance and does not provide an objective picture. This fact should be remembered when interpreting the radiographic data [17, 18].

To assess the global alignment as the most objective method for sagittal balance assessment, the following key parameters were proposed: cervical lordosis (CL), T1 vertebra slope (T1S), thoracic kyphosis (TK), lumbar lordosis (LL), position of the pelvis, lower extremities. The cervical spine alignment and the global alignment are commonly distinguished separately [8, 17, 19–21].

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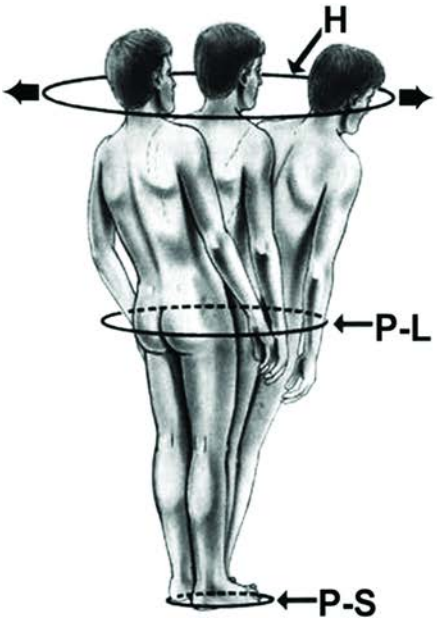

Fig. 1 Optimal human body posture according to "cone of economy' concept [13]

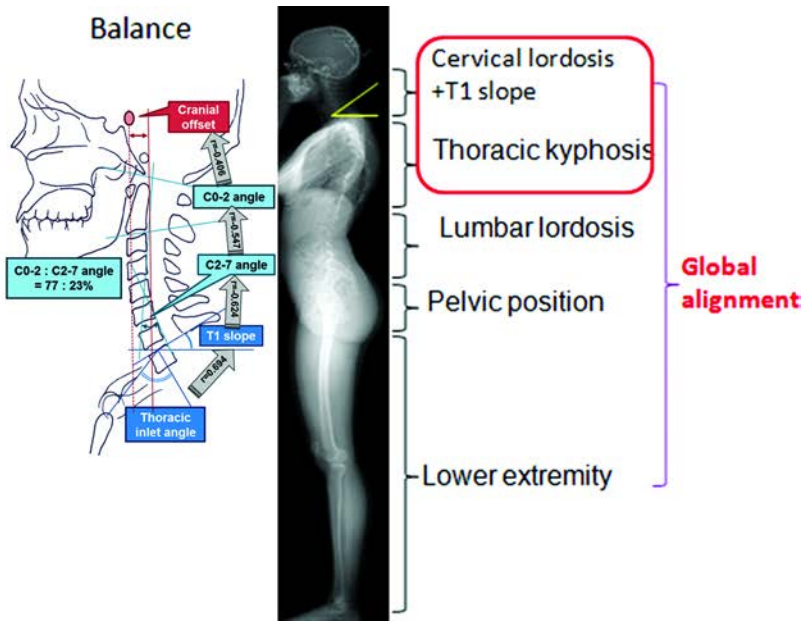

Fig. 2 Radiographic parameters of sagittal balance [22]

SAGITTAL BALANCE PARAMETERS AND THEIR SIGNIFICANCE

Cervical balance Assessment and interpretation of the cervical alingment is most difficult due to a relatively recent introduction of its radiographic indicators for clinical use, technical difficulties in assessing the results of radiography, and unambiguous interpretation of the results. To understand these changes, one should know the main role of the cervical spine (CS) in maintaining the posture.

CS plays a key role in head position over the body and in providing a horizontal gaze. The center of the head mass is located 1 cm higher and anterior to the external auditory canal [23]. Its displacement leads to a redistribution of the load and an increase in the expenditure of muscle energy. The weight of the head is transmitted through the occipital bone condyles to the C1 lateral masses, then to the joints of C1–C2. C2 transfers the load to the anterior column (C2–C3 disc) and the posterior columns (C2–C3 joints), with 36 % of the load on the anterior column and 64 % on the posterior columns [22, 24].

The cervical spine has a decisive impact on the changes in the global alignment aimed at maintaining a horizontal gaze. This mechanism is largely provided by cervical lordosis which is usually divided into craniocervical C0–C2 (provides 77 %) and subaxial C3–C7 (provides 23 %). The key parameter that influences all the others is the slope of the T1 (T1 slope) (**Fig. 3**) [6, 25–31].

From the point of view of radiographic evaluation, the following parameters were developed (**Fig. 3**): C0–C2 angle, C2–C7 angle, T1 slope (T1S), thoracic inlet angle, neck tilting, and C2–C7 sagittal vertical axis (SVA). Assessment of the horizontal eye gaze is made on the basis of the patient's photo in full height and laterally. For this purpose, the so-called chin-to-brow vertical angle was proposed known in the literature as CBVA [32–37]. The average values of the cervical balance parameters are presented in **Table 1** [22, 31, 38–43].

Table 1

Mean values of the cervical balance parameters [43]

Parameter	Value
C0–C2 angle	-30°
C2–C7angle	-9.6°
T1S	40°
C2–C7 SVA	4 см
TIA	44°
CBVA	(-10°)–(+10°)

Global alingment The estimation of the sagittal balance should be made taking into account the gravity line which reflects the load distribution from head to foot (**Fig. 4**). In this regard, the correct interpretation of the parameters is possible only if images are taken in a standing position [2, 15, 18, 19].

Sagittal vertical axis (SVA) is an objective reflection of the global alignment. It is measured from the middle of C7 body as a drop line down. The distance from this line to the S1 joint processes should not exceed 4 cm. When it is shifted forwards it means a positive balance. If it is shifted backwards the balance is negative (Fig. 5) [11, 19–21, 44].

Thoracic kyphosis (TK) The definition of this parameter is based on the measurement of the angle using the Cobb method (**Fig. 5**). It is most commonly accepted to measure the angle between the upper end plate of the T5body and the lower end plate of the T12 body. However, the level of T5, as a rule, is the apex of physiological kyphosis and, accordingly, can not reflect its true value. Another (more reliable) method is the measurement from

the upper end plate of the body of the uppermost thoracic vertebra that is clearly visualized in the lateral radiograph down to T12. The mean value of TK is 49.3 ° ± 9.2° and varies between 33 and 71° [45, 46].

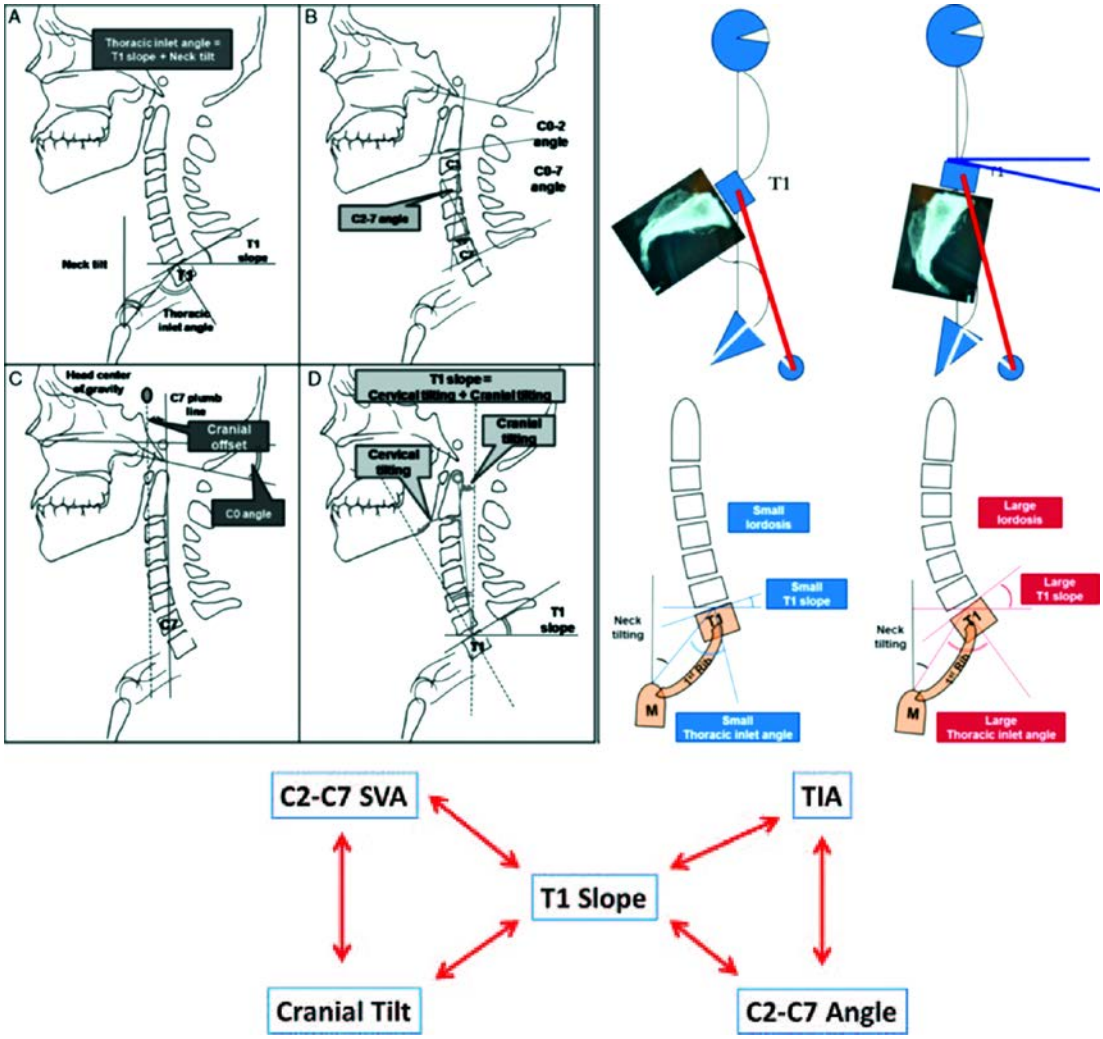

Fig. 3 Cervical balance parameters and their relationship [31, 40]

Fig. 4 Diagram of the gravity line relative to the vertebral column [19]

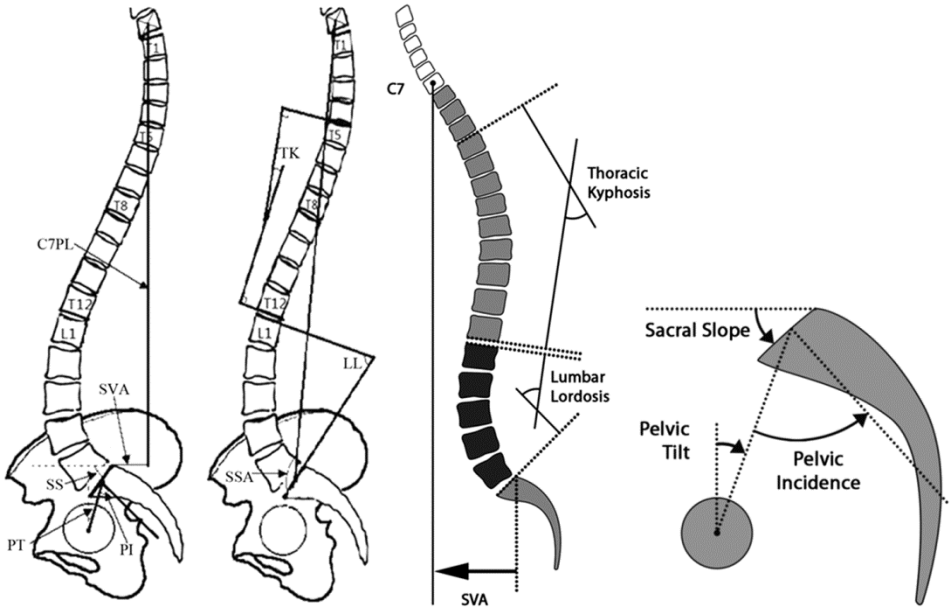

Fig. 5 Parameters of the sagittal vertical axis (SVA) relative to the C7PL line [10, 47]

Lumbar lordosis (LL) The measurement is also carried out using the Cobb method from the upper edge of the end plate of the L1body to the upper end plate of the S1 body (**Fig. 5**). The mean value of LL is 63.5° ± 10.9° and is between 45 and 87° [11, 19, 29, 45–48].

Position of the pelvis Assessment of the pelvis position is a key in determining the sagittal balance of the spine. It should be remembered that most of the compensatory capabilities in the formation of imbalance is possible at the expense of changing the position of the pelvis. The following parameters are used to evaluate the position of the pelvis: PI (pelvic incidence) – a morphological (static) parameter – 55° ± 10.6°, PT (pelvic tilt) – a dynamic (compensatory) parameter (LL gravity center) – 13° ± 6° (not more than 20°), and SS (sacral slope) – a dynamic parameter – 41° ± 8° (**Fig. 5**) [7, 18, 19, 44, 46, 48, 49].

Interpretation of the above-listed parameters of the global alignment is made only based on the results of their integration, taking into account the types of sagittal balance (**Fig. 6**). The most common are the formulas proposed by a number of authors: TK + PI + LL ≤ 45° (Rose P.S., 2009); TK + LL ≤ 20° (Kim Y.J., 2006); LL = PI + 9° (Schwab F., 2009); PI = PT + SS (Klineberg E., Schwab F., 2013) [5, 50, 51]. Recently, the assessment of sagittal modifiers which form the base of the SRS-Schwab classification (**Fig. 7**) has been widely accepted [29, 52–54].

Interpretation of global alignment parameters The spread of sagittal modifiers in clinical practice was due to their close correlation with the quality of life based on the clinical questionnaires used (ODI, SF-36, SRS, HRQOL). However, recent studies have shown that the correlation of these sagittal modifiers and changes in the quality of life do not have deterministic correlation. The most significant is the evaluation of the ratio PI-LL ≤ 9° whereas PT (to assess the position of the pelvis) does not show significant correlation with the change in the quality of life [44, 52, 55, 56].

Lower extremities Radiographs of the cervical, thoracic and lumbar spine are not enough to fully assess the sagittal balance. For this, a radiographic examination of the whole body is required, including lower limbs. Currently, the EOS system allows us to evaluate the compensatory mechanisms to correct the balance (pelvis and/or lower extremities). To quantify the position of the pelvis on the basis of EOS measurements of the balance parameters, the pelvic shift parameter was proposed (**Fig. 8**). Based on the results of the correlation analysis between the parameters of the sagittal balance and the bending of the knee joints, it was found that the change in the PI-LL ratio has a clearly traceable relationship. It was established that the pelvic shift correlates with changes in ODI results. Pelvic shift and flexion of the lower extremities are important parameters that show compensation for imbalance, and should be taken into account in assessing the balance disorder [2, 49, 57–60].

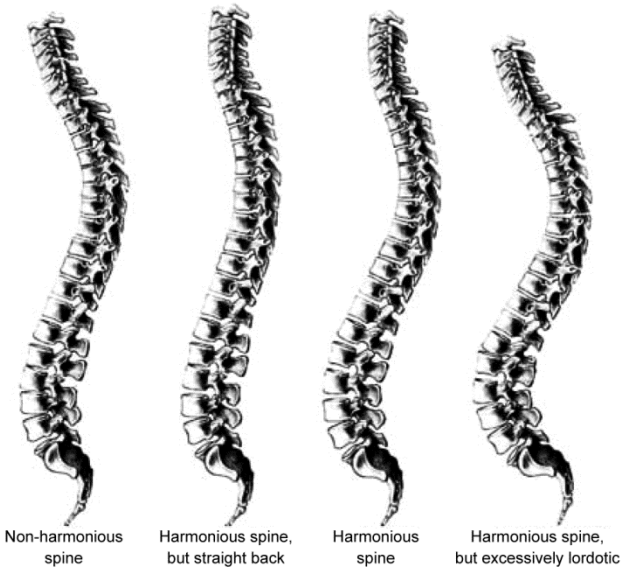

Fig. 6 Sagittal balance types [19]

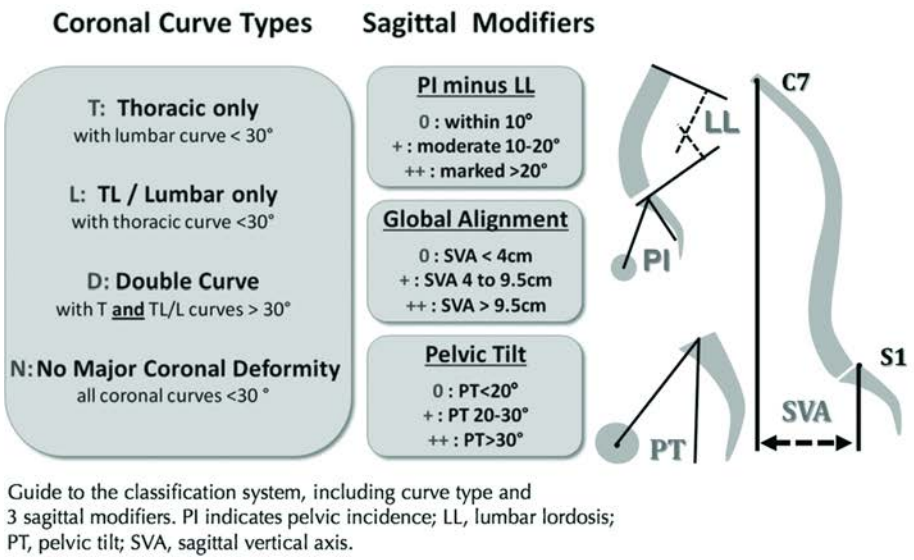

Fig. 7 Diagram of ASD SRS – Schwab classification [29]

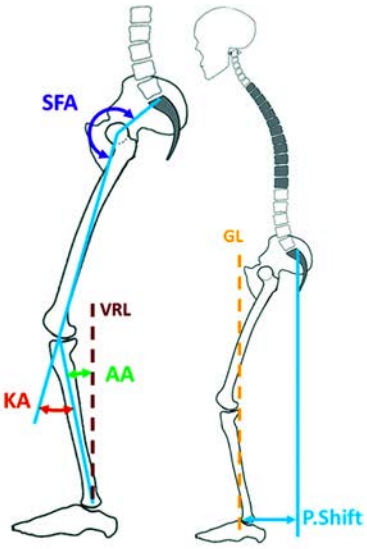

Fig. 8 Diagram for lower limbs radiographic parameters assessment [58]

CONCLUSION

- Estimation of the sagittal balance should be made taking into account the spatial position of the body using the concept of the "cone of economy" and the gravity line.
- Cervical spine and pelvis are key compensation mechanisms for correcting sagittal balance changes.
- PI–LL ratio is one of the most significant since it correlates with changes in the quality of life.
- Clinical interpretation of the changes in the sagittal balance should be made on the basis of their integration with mandatory consideration of clinical manifestations and changes in quality of life.

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