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Topographic manifestations and criteria of mobile spine deformities

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Purpose To determine topographic manifestations and mobility criteria in spine deformities **Materials and methods** Twelve patients aged from 10 to 27 years with clinical and radiographic signs of scoliosis of grades 2 to 3 (according to V.D. Chaklin) were examined using computer optical topography. Inclusion group was patients with high positive results of conservative treatment and with a diagnostic mismatch between the methods of radiography and topography. **Results** It was established that on the scale of a live examination a topographic monitoring of the postural activity of the patient's trunk in a standing position up to 3 minutes enables to reveal mobile manifestations of spine deformities in the form of arbitrary and involuntary variation of their angular characteristics in compensated and decompensated types with strengthening or weakening of the pathology signs. By instrumental control, high mobility was manifested by the following types of combinations of X-rays and topograms: 1) radiographic and topographic signs of spinal deformities coincided in location but significantly (more than 4º) differed in severity grade; 2) in the presence of radiographic signs of scoliotic deformity, their topographic analogs in orthostatics were either not detected or were recorded only at the end of a prolonged examination. **Conclusion** The degree of mobility of spinal deformities in orthostatics and its dynamics can be judged from the range of numerical values of the lateral asymmetry angle (S1_LA), the topographic analogue of the Cobb angle. The smaller is the range of its arbitrary and involuntary postural variations the lower is the mobility of spinal deformities. In a high mobility of spinal deformities, the lateral asymmetry angle varies over a range of values greater than 7°.

Keywords: topographic monitoring, postural orthostatic activity, spine, mobile deformities, angular deformities, variability

INTRODUCTION

Most researchers emphasize that the amount of surgical correction in spinal deformity depends on its initial mobility [1, 2]. Therefore, traditionally, from the beginning of corrective surgery, the assessment of deformity mobility is important for determination of its structurality, choice of fixation level, maintenance of a reliable correction and prevention of decompensation – the main issues of corrective surgery in scoliosis. According to a number of researchers [3], X-rays in the prone position are used only to assess the natural mobility of the deformity but do not give an idea of the maximum possible values of its mobility under loads. As a result, the postoperative "degree of correction" presents the amount of deformity correction achieved in each individual observation but does not allow adequate comparison or assessment of different clinical cases since the initial mobility of the deformed spine is not taken into account. In this regard, there are publications in which the authors [4] propose an obligatory comparison of the instrumental correction results of spinal deformity with its initial mobility. Due to a large number of different methods used for radiological evaluation of deformity mobility [5, 6], there is no generally accepted criterion for it. However, according to the latest publications [7], it is suggested to consider the deformity to be mobile when the values of the main arc of the curvature under the conditions of simulated load in radiographs change by more than 30 % of the initial values, and for a fixed scoliosis the deformity should not increase by more than 5º by radiographic examination with an interval of four hours [8].

Given the relevance of the problems associated with mobility assessment in severe spinal deformities by corrective surgery, we have not found similar attempts in the available literature to solve it in conservative treatment.

However, in the information sources there occasionally appear cases of a very effective conservative treatment effect on scoliotic deformities. For example, in one patent specification [9], clinical cases with grade 3 idiopathic scoliosis (according to V.D. Chaklin) were presented. In one of them, two months after the treatment course of pulsed magnetic therapy the objective computer optical topography confirmed the decrease in the angular deformity equal to 14.7° (from 44.1° to 29.4°). The reason for such a positive transformation over a 2-month observation interval could

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not be attributed only to the effect of a pulsed magnetic field. The following arguments served as grounds for this doubt:

– taking into account a very high level of resistance to conservative therapy and low correction values [10], the pace of such a correction is not only excessive for conservative therapy measures but also for comparison with the probable value of the deformity progression according to the degree of its severity and the patient's age;

– when compared with another example, where the decrease in the angular deformity in the patient of the same age and the same degree of curve according to computer optical topography was 7.4°, the difference in efficiency was almost 100 %.

We assume that the true cause of high efficiency is not the procedure itself (it was the same in both cases), but in the individual features of the compared spinal deformities, that is their mobility. Since the mobility of up to 35 % is also recorded in severe deformity grades [11], its presence should not be less evident in less severe forms of the disease.

Purpose Determine topographic manifestations and criteria for mobility of spinal deformities in the conditions of orthostatic activity.

MATERIAL AND METHODS

Twelve patients aged 10 to 27 years with clinical and radiographic confirmation of spinal curvatures of grades 2–3 (according to V.D. Chaklin) were examined. Inclusion group was patients with unexpected high positive results of conservative treatment and with a diagnostic mismatch between conventional radiography and computer optical topography.

The following types of the combinations of X-ray and topogram findings were distinguished:

1. Patients in whom radiographic and topographic signs of spinal deformities almost coincided in location but paradoxically differed in degree of expressiveness (5 subjects). In these case examined, the X-ray signs of deformities of the spine in the prone position were more pronounced than similar topographic features of curves in orthostatic position. For example, if the Cobb's angle in the X-rays in prone position was 32º at the L2 level, then its topographic analogue in the same location was only 27.6º.

2. Patients with X-ray signs of scoliotic deformities of the spine who had either complete absence of topographic signs of scoliosis in orthostatic postural activity or they appeared only at the end of a prolonged examination (2 subjects).

3. Patients showed unexpectedly high (more than 7º) correction of angular deformity under the influence of various conservative therapies (5 subjects).

Instrumental topographic analysis of the monitored postural activity of the trunk and spine in orthostatics was carried out with the optoelectronic method of KOMOT [12].

The following topographic indices of angular spinal deformity were analyzed (**Fig. 1**): S1_LA – an angle of lateral asymmetry (topographic analogue of Cobb's angle), S1_RA – an angle of rotation at the apex of the curvature and S1_IA – a calculated index of total curve angle according to two previous parameters. By the criterion of normalized deviations, the automated diagnosis of the dominant disorders in the spine and trunk shapes was performed (**Fig. 2**). Analysis of the biomechanical parameters of the spine according to the topograms in the dynamics of postural activity makes it possible to study the effect of various phenotypic factors on the characteristics of curvature arcs of the spine not only in isolation but in direct connection with other elements of a particular postural system of the trunk. Depending on the capabilities of the subject, the spatial characteristics of the trunk and spine were evaluated by a prolonged standing up to 3 minutes in 7-14 topographic views. The duration of the intervals between the shots ranged from 10 to 20 seconds. To simplify the perception and analysis of the information obtained the interest parameters of the output forms were displayed as corresponding composite tables (**Fig. 2**). The table results of the examinations were, in their essence, dynamic models of controlled motor stereotypes.

Right-sided and left-sided redistribution of support loads on the limbs was carried out by modeling leg discrepancy. For this purpose, a special 2-cm stand was placed under one of the limbs. The results obtained for each patient were analyzed by qualitative (formalized topographic diagnosis) and quantitative changes in his/her postural status, taking into account the absolute and relative variation of the previously listed parameters [13].

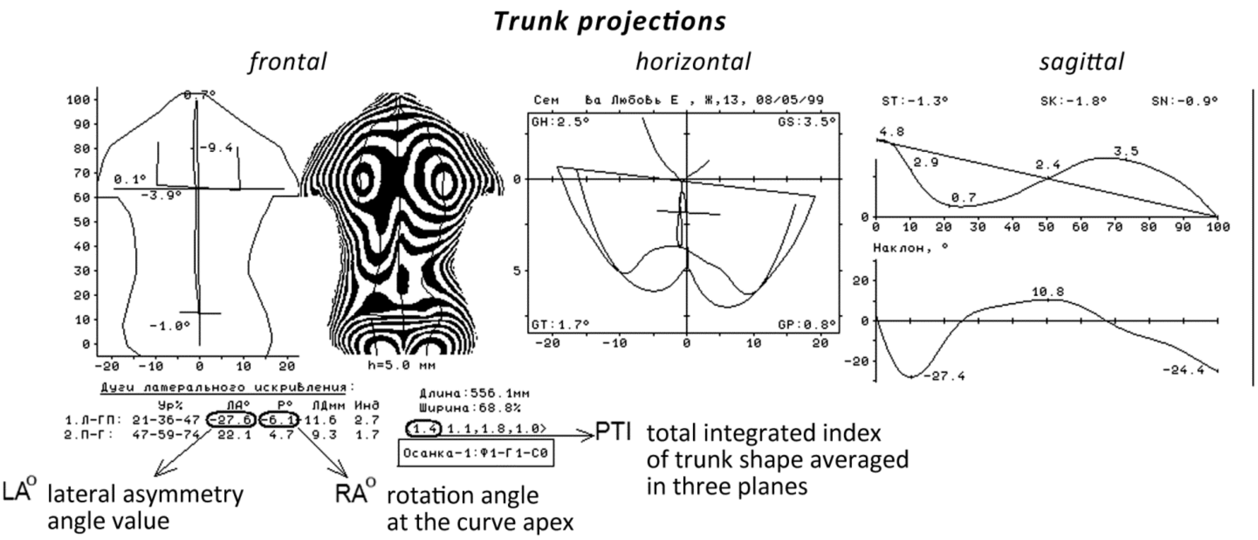

Fig. 1 Topograms as diagrams of biomechnical profile of the postural trunk system

Patient	Date	PTI	PTI_F	PTI_G	PTI_S	S1_IA	FP	HP	SP
Сем Ба Любо Е	09/04/12	1.4	1.2	1.8	0.9	23.4	SD-G2	HS	HS-Inc
Сем Ба Любо Е	09/04/12	1.4	1.1	1.8	1.0	23.0	SD-G2	HS	HS-Inc
Сем Ба Любо Е	09/04/12	1.4	1.3	1.9	1.0	26.0	SD-G3	HS	HS-Inc
Сем Ба Любо Е	09/04/12	1.4	1.0	1.9	1.3	27.2	SD-G3	HS	HS-Inc
Сем Ба Любо Е	09/04/12	1.4	1.2	1.9	0.8	27.2	SD-G3	HS	HN
Сем Ба Любо Е	09/04/12	1.3	1.0	1.9	0.8	27.1	SD-G3	HS	HN
Сем Ба Любо Е	09/04/12	1.4	1.1	1.9	1.0	26.6	SD-G3	HS	HS-Inc
Сем Ба Любо Е	09/04/12	1.4	1.2	2.0	0.6	27.4	SD-G3	PD-PR	HN
Сем Ба Любо Е	09/04/12	1.4	1.4	1.8	0.7	27.4	SD-G3	HS	HN
Сем Ба Любо Е	09/04/12	1.4	1.3	1.8	0.9	27.4	SD-G3	HS	HN

Fig. 2 ScreenShot of the output form of a prolonged topographic examination of postural activity by a 2-minute interval of standing with generalized topographic characteristics of the trunk and topographic diagnoses for frontal (FP), horizontal (HP) and sagittal (SP) projections in ten topograms in patient C., 13 years old . DS: S-shaped idiopathic scoliosis of grade 3: PTI is the total integral index of distorted trunk shape; PTI_F is the integral index of the torso shape disorder in the frontal plane, PTI_G is the integral index of the disorder in the horizontal plane, PTI_S is the integral index of the disorder in the sagittal plane, S1_IA - total angle of the dominant curvature. Topographic automated diagnoses corresponding to a healthy norm (HN) and a healthy subnorm (HS) with an increased physiological curvature of the spine in the sagittal plane (HS–inc), posture disorder (PD); in the horizontal plane – rotated posture (RP); SD–G2 and SD–G3 – spinal deformities corresponding to scoliosis of grade 2 and 3

RESULTS

The results of the study showed that in spite of the scoliotic deformities established radiographically as grades 2-3, those examined subjects who had the coefficients of variation (KV) of the topographic deformity characteristics in orthostatic stereotypes more than 15 % featured postural corrective non-rigid curves of a functional nature with a subsequent always positive dynamics by observation. Patients in the usual orthostatics with a coefficient of variation (KV) of the curvature arc characteristics of the spine of the less than 15 % had only a negative dynamics recorded, and by modeling a different height of the legs, it was possible to correct the curvature of the spine only partially. Moreover, the recorded KV values only decreased in the conditions of a different leg height in such patients.

The effect of the angular deformity variation degree in orthostatic motor stereotypes was also observed in adaptive responses of the musculoskeletal system. According to topographically formalized diagnostic criteria, adaptive responses of the musculoskeletal system were significantly different and manifested themselves in the examined patients, depending on the types identified.

Thus, in type 1 patients, depending on the degree of deformity severity, the adaptive responses of the musculoskeletal system were accompanied by topographic signs of scoliotic deformities from the first seconds of standing and were observed in two variants (**example 1**, **example 2**).

In the adaptive responses of the musculoskeletal system in the type 2 patients, the topographic features of scoliotic deformities were either completely absent (**example 3**), or appeared only after a prolonged standing as a postural decompensation.

Example 1

Time	LA°	FP
11:01:50	-28.4	SD–G2
11:02:18	-27.6	SD–G2
11:02:34	-32.1	SD–G3
11:02:58	-32.8	SD–G3
11:03:12	-33.2	SD–G3
11:03:26	-34.7	SD–G3
11:03:48	-33.1	SD–G3
11:04:11	-33.9	SD–G3
11:04:34	-33.9	SD–G3
11:04:54	-33.5	SD–G3

– Onset of postural decompensation and, namely, the enhancement of topographic signs of scoliosis. In statics, the negative values of the lateral asymmetry angle (LA°, Cobb's angle analog) increase in the range from -27.6° to -33.9° from grade 2 of scoliosis (SD–G2) to grade 3 (SD–G3)

Example 2

Time	LA°	FP
15:02:57	17.0	SD–G2
15:03:11	15.7	SD–G2
15:03:24	16.1	SD–G1
15:03:38	13.4	SD–G1
15:03:52	12.2	SD–G1
15:04:06	11.6	SD–G1
15:04:18	-6.9	PD–SD
15:04:31	-8.0	PD–SD
15:04:44	-6.6	PD–SD
15:04:58	-5.9	PD–SD

– Onset of postural compensation and decrease of scoliotic curves. In statics, the absolute values of the lateral asymmetry angle (LA°) decrease from 17° to (-5.9°), or from grade 2 of scoliosis (SD–G2) to grade 1 (SD–G1), and then up to a complete disappearance of topographic signs of scoliotic deformity with preservation of only trunk posture distorsion (PD–SD)

Example 3

Time	LA°	FP
13:55:42	6.4	HS
13:55:59	4.1	HS
13:56:12	-3.2	HS
13:56:25	0.0	HS
13:56:39	-3.9	HS
13:56:54	5.5	HS
13:57:08	4.6	HS
13:57:21	5.7	HS
13:57:34	0.0	HN
13:57:47	4.7	HS

– In statics, the absolute values of the angle of lateral asymmetry (LA°) vary in the range of a healthy norm (HN) and a healthy subnorm (HS) from (-3.9°) to 6.4°

In type 3, when an unexpected high correction (more than 7°) of angular deformities was detected under the influence of various conservative therapies, all the adaptive responses of the musculoskeletal system were observed. The only distinguishing feature of these patients was their ability to significantly adjust angular values of deformations in their postural activity, even with severe structural signs of the pathology (scoliosis of grade 3).

It should be noted that a significant orthostatic variation of angular deformities (S1_IA) in patients with postural activity stereotypes in the form of decompensated responses was recorded not only in the natural posture (**Fig. 2**, where the range of variation of S1_IA is shown from 23.0° to 27.4°). When modeling different height of legs, the range of variation increased even more. Thus, according to the generalized angle of the curvature, the redistribution of the load on the right leg was accompanied by a decrease in the angular deformity of the spine to 20.5°, and when the reference load was redistributed to the left one, the angular deformity increased to 29°. Thereby, the range of lateral asymmetry angles (S1_LA), the analog of the Cobb angle, varied from −25° with the stand on the left up to −37.4 ° with the stand on the right.

In natural orthostatics, without modeling the difference of the legs, the variation range in the generalized angle of curvature (S1_IA) did not exceed 4.4 °, and in the lateral asymmetry angle (S1_LA) was 8.0°, while in modeling the difference in height, the range of variation expanded to: the generalized angle of curvature was already 8.5°, and the lateral asymmetry angle even to 12.4 °. It turns out that by redistribution of reference loads, the angular values of mobile deformities can be corrected posturally up to 33 % from the maximum values.

At the same time, it should be noted that in the group of patients examined, significant results of postural correction were achieved not only by the corresponding activity of the support reactions. In single observations, the essential values of postural correction were achieved by arbitrary actions that were not associated with the redistribution of support loads on the limbs.

Example In the first topographic examination, patient B., 16 years old, with idiopathic scoliosis of grade 3 had the maximum lateral asymmetry angle (S1_LA°) 52.1° at the Th9 level in the usual orthostatics while by an arbitrary correction of the postural stereotype due to the elimination of the twisting of the shoulder girdle relative to the pelvis it was only 36.5° at the same level (**Fig. 3a**). As a result, the overall variation range of angular deformity in absolute values was 15.6° and in relative values to the maximum recorded values it was 29.9 %.

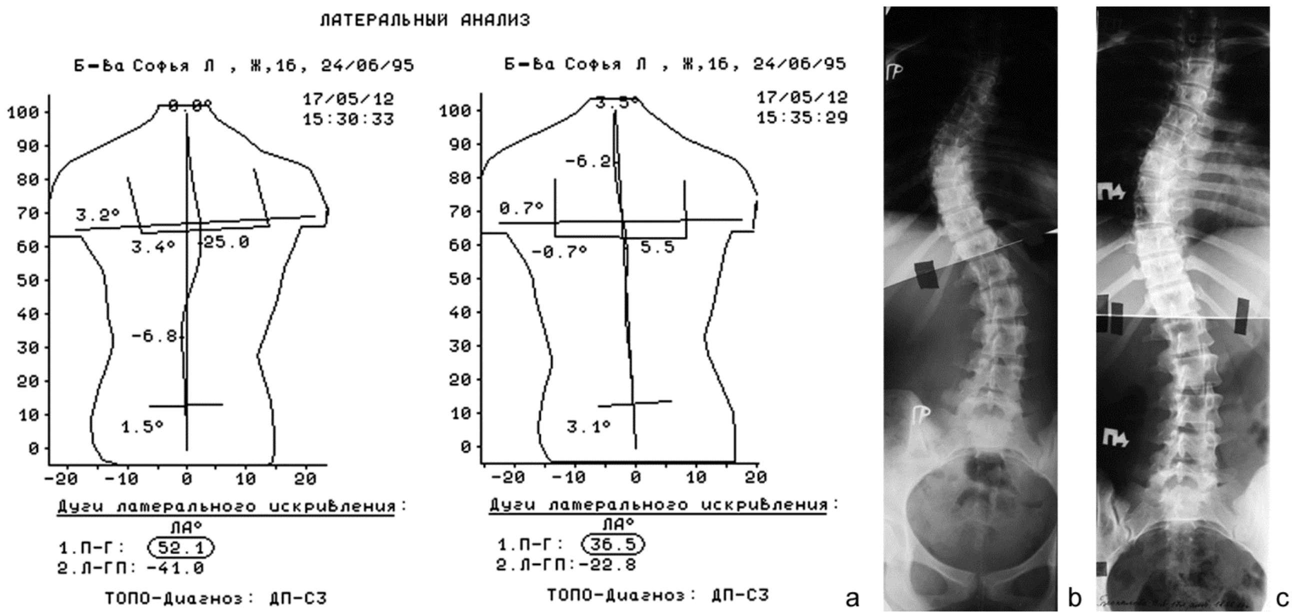

Fig. 3 Mobility of spinal deformity in patient B., 16 years old, with idiopathic scoliosis of grade 3: (a) according to topography with prolonged monitoring in orthostatics; (b) the spine in the frontal projection, Cobb angle 52º (Th9); (c) X-ray of the spine 1.5 years later, Cobb angle 40º (Th9)

The repeated topographic examinations performed a month later before and after the simulated leg discrepancy as well as after a manual therapy session confirmed high mobility of the observed deformity. In the cases examined, the arbitrary postural correction proved to be significantly more effective than manual therapy and simulated leg difference. Regarding the registered maximum in the usual orthostatics (S1_LA = 55.94°), the minimum values of angular deformity were 45.53° after manual therapy, 46.55 ° at modeling different leg height, and 38.88 ° at an arbitrary postural correction. That is, even after a month it was possible to register spontaneous and arbitrary changes in the mobility of the deformed spine. Absolute and relative values of mobility increased. The overall range of mobility was 17.06°, and in relative values to the maximum recorded values it was 30.5 %.

The subsequent positive 1.5-year radiographic dynamics of deformity (**Fig. 3 b, c**) from 52° to 40° of the Cobb angle at the same level confirmed a high degree of mobility of the spine and an excellent clinical correction result at the time of the examination. At the same time, new radiographically recorded angular values of the deformity in the prone position became the ground for specifying the degree of postural mobility in orthostatic conditions. At a 2-months follow-up, the range of mobility in the conditions of arbitrary postural correction decreased and in absolute values of the lateral asymmetry angle it was only 9.8°, or 19.2 % as referred to the maximum values.

DISCUSSION

The presented materials on several clinical examples demonstrated the capabilities of postural monitoring technology to study the variability of the angular characteristics of spinal deformities using computer optical topography. It is shown that in orthostatics the angular characteristics of mobile deformations of the spine, even of moderate severity, can vary within a fairly wide range of values - more than 7°. In addition, depending on the duration of standing and the degree of mobility of the postural system of the trunk, the variability in the stereotypes of postural activity in case of unidirectional dynamics of diagnostically significant indices can be manifested either in compensation (signs of scoliotic deformations do not appear, and if they do, they do not increase) or decompensation (signs of scoliotic deformities intensify or start to manifest themselves). The postural stiffness test for spinal deformities that was previously established has been confirmed. According to it, compensatory nonstructural scoliosis with correction of pelvic girdle have coefficients of more than 15 % of variation for the parameters of the generalized angle of the curve and lateral asymmetry angle [13]. The degree of mobility of spine deformities in orthostatics and its dynamics can be judged from the range of extreme numerical values of the angle of lateral asymmetry (S1_LA), an analog of the Cobb angle. The smaller is the range of its variation the lower is the mobility of spinal deformities. In highly mobile deformities, the angle of lateral asymmetry varies in a range of values greater than 7º, which explains the significant diagnostic differences between radiographic and topographic examinations, especially in patients with non-rigid spinal deformities.

CONCLUSIONS

1. Topographic monitoring of orthostatic activity makes it possible to study and monitor the functional lability of the spine, not in isolation but in the postural system of the trunk.

2. In adaptive responses of the musculoskeletal system, mobile deformities of the spine are characterized by different degrees of variation of their angular parameters and the coordinates of the curvature arcs location.

3. Topographic monitoring of the trunk in orthostatics makes it possible to detect compensated (signs of scoliotic deformity do not enhance) and decompensated (increasing signs of scoliotic deformity) forms of postural activity.

4. The degree of mobility of spinal deformities in orthostatics can be judged from the range of the extreme numerical values of the angle of lateral asymmetry (S1_LA), an analogue of the Cobb angle. The smaller is the range of its variation the lower is the mobility of spinal deformities. In highly mobile spinal deformities, the lateral asymmetry angle varies in a range of values greater than 7°.

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