SURGICAL CORRECTION OF ADULT IDIOPATHIC SCOLIOSIS IN PATIENTS OF YOUNG AND MIDDLE AGE

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Objective. To evaluate the results of surgical correction of idiopathic scoliosis in patients aged 18—50 years, in terms of different age groups.

Material and Methods. A total of 393 patients (348 women, 45 men) with idiopathic scoliosis were operated on during 1996—2015. In all cases, posterior correction of the deformity was performed using segmental third-generation instrumentation. The primary curve and structural countercurve were included in the fusion area. Hook fixation was performed in 298 cases, and hybrid (hooks and pedicle screws) in 95. The period of postoperative follow-up was 4.4 years on average. Analysis of immediate and long-term results was performed using X-ray and computer optical topography in three age groups (age at the time of surgery): 18 to 24 years (274 patients), 25 to 34 years (95 patients), 35 years and older (24 patients).

Results. No statistically significant differences between age groups were revealed, both in initial parameters (magnitude of the primary curve, countercurve, and the apical vertebra rotation) and in surgical results (magnitude of correction, loss of correction and mobility). When interviewing patients with the SRS-24 questionnaire, the best results were obtained in the group of age 18—24, worse in the group of age 25—34, and even worse in the group of age over 35. Computer topography also revealed the absence of statistically significant difference between age groups.

Conclusion. Surgical treatment of adult idiopathic scoliosis provides quite satisfactory results, especially in terms of improving the quality of life, that do not have significant differences when comparing three age groups within the age range exceeding 30 years.

Key Words: adult idiopathic scoliosis, scoliosis surgery, SRS-24.

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In the last two decades, treatment of spinal deformities in adults turned into one of the most important problems of vertebrology. Population aging in highly developed countries of Europe, Asia, and the USA, ongoing improvement of spinal instrumentation and anesthetic protection methods sharply increased surgical activity in patients with adult scoliosis of various etiology. In full accordance with these changes, there is increasingly more publications dealing with various aspects of the problem and discussing the results of treatment of a wide age range of patients, including those in the eighth and ninth decades of life with *de novo* and degenerative deformities. Substantially less attention is paid to the results of surgical correction of idiopathic scoliosis in patients under 50 years old, who are equally far from adolescence and old age. Furthermore, the results are usually analyzed taking into account the magnitude and rigidity of the deformity, while the studies discussing the relationship between the outcomes and patient's age (age group) at the time of surgery are extremely scarce.

The study was aimed at evaluating the results of surgical correction of idiopathic scoliosis in patients aged 18—50 years, taking into account particular age subgroups within these limits.

Material and Methods

A total of 393 patients (348 females, 45 males) were operated on in 1996—2015, all of them met the following criteria:

– idiopathic scoliosis of the thoracic or lumbar/thoracolumbar spine;

– age at the time of surgery 18 to 50 years;

– corrective surgery through the posterior approach using third-generation posterior instrumentation;

– two-year or longer postoperative follow-up;

– no history of surgical treatment.

The average age of patients at the time of surgery was 23.8 (18.0 to 47.8) years; postoperative follow-up averaged 4.4 (2.0 to 15.7) years.

Taking into account the objective of the study, the studied cohort was divided into three age groups: 18—24 years (274 patients); 25—34 years (95); 35 years and older (24). This ranging should be commented: the first group included patients with completed spinal growth, which continues up to 25; the other groups were formed over 10—year intervals. The group of patients older than 35 years also includes three patients aged 45—48 years, since it was unreasonable to assign them to a separate group from the point of view of statistical processing.

The distribution of patients in terms of the deformity type was as follows: thoracic — 273 (right-sided — 257, left-sided — 16), 225 of them had secondary curves (lumbar/thoracolumbar — 178, upper thoracic — 47); lumbar/thoracolumbar primary curve — 120 (right-sided

— 46, left-sided — 74), 97 of them had thoracic countercurve.

Clinical examination included survey of the patients by spine surgeon, neurologist, therapist and, when necessary, specialized doctors. Traction test was performed in 25 patients with deformities exceeding 90°, i.e. examination by a neurologist in patient's position of vertical suspension over the head with full body weight traction [1].

Concomitant extravertebral pathology was detected in 178 (45.6 %) patients.

All patients underwent a plain X-ray study of the thoracic and lumbar spine in standard projections in the standing position and with lateral bending in the supine position. X-ray films were used to assess the Cobb angle of the primary and secondary curves, thoracic kyphosis and lumbar lordosis; frontal balance (in mm) based on the distance between the centroid of T1 vertebra and the central sacral line; the magnitude of apical vertebral rotation of the primary curve according to Sullivan et al. [20] using the formula: AVR (apical vertebral rotation) = 0.26 (T5—T12 kyphosis) + 0.34 (Cobb angle) – 5.38.

MRI of the thoracic spine was also performed.

Computer-optical topography (COT) was carried out only in 98 patients to analyze of the topography of the posterior surface of the trunk [2], which enabled formation of only two comparison groups: 18—24 years (75 patients, mean age 20.4 years) and older than 24 years (23 patients, mean age 31.2 years).

All patients completed the SRS-24 questionnaire.

A total of 37 (9.3%) out of 393 patients underwent surgery before admission to the clinic, including 21 operations for pathology of internal organs (congenital heart defects — 6, abdominal pathology — 12, of which 8 — acute appendicitis; lung pathology — 2, thyroid pathology — 1); caesarean section — 7, tumors of various localization — 4, scleroplasty — 1, extravertebral pathology of the musculoskeletal system — 4 (hip replacement, sternal plastic surgery, osteosynthesis of clavicular fragments).

Surgical treatment. All patients underwent posterior correction of deformity using third-generation segmental instrumentation with inclusion of the primary curve and structural secondary curve in the fused area under intraoperative traction by the head and supramalleolar regions with a load not exceeding 50% of patient's body weight. Hook fixation was used in 298 cases, hybrid fixation (hooks and pedicle screws) — in 95 cases. In 88 patients with rigid thoracic deformities, the corrective stage was preceded by discectomy at 3—5 levels and interbody spinal fusion with an autologous bone through the transthoracic approach (in all cases, both operations were carried out in a sequential order within one session). Three patients were pretreated with a halo-pelvis apparatus, while segmental instrumentation only fixed the effect. In 31 cases, residual rib hump was resected for cosmetic indications 1.5—2 years after the primary surgery.

Mean blood loss was 941 (100—2600) ml during stand-alone posterior correction and 1130 (300—3300) ml during two-staged operation (discectomy, interbody fusion, posterior correction). The duration of these procedures was 169 (65—390) and 260 (155—545) min, respectively.

Statistical methods. Calculations using the R Statiscal Package software was carried out based on structured data summarized in spreadsheets followed by analysis for data completeness and errors. The differences were considered as significant at $p < 0.05$. Empirical data distributions were tested for compliance with the normal distribution law using the Shapiro – Wilk, Anderson – Darling, Cramer – von Mises, Lilliefors and Shapiro – Francia tests.

Paired Mann – Whitney U test for dependent groups and unpaired Mann – Whitney U test (also known as Wilcoxon test) for independent groups were used for statistical verification of the hypotheses of equal numerical characteristics of sample distributions. The displacement of the distributions was calculated with the 95 % confidence interval for the displacement with both paired and unpaired Mann – Whitney U tests. Statistical correlations were studied by calculating Pearson's correlation coefficient (r) for linear relationships and Spearman's correlation coefficient for detection of additional nonlinear relationships. Qualitative characteristics of dependent groups were compared using the MacNemar 2 test and exact Fisher test for independent groups. The results are shown in the form of a median and interquartile range (0.75 quantile — 0.25 quantile).

Results

When assessing the overall results of treatment, the following facts should be noted: the average height of patients before and after the operation and at the end of the follow-up period was 161.8, 164.7, and 164.3 cm, respectively; average weight was 54.1, 53.5, and 56.6 kg; lung capacity (according to spirometry) — 2394; 1912; and 2429 ml.

Postoperative complications in different follow-up periods were observed in 99 (25.1%) patients, and mechanical complications were the most common ones (60 patients). Rod fractures (one or both) occurred in 30 cases in different periods after the operation; the fractures occurred more than once in 8 cases, instrumentation was remounted in 16 patients (24 operations) and removed in 5 cases; in 7 cases, rod fracture did not necessitate reoperation. In another 30 cases, instability of the spinal instrumentation system arose due to violation of the integrity of the supporting bone structures or partial dismounting of the metal structure (unscrewed lockwashers, displaced rods and hooks). These complications necessitated remounting of the instrumentation in 6 cases and its removal in 5 cases. In other cases, there were no indications for reoperation. The relationship between the incidence of mechanical complications and the type of instrumentation was noted: complications were detected in 50 (16.3 %) cases with hook fixation, and in 10 (10.1 %) cases with hybrid instrumentation.

Neurologic complications are the second most common ones; they developed in 17 (4.3 %) patients. Flaccid lower

limb monoparesis was observed in one patient with an initial deformity of 80°, which did not necessitate reoperation due to significant regression of neurologic symptoms. Various severity of radicular pain was observed in 12 cases, shoulder plexitis in 3 cases, intraoperative liquorrhea in 1 case (all complications were jugulated). It should be noted that none of 13 patients who initially had neurologic symptoms (12 cases of pyramidal insufficiency, including 6 cases detected during the traction test and 1 case with the signs of L5 root compression) demonstrated their postoperative worsening.

In 10 (2.5 %) cases, a proximal upper thoracic countercurve, which was absent before surgery, was detected in the late postoperative period. Newly formed curve was located within the interval from T1 to T5, and Cobb angle did not exceed 26°. None of these cases demonstrated symptoms necessitating reoperation.

Deep surgical site infection was diagnosed in 8 (2.03 %) cases, out of them only one case required the removal of instrumentation due to inability to stop the process .

General surgical complications were detected in 6 (1.9 %) patients, including enterocolitis (2), pneumothorax (2), cystitis (1), and renal failure (1). All these complications were stopped without consequences. There was no correlation between patient's age and the incidence of complications.

The results of intergroup evaluation of primary and compensatory curves, thoracic kyphosis and lumbar lordosis, apical vertebral rotation, and magnitude of the frontal imbalance at different stages of treatment are summarized in Tables 1—3. Significant difference was found in the following parameters:

1) the differences between 18—24-year-old and 25—34-year-old groups, respectively, were as follows: primary curve — in standing position before the operation, in prone position with lateral bending before the operation, immediately after the operation, and at the end of the follow-up period; secondary curve — in standing position before and immediately after the operation; thoracic kyphosis — before and immediately after the operation and at the end of the follow-up period;

2) between 25—34-year-old and ≥35-year-old groups, respectively: secondary curve — immediately after the operation and at the end of the follow-up period; thoracic kyphosis — at the end of the follow-up period.

No significant differences between groups were detected in terms of correction, loss of correction, and mobility according to all parameters (primary and secondary curves, kyphosis and lordosis). *Data of the SRS-24 questionnaire.* Analysis of 208 completed questionnaires showed no correlation between the "postoperative function" parameter and the age; it was rated as low in all three groups. More intense postoperative pain was reported by young patients, who rated it as 3.44 ± 0.46 (patients aged 25—34 years rated it as 3.57 ± 0.50, and patients older than 35 years as 3.65 ± 0.60). However, the best results in terms of other five domains (overall appearance, appearance after surgery, general activity, professional activity, satisfaction with the results of the operation), as well as the overall evaluation of the surgical outcome, were obtained in the group of patients aged 18—24 years, lower results – in 25—34-year-old group, and the lowest — in ≥35-year-old group (Fig. 1).

The final results for the domains are shown in Table 4.

The results of COT are shown in Fig. 2.

The histograms of the PTI index (the overall integrated posture index) for the two comparison groups (75 patients under the age of 24 and 23 patients aged 25 years and older) in the preoperative and postoperative periods show that there is no statistically significant difference (Fig. 2a, b). There are also no differences between the groups in the magnitude of correction (%) of trunk deformity (Fig. 2c). The average correction was 37.5 % in the group up to 24 years and 37.75 % in the group 25 years and older. At the same time, in the group up to 24 years, minimum correction was +18 % (worsening) and maximum correction was -63.1 %, while in the group 25 years and older, it was -14.2 % and -58.6 %, respectively.

Discussion

There is a lot of literature data on the operative correction of adult scoliosis and the number of these publications increases every year [11, 18]. Our article is not an attempt of meta-analysis (these have already been undertaken), but rather analysis of the results of treatment of patients with idiopathic scoliosis of no older than 50 years. In the world literature, there is usually no upper age limit in the study cohorts and analysis includes patients with deformities of various etiology: idiopathic, degenerative, scoliosis *de novo*, and others. We used an extensive clinical material to analyze the results of treatment of young and middle aged adult patients. We were interested, in the first place, how the results of surgical correction of idiopathic scoliosis change with maturation of patients who are not near old and senile age. To this end, we divided the patients into three age groups, suggesting that the results will differ both between these groups and possibly when comparing the entire cohort to that with adolescent idiopathic scoliosis.

Adult spinal deformities have a different origin, including untreated scoliosis of adolescents, newly developed deformities (scoliosis *de novo*), the results of degenerative changes, the consequences of injuries, tumors, infections, and other lesions. The incidence of adult scoliosis is 32 % in the general population, and 68 % in patients older than 65 years [8].

Selective analysis of the data published in the most authoritative publications over the past two decades demonstrates the possibilities of radical solution of the problem of adult spinal deformities, while the very concept of "adult" is interpreted ambiguously. Cho et al. [10] consider that adult patients are those aged 21 years and older, but the majority of authors consider 18-year-old patients as adults [3, 4, 14, 15, 17]. In the studies of many authors, the average age of operated patients [12, 17, 20] varies from 38 to 53 years, and the age limits

Table 1

The dynamics of the primary and secondary curves at different stages of treatment

Age group, years	Primary curve, deg.				Secondary curve, deg.			
	Preoperative (standing)	Preoperative (side bending)	Immediately after the operation	At the end of the follow-up	Preoperative (standing)	Preoperative (side bending)	Immediately after the operation	At the end of the follow-up
18–24	67.8 (27–162)	45.2 (1–146); correction 33.6 %	32.1 (1–133); correction 52.7 %	35.0 (5–125); correction 48.9 %; progression 2.9°	43.1 (13–88)	21.0 (30–74); correction 51.3 %	22.2 (1–96); correction 48.5 %	25.9 (4–78); correction 40.0 %; progression 3.7°
25–34	79.9 (34–180)	54.4 (2–133); correction 32.0 %	42.9 (46–172); correction 46.4 %	46.6 (2–125); correction 41.7 %; progression 3.7°	49.9 (19–105)	27.7 (1–75); correction 44.5 %	28.3 (-30–68); correction 43.3 %	31.9 (9–79); correction 36.1 %; progression 3.6°
35 and older	77.3 (32–127)	57.0 (7–113); correction 26.2 %	43.8 (9–114); correction 43.0 %	45.3 (6–114); correction 41.4 %; progression 1.5°	52.6 (13–122)	31.3 (6–51); correction 40.4 %	37.2 (10–117); correction 29.3 %	41.4 (11–107); correction 21.3 %; progression 4.2°
Overall	71.3 (27–180)	48.0 (1–146); correction 32.7 %	35.4 (1–172); correction 50.4 %	38.4 (2–172); correction 46.2 %; progression 3.0°	45.3 (13–122)	23.1 (-30–70); correction 48.5 %	24.7 (-30–117); correction 45.4 %	28.2 (4–107); correction 37.7 %; progression 3.5°

Table 2

Dynamics of thoracic kyphosis and lumbar lordosis change at different stages of treatment

Age group, years	Primary curve, deg.			Secondary curve, deg.		
	Preoperative	Immediately after the operation	At the end of the follow-up	Preoperative	Immediately after the operation	At the end of the follow-up
18–24	36.8 (-8–153)	27.6 (2–143)	31.7 (3–148)	60.3 (24–113)	51.0 (18–113)	53.9 (9–165)
25–34	46.8 (3–180)	37.8 (7–138)	39.3 (4–125)	60.6 (30–130)	52.0 (59–95)	53.3 (22–87)
35 and older	44.7 (3–145)	34.0 (4–91)	40.8 (16–81)	68.6 (44–95)	55.0 (29–81)	53.4 (28–78)
Overall	39.6 (-8–108)	30.4 (2–143)	34.1 (3–148)	60.9 (24–130)	51.0 (59–113)	53.8 (9–165)

Table 3

Change in the rotation of the apical vertebra in the primary curve

Age group, years	Primary curve, deg.			Secondary curve, deg.		
	Preoperative	Immediately after the operation	At the end of the follow-up	Preoperative	Immediately after the operation	At the end of the follow-up
18–24	29.9 (23–32)	13.2 (11–19)	15.3 (13–19)	16.9° (9–19)	17.9 (5–8)	13.1 (5–6)
25–34	32.8 (22–35)	19.0 (10–18)	19.7 (14–21)	15.2 (1–90)	18.4 (2–9)	11.3 (1–9)
35 and older	35.1 (29–37)	18.1 (14–23)	18.9 (16–24)	10.9 (12–23)	13.2 (2–8)	10.0 (2–7)
Overall	30.2 (22–37)	13.8 (10–23)	15.7 (13–24)	16.1 (1–90)	17.8 (1–9)	12.2 (1–9)

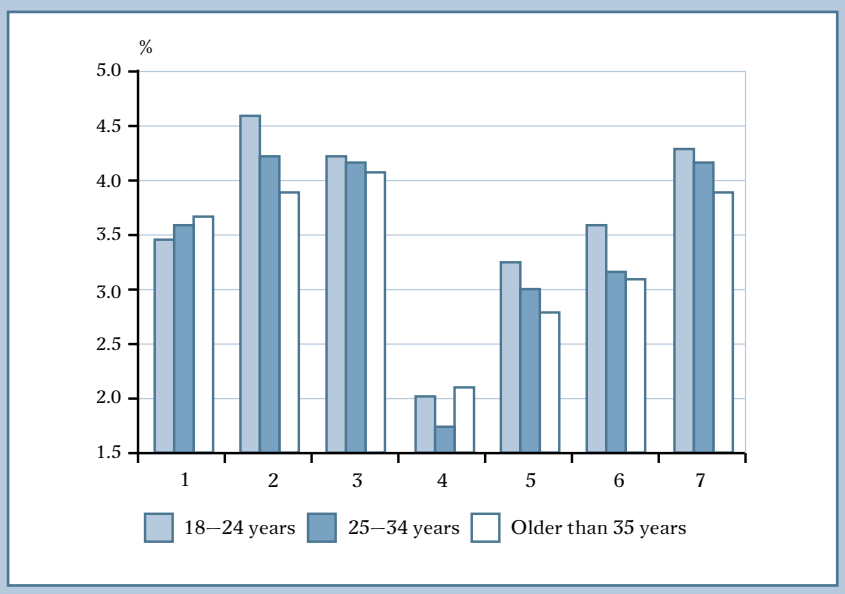

Fig. 1
Patients' rating of the results of surgical treatment for seven domains of the SRS-24 questionnaire

Table 4
The SRS-24 questionnaire results in the age groups under study

Domain	Age group		
	18–24 years	25–34 years	older than 35 years
Pain	3.44 ± 0.46	3.57 ± 0.50	3.65 ± 0.60
General appearance	4.60 ± 0.76	4.22 ± 0.98	3.94 ± 0.91
Postoperative appearance	4.33 ± 0.58	4.30 ± 0.77	4.08 ± 1.07
Postoperative function	2.00 ± 1.28	1.66 ± 1.09	2.05 ± 1.43
Total activity	3.26 ± 0.77	2.99 ± 0.95	2.79 ± 1.01
Professional activity	3.63 ± 0.71	3.17 ± 1.05	3.05 ± 1.09
Satisfaction with surgical outcome	4.29 ± 0.62	4.13 ± 0.79	3.87 ± 0.93
Total	87.81	83.79	81.52

are 18 to 84 years. Only a few researchers [3, 4] analyze the results obtained in younger patients (18 to 50 years). At the same time, the average Cobb angle is specified only in several publications, which is quite surprising [3, 5, 10, 12]. However, the operations are carried out in patients with almost any degree of deformity (from 47 to 97°). Correction rarely exceeded 50 % and postoperative progression was noted only in one article [12] and did not exceed 4°. It seems that the initial severity of deformity and achieved correction are of less interest to surgeons than the number and types of complications and changes in the quality of life (it is well known that the situation is completely different in the case of adolescent idiopathic scoliosis). The results of surgical treatment of 22,932 patients are reported in 11 publications [7, 9, 10, 12–17, 20, 22], some of which are multicenter ones and meta-analyzes. In these publications, the incidence of complications varies from 28.5 to 55.0 % [12, 15, 20, 22] and increases from 33 to 84 % with increase in patient's age (from 21 to 60 and more years) [10]. The incidence of pseudoarthrosis, which is a typical complication in adult patients, ranges from 3 to 27% [9, 14, 17, 20, 22], the frequency of reoperations for various reasons (including the development of pseudoarthrosis) is 3 to 25 % [7, 13, 15, 20]. Infectious complications, including sepsis, were detected in 1 to 8 % of cases [9, 15, 20], neurological complications of varying severity, including intraoperative injury to the dural sac — from tenths of percent to five percents [9, 15, 20], pulmonary thromboembolism — 1 to 20 % [9, 16]. Only one publication reports data on fatal outcomes [15], which amount to 19 cases per 4,555 operations. Many authors studied patient's satisfaction with the results of treatment [5, 7, 9, 10, 14, 21] and concluded that, despite the significant number of complications and reoperations, the quality of life of patients is significantly improved.

Earlier, we attempted to analyze the results of surgical correction of adult idiopathic scoliosis [6], but without age differentiation. Analysis of the results reported in this publication shows that the initial mean value of the primary curve in patients aged 18–24 years is less than in the other two groups. Preoperative mobility of the primary curve determined in the side bending position is significantly lower than surgical correction both in the whole group (32.7 vs. 50.4 %) and in all age subgroups. At the same time, the magnitude of surgical correction decreases with age from 52.7 % (18–24 years) to 46.4 % (25–34 years) and 43.0 % (over 35 years). Preoperative mobility demonstrates the same trend. Postoperative progression did not exceed 4° both in the overall group and in age subgroups, i.e. it was below the measurement error characteristic of the Cobb method.

The secondary curve demonstrates the same behavior with the same low confidence level, but with one exception: preoperative mobility of the coun-

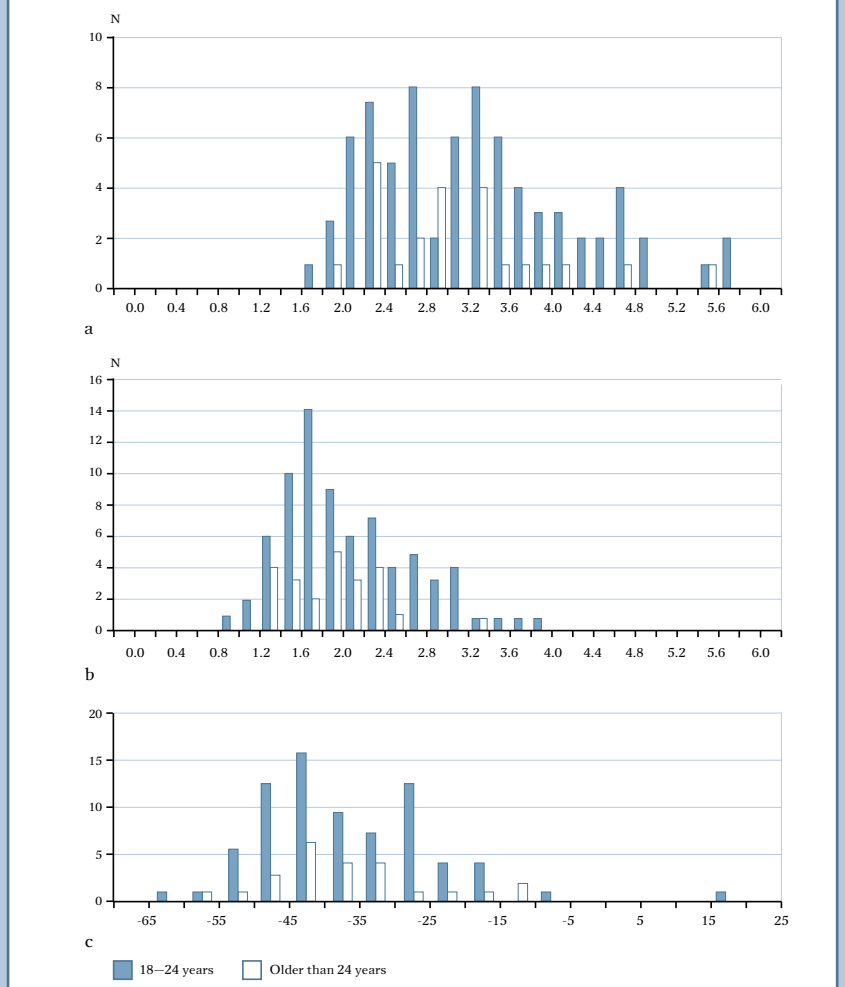

Fig. 2
Histograms of the distribution of the integral PTI index before the operation **(a)**, after the operation **(b)**, and correction magnitude in percent **(c)**: histograms **a** and **b** specify the distribution of the topographic integral index PTI, which gives an estimation of deviation of the posterior surface of the trunk from the well-balanced posture: 1 < PTI < 2 — moderate disorders, PTI > 2 — spinal deformities; histogram **c** shows the correction magnitude vs PTI (%) distribution with respect to the preoperative state (the minus sign corresponds to decrease in the index and posture improvement)

tercurve always slightly exceeds the value of intraoperative correction. Every spine surgeon knows that secondary curve is less susceptible to structural changes, so the difference from the primary curve is quite understandable.

The kyphotic thoracic deformity is flattened by about 10° immediately after the operation (both in the overall group and in the age subgroups), but it partially returns to the baseline level at the end of the follow-up period. Exactly the same dynamics was observed in patients with adolescent idiopathic scoliosis. There is only mild flattening of the lumbar lordosis, which practically does not change during the entire follow-up period.

Apical vertebral rotation is assessed using the method recently described by Sullivan et al. [19] based on two values: thoracic kyphosis value and Cobb angle of the primary curve. Of cause, its calculation is possible only in the case of thoracic deformity. We have no information about other cases where this method was used, but the changes detected in this way are quite predictable: significant (40 % or more) intraoperative derotation of the apical vertebra with partial loss of correction by the end of the follow-up period, mainly in the group of patients aged 18—24 years.

The dynamics of frontal imbalance is similar to that observed in adolescent idiopathic scoliosis: mild initial worsening followed by significant normalization.

The number of detected surgical complications (25.1 %) corresponds to the lower limit of the range presented in the literature (from 28.5 to 55.0 %).

Additional research methods showed controversial results. It turned out that the differences between age subgroups are statistically significant only when assessing the initial state (Cobb angle), but not the results of correction and postoperative dynamics of deformity. This is also evidenced by COT data. At the same time, the results of patient-filled SRS-24 questionnaires show that the younger the patients, the more readily they state an improvement in the quality of life in the immediate and long-term postoperative period.

Despite the high number of patients (393) who were evaluated for surgical outcomes, it can be stated that this number is insufficient for more definite conclusions. The results were analyzed in the group of patients with various locations of the primary curve, which is another limitation of our study and necessitates an additional research, which is planned for the nearest years.

Conclusion

Surgical treatment of idiopathic scoliosis in adults aged 18 to 50 years is a challenging problem, which is almost not

covered in the special literature from the point of view discussed in this article. Clinical results obtained during the analysis can be considered as quite satisfactory in terms of deformity correction and changes in patients' quality of life. At the same time, we found no significant differences in the effect of the operation, taking into account age differentiation within the analyzed cohort, which is an interesting new finding.

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