SCHEUERMANN'S DISEASE SURGERY. MAJOR PROBLEMS

Non-systematic literature review (part I)

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Objective. To perform multivariate comparison of two surgical strategies in the treatment of patients with severe Scheuermann's disease.
Material and Methods. The search of sources (in Scopus and Web of Science databases) revealed 56 publications containing the required information. The literature data were analyzed in four directions: the results of one- and two-stage interventions are compared in terms of the magnitude of achieved correction and its preservation, the complication rate, the surgery duration and the volume of intraoperative blood loss, and the quality of life of patients in the postoperative period.
Results. The magnitude of the achieved correction of kyphotic deformity and postoperative loss of correction in patients after one- and two-stage operations are almost identical. Implant-associated complications are more often observed after one-stage operations, and purulent, neurological and other complications — after two-stage operations. Surgery duration and intraoperative blood loss volume are greater in two-stage operations. The quality of life assessed by various questionnaires is significantly improved, regardless of the type of surgery.
Conclusion. Two-stage surgical correction of Scheuermann's kyphosis has no noticeable advantages over one-stage surgery, however, new studies with long (more than 15–18 years) postoperative follow-up are needed.
Key Words: Scheuermann's disease, surgical treatment, one-stage intervention, two-stage intervention.
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The etiology and pathogenesis of spinal deformities affected by Sheuermann's disease are unknown. Holger Werfel Scheuermann, a Danish orthopedist and radiologist, defined kyphoses of unclear genesis, but with a typical clinical and radiological picture as juvenile and with his classical articles [1, 2] opened a discussion which is valid even today. Holger Werfel Scheuermann looked at the issue comprehensively (within the possibilities of his time). However, his publications do not contain any references to surgical treatment. Only in 1964, Sorensen mentioned in his excellent monograph [3], based on the experience of a thorough examination of 103 patients, first attempts of surgeries. They are aimed at progression control and feasible correction of severe kyphotic deformities. He enumerates a few papers (mainly in French-language literature) devoted to spinal fusion in the area of kyphotic deformity: Naquet (1935), Berg (1948), Soeur (1958), and Stagnara, Perdriolle (1958). Ferguson Jr. (1956) performed posterior spinal fusion after preparing a patient with severe deformity applying an extension plaster jacket.

If the deformity of vertebral bodies in patients with incomplete growth was irreversible, Roaf [4] recommended an attempt to constrain the progression of deformity by forming secondary curves above and below thoracic kyphosis, followed by posterior spinal fusion with the capture of adjacent areas to further increase compensatory curvature. The above-mentioned researcher considered it essential to remove articular processes, laminae and spinous processes for achieving sufficient hyperextension. Hallock et al, believe that the spinal fusion is unreasonable in children suffering from Scheuermann's disease. This owes to the fact that vertebral bodies grow worse in the anterior than in the posterior part, even after surgery. (cit. by: Sorensen, 1964 [3]). It is pretty obvious that none of the listed surgeons used any metal implants due to their unavailability. Nevertheless, the implementation of the Harrington tools into wide practice [5], as expected, radically changed the situation. The heavy threaded constricted rods, which allow the use of multiple anchor points (mainly transverse processes) and can be bent in compliance with the normal sagittal contour of the spine, provided a reasonably effective technique for correcting kyphoses and preserving the achieved result. The subsequent history of surgical correction of Sheuermann's kyphosis represents the development of vertebral instrumentation with one exception. We have not been able to find articles (as well as links to them) devoted to the use of Luque endocorrectors in this pathology (II generation). As early as the end of the 70s of the twentieth century, two main options were defined: one-stage (posterior correction and spinal fusion) and two-stage (discectomy, interbody fusion, posterior correction and spinal fusion) interventions. The findings of both surgical strategies were first published by Brad-

ford et al. [6, 7]. The next 40 years were a period of ongoing discussion concerning the advantages of one of the methods. Moreover, the supporters of one-stage intervention are tending to prevail. Meanwhile, there are surgeons who prefer two-stage intervention (the most recent example is McDonnell et al. [8]). We have not been able to find articles devoted to the multifactorial comparison of two surgical strategies in the treatment of severe forms of Sheuermann's disease.

Objective: To perform multivariate comparison of two surgical strategies in the treatment of patients with severe Scheuermann's disease.

Material and Methods

The search of sources (in Scopus and Web of Science databases) revealed 56 publications [6–61] containing the required information. We have chosen publications of the level of evidence SIGN-3 and CEBM-4 (series of cases and studies of higher levels of evidence). There are indications that a very small number of articles remain outside of this list. The articles selected were divided into two unequal groups. The first (40 sources) included papers devoted to the use of one method – posterior correction or two-stage intervention (anterior release and posterior correction). The second one consisted of articles (16 sources), the authors of which had experience in using both surgical strategies and aimed to compare the results of treatment of two groups of patients. All the articles were published from 1975 to 2020 (Table 1). The average age of patients exceeded 20 years in only 15 publications. Only two articles defined patients older on average than 30 years. The gender distribution of patients is given in 41 articles; the total number of patients in them is 1183; 414 (35 %) of them are women, and 769 (65 %) are men. The average postoperative follow-up period of less than two years (but not less than a year) is given in only four articles; in the rest ones they are much longer, reaching even 18 years. In this review, we will deal only with the average data provided in individual articles, and, given the considerable number of the latter, believe this approach is reasonable and acceptable. The literature data were analyzed in four directions: the results of one- and two-stage interventions are compared in terms of the magnitude of achieved correction and its preservation, the complication rate, the surgery duration and the volume of intraoperative blood loss, and the quality of life of patients in the postoperative period.

The descriptive statistics of the measures of the angles, given in the articles as the median and the inter quartile range, were transformed to a single form by the inverse variance method: mean ± standard deviation. The overall correction in the groups was estimated for the mean differences before the surgery and immediately after it. As for the loss of correction in groups in the long-term period – for the differences of averages in the long-term period and immediately after the surgery.

The common group as well as subgroups of one-stage and two-stage interventions were examined for heterogeneity with the calculation of heterogeneity statistics Q, I2 and the achieved significance level p by the χ-squared technique. We also evaluated the square of the mean deviation of the corrections τ^2. According to the correction value, all groups are heterogeneous: general ($p < 0.001$), one-stage interventions ($p < 0.001$), two-stage interventions ($p < 0.001$). As for the loss of correction, the group of one-stage interventions is heterogeneous ($p = 0.005$); no heterogeneity was revealed in the general group and the group of two-stage interventions ($p = 0.111$ and $p = 0.995$, respectively). In consequence of the revealed heterogeneity of the groups, models with random effects (RE model) were applied for comparison and description. The estimation findings and a visual comparison of the correction as well as its loss in the postoperative period are given in the forest plots.

The calculations were carried out in the RStudio software (version 1.4.1106) in the R language (version 4.0.5) using the metaphor package.

Results

Correction of kyphotic deformity. Totally 56 publications contain data presenting the correction obtained during the intervention and its preservation in the long-term postoperative period. In total, the authors of the articles operated 1886 patients. 1046 of them underwent one-stage intervention, 840 – two-stage intervention. The one-stage intervention gave the opportunity to reduce the kyphotic deformity from 77.9 to 44.3°, and at the end of the observation period it was 47.3°. It means that the correction loss was 4.0°. The two-stage intervention resulted in correction of kyphosis from 78.2 to 44.1°, correction loss – 3.8°. The findings are almost identical, which is affirmed by the statistical study data. There was no statistically significant difference in the correction value (Fig. 1) and correction loss (Fig. 2) between one-stage and two-stage interventions ($p = 0.789$ and $p = 0.437$, respectively).

The same is true for the change in the boundary of lumbar lordosis (according to 31 articles): after a one-stage intervention, it declined from 69.0 to 48.8 °, and then increased to 50.9°. After two-stage intervention, the data are almost identical: 69.5°, 50.4°, 55.0°, respectively. In almost all cases, the indicators of lumbar lordosis remained within normal limits.

Complications. The literature data analysis for complications developing during and after the operative correction of juvenile kyphosis includes consideration of various types of publications: articles focused on the treatment findings of homogeneous groups of patients, single observations and, finally, reviews of rich source of data. We have at hand 34 publications presenting the findings of the surgical correction of Sheuermann's kyphoses and the complications recorded by the authors. The size of clinical groups ranges from 8 to 131 patients. Their total number is 1,313. A one-stage posterior intervention was carried out 672 times, a two-stage posteroanterior intervention – 641. We consider it essential to group the complications as follows: inflammatory, neurological, implant-assosiated, and others

Table 1
Dynamics of kyphotic deformity and lumbar lordosis after surgical correction of Sheuermann's (according to the literature data)

Authors	Year	Number of patients, n (w/m)	Age, years	Instrumentation	Follow-up period, months	One stage			Two stages			One stage			Two stages		
						Kyphosis before surgery, deg.	Kyphosis immediately after surgery, deg.	Kyphosis at the end of the follow-up period, deg.	Kyphosis before surgery, deg.	Kyphosis mmediately after surger, deg.	Kyphosis at the end of the follow-up period, deg.	Lordosis before surgery. deg.	Lordosis after surgery, deg.	Lordosis at the end of the follow-up period, deg.	Lordosis before surgery, deg.	Lordosis after surgery, deg.	Lordosis at the end of the follow-up period, deg.
Bradford et al. [6]	1975	22 (15/7)	18.0	Harri contractors	35.1	72.7	31.1	47.1	–	–	–	–	–	–	–	–	–
Griss et al. [9]	1978	20	–	Harri contractors	40.0	52.0	24.0	36.0	–	–	–	–	–	–	–	–	–
Taylor et al. [10]	1979	27 (12/15)	16.7	Harri contractors	24.0	72.0	40.4	46.1	–	–	–	84.0	73.0	–	–	–	–
Bradford et al. [7]	1980	24 (11/13)	19.5	Harri contractors	36.9	–	–	–	77.0	41.0	47.0	–	–	–	–	–	–
Herndon et al. [11]	1981	13 (4/9)	19.0	Harri contractors	29.0	–	–	–	78.0	40.0	47.8	–	–	–	–	–	–
McPhee et al. [12]	1983	22	До 20.0	Harri contractors	12.0	60.0	32.0	46.0	71.0	35.0	38.0	–	–	–	–	–	–
Heine et al. [13]	1984	11	22.6	Harri contractors	36.0	–	–	–	75.7	38.6	41.0	–	–	–	–	–	–
Speck, Chopin [14]	1986	61 (16/45)	17.5	Harri contractors	12.0	77.0	–	41.0	–	–	–	75.0	–	55.0	–	–	–
Nerubay et al. [15]	1986	14 (4/10)	14.0	Harri contractors	42.0	–	–	–	76.0	49.0	54.0	–	–	–	56.0	37.0	–
Lowe [16]	1987	24 (12/12)	21.5	L-rods	32.4	–	–	–	84.6	44.2	49.9	–	–	–	–	–	–
Otsuka et al. [17]	1990	10 (5/5)	18.4	Harri contractors	26.6	71.5	31.5	39.3	–	–	–	–	–	–	–	–	–
Reinhardt, Bassett [18]	1990	14 (5/9)	17.0	Harri contractors	32.0	68.0	26.6	32.9	75.0	33.3	42.8	–	–	–	–	–	–
Sturm et al. [19]	1993	30 (10/20)	19.0	Harri contractors	71.8	71.5	32.7	37.7	–	–	–	–	–	–	–	–	–
Lowe, Kasten [20]	1994	32 (15/17)	25.0	CDI	42.0	–	–	–	85.0	41.0	45.0	–	–	–	73.0	56.0	56.0
Ferreira-Alves et al. [21]	1995	38 (13/25)	16.3	Portugal equipment	60.0	67.7	39.3	43.2	–	–	–	–	–	–	–	–	–
De Jonge et al. [22]	2001	8 (3/5)	19.0	CDI	60.0	85.9	43.5	48.1	–	–	–	67.0	–	48.0	–	–	–
Papagelopulos et al. [23]	2001	21 (7/14)	22.6	Harri contractors	60.0	68.5	34.3	40.0	86.3	42.0	46.4	–	–	–	–	–	–
Poolman et al. [24]	2002	22 (14/8)	23.0	CDI, Miami-Moss	75.0	–	–	–	70.0	39.0	55.0	–	–	–	68.0	49.0	57.0
Hosman et al. [25]	2002	33 (10/23)	24.0–26.0	SI	50.0–55.0	76.6	52.4	55.8	80.8	51.1	52.6	–	–	–	–	–	–
Yang et al. [26]	2004	16	–	CD Horizon	–	–	–	–	78.8	40.5	41.7	–	–	–	–	–	–
Atici et al. [27]	2004	10 (2/8)	18.0	SI	60.0	71.0	41.0	50.0	–	–	–	–	–	–	–	–	–
Lim et al. [28]	2004	23 (11/12)	19.0	SI	38.0	–	–	–	83.0	46.0	51.0	–	–	–	–	–	–
Herrera-Soto et al. [29]	2005	19 (4/15)	17.4	SI	31.0	–	–	–	84.8	43.7	45.3	–	–	–	–	–	–
Johnston et al. [30]	2005	27 (5/22)	15.0–16.0	TSRH	30.0	80.5	38.8	37.9	79.0	41.6	42.6	74.8	53.7	54.0	75.8	55.4	57.8
Arun et al. [31]	2006	15	20.0–21.0	3-Lok SS, Corin SS	66.0–70.0	–	–	–	86.0	42.0	42.0	–	–	–	66.0	45.0	42.0
Lee et al. [32]	2006	39 (17/22)	17.0–18.0	TPF, SPO	31.0–67.0	84.4	38.2	40.4	89.0	51.9	54.4	–	–	–	–	–	–
Jansen et al. [33]	2006	30 (13/17)	28.0	Harri, CDI	12.0	–	–	–	80.0	–	47.0	–	–	–	72.0	–	59.0
Lonner et al. [34]	2007	78 (25/53)	16.0–17.0	Hooks, hybrids, TPF	29.0–39.0	79.7	50.0	52.0	70.2	37.9	41.8	67.4	49.3	54.7	62.6	43.3	48.4

Authors	Year	Number of patients, n (w/m)	Age, years	Instrumentation	Follow-up period, months	One stage			Two stages			One stage			Two stages		
						Kyphosis before surgery, deg.	Kyphosis immediately after surgery, deg.	Kyphosis at the end of the follow-up period, deg.	Kyphosis before surgery, deg.	Kyphosis immediately after surger, deg.	Kyphosis at the end of the follow-up period, deg.	Lordosis before surgery. deg.	Lordosis after surgery, deg.	Lordosis at the end of the follow-up period, deg.	Lordosis before surgery, deg.	Lordosis after surgery, deg.	Lordosis at the end of the follow-up period, deg.
Geck et al. [35]	2007	17 (3/14)	16.4	TPF, Ponte	24.0	75.0	38.0	38.0	–	–	–	65.0	45.0	49.0	–	–	–
Koptan et al. [36]	2009	33 (21/12)	15.0–16.0	TPF, Ponte	–	85.5	45.1	47.1	79.8	38.8	41.2	–	–	–	–	–	–
Denis et al. [37]	2009	67	37.0	Harri, Luque, CDI.	73.0	–	–	–	78.0	45.0	49.0	–	–	–	77.0	58.0	60.0
Cho et al. [38]	2009	31 (11/20)	18.0	SI	–	–	–	–	86.6	50.1	53.0	–	–	–	–	–	–
Tsutsui et al. [39]	2011	22 (9/13)	15.0	SI, Ponte	–	82.7	47.9	–	84.9	48.6	–	63.5	39.7	–	70.1	46.7	–
Bilgic et al. [40]	2011	12 (9/3)	17.0	SI	38.0	74.5	38.7	42.3	–	–	–	–	–	–	–	–	–
Tempori et al. [41]	2011	28 (6/22)	19.0–27.0	SI, SPO	23.0–37.0	72.8	44.3	–	77.6	35.8	–	–	–	–	–	–	–
Nakamura et al. [42]	2011	62	18.0–20.0	SI, SPO	24.0	88.8	52.4	53.7	91.0	54.3	57.0	–	–	–	–	–	–
Koller et al. [43]	2013	111 (37/74)	23.6	XIA, USIS	23.5	–	–	–	66.3	42.5	43.7	–	–	–	66.3	51.0	56.2
Behrbalk et al. [44]	2014	21 (3/18)	19.0–22.0	SI, Ponte	26.0–32.0	72.0–78.0	42.0–44.0	43.0–44.0	–	–	–	71.0–73.0	–	50.0–56.0	–	–	–
Ashraf et al. [45]	2014	18 (5/13)	16.7	TPF	32.0	76.0	56.0	–	–	–	–	77.0	–	57.0	–	–	–
Mikhaylovskiy et al. [46]	2015	36 (4/32)	19.0	SI, Ponte	42.0	–	–	–	79.3	40.6	45.5	–	–	–	–	–	–
Nasto et al. [47]	2015	37 (6/31)	18.8	SI, Ponte	49.0	81.3	47.4	48.6	–	–	–	71.0	46.8	46.5	–	–	–
Faldini et al. [48]	2015	20	19.6	SI, Ponte	25.0	78.6	–	45.8	–	–	–	74.5	–	53.5	–	–	–
Koller et al. [49]	2015	92	20.0–23.0	SI	–	78.7	48.2	47.1	75.9	42.3	43.4	–	–	–	–	–	–
Etemadifar et al. [50]	2015	30	20.0	SI	57.6	81.9	40.1	43.2	83.6	41.4	43.0	70.3	49.6	50.8	74.6	56.9	57.5
Padilla et al. [51]	2015	5 (2/3)	16.6	SI, Ponte	6.0	76.1	42.2	–	–	–	–	–	–	–	–	–	–
Graat et al. [52]	2016	33	–	SI	216.0	79.0	–	65.4	85.0	–	62.1	–	–	–	–	–	–
Ghasemi et al. [53]	2016	40 (4/36)	25.2	TPF	24.0–36.0	81.1	47.0	48.7	–	–	–	70.7	46.4	52.3	–	–	–
Cobden et al. [54]	2017	20 (2/18)	19.0	SI, Ponte	41.0	79.8	44.6	44.9	–	–	–	72.8	44.6	44.9	–	–	–
Kim et al. [55]	2017	44	17.0–20.0	TPF	37.0	80.0–82.0	–	45.0–49.0	–	–	–	70.0–75.0	–	55.0–61.0	–	–	–
Dikici et al. [56]	2017	39 (19/20)	18.6	SI	92.0	73.3	–	39.0	–	–	–	–	–	–	–	–	–
Riouallon et al. [57]	2018	131	23.0	CDI	50.0	78.0	59.0	61.0	76.0	53.0	57.0	74.0	57.0	58.0	75.0	58.0	58.0
Mirzashahi et al. [58]	2018	18 (6/12)	22.4	SI, SPO	9.0	87.2	47.4	–	–	–	–	–	–	–	–	–	–
Lonner et al. [59]	2018	96 (29/67)	16.0	SI	24.0	74.7	–	46.1	–	–	–	63.3	–	53.3	–	–	–
Hwang et al. [60]	2019	15	33.0	SI	–	92.8	48.5	49.5	–	–	–	–	–	–	–	–	–
Zhu et al. [61]	2019	45 (3/42)	15.8	SI	24.0	78.8	37.9	39.0	–	–	–	55.1	46.2	46.9	–	–	–
McDonnell et al. [8]	2020	62	18.0–19.0	–	33.0	83.9	41.4	42.5	–	–	76.5	51.2	39.9	39.4			

SI – unspecified segmental instrumentation, TPF – transpedicular fixation.

(Table 2). The challenges associated with the development of junctional, proximal and distal kyphoses will be discussed in the second part of the review.

We have noted a total of 62 cases of suppuration (superficial and deep), which is 4.7%. If there were one-stage interventions, complications were found 25 (3.7 %) times; in case of two–stage interventions – 37 (5.8 %). Reoperation was required only 2 times.

The neurological complications developed in 14 (1.07 %) cases: 5 (0.38 %) – after one-stage interventions, 9 (0.68 %) – after two–stage ones. The complications should be regarded as severe in four cases: 2 of them – after a one–stage intervention, 3 – after a two-stage one (1 – without recovery of the lost functions).

The implant-associated complications were reported in 132 (10.05 %) cases. This includes fractures and displacements of the endocorrector, its protrusion under the skin, bursitis, damage to bone points of support, false joints of the block. After a one-stage intervention, such complications were found 77 (5.8 %) times. It required 23 reorepations, after a two-stage intervention – 56 (4.2 %) times and four reoperations.

The other complications (some authors report only their number) were found 158 (12.0 %) times. There were 77 (13 reoperations) after one-stage intervention, 81 (47 reoperations) after two-stage intervention. We have established two fatal outcomes: due to coagulopathy (posterior intervention) and *a. mesenterica sup* syndrome (two-stage intervention).

Roddy and Diab [62] analyzed the frequency and risk factors of readmissions in patients under 21 suffering from spinal deformities. Totally, the study included 13,287 people from the state database of indoor patients in the USA: idiopathic scoliosis – 8175 (62.0 %), neuromuscular scoliosis – 1180 (14.0 %), congenital deformities – 721 (5.0 %), Sheuermann's kyphosis – 398 (3.0 %). The readmissions during the first 30 and 90 days were 4.7 % and 6.1 %, respectively. The most common causes of readmissions are the following: infectious complications (38.0 %), wound dehiscence (19.0 %), pulmonary complications (12.0 %). The most considerable predictors of readmission are: male gender, neuromuscular and congenital deformities, Sheuermann's kyphosis. 23 out of 398 patients with juvenile kyphosis were readmitted to hospital in the first 30 days after discharge. It was 4.0 % in relation to the whole group of re-hospitalized individuals and 5.8% of the number of those operated for Sheuermann's disease.

Coe et al. [63] analyzed SRS data from 2001 to 2004 for complications manifested during surgical correction of juvenile kyphoses. Totally there were 683 such patients, the average age was 21 (5–75). It is difficult to imagine a surgery for Sheuermann's disease in a 5-year-old child. Nevertheless, the authors do not provide any details. Surgeries: posterior – 338 (48.0 %), anterior – 73 (11.0 %), posteroanterior – 272 (40.0 %). We have identified a total of 99 (14.0 %) complications; the most frequent is suppuration (26); implant–associated complications (17), early and late neurological complications (17), including 4 cases of spinal cord injury. The fatal outcome was revealed 4 times. The complications are more common in patients older than 19 (22.0 %) than in younger individuals (12.0 %). Generally, the frequency of complications after posterior spinal fusion (14.8 %) differs only slightly from that after anteroposterior intervention carried out in one session (16.9 %).

Hamilton et al. [64] provided the results of the analysis of the SRS database on the evaluation of the frequency of neurological postoperative complications in patients with spinal deformities of various etiologies. 108,419 patients were examined in total. The cases of injuries of spinal roots, cauda equina and spinal cord were determined separately. This group included 227 patients operated for Sheuermann's disease. It should be noted that in three cases the development of postoperative neurological deficit was observed: an injury case of spinal root, 2 cases of spinal cord injury. Generally, the frequency of neurological complications was 1.32 %.

Tribus [65] described a case of a severe complication in surgery of Sheuermann's disease. A 16-year-old patient with 80° kyphosis was operated using a two-stage intervention. While implanting posterior instrumentation, disorders of somatosensory evoked potentials were observed. During the wake-up test, the absence of movements in the lower extremities was noted. The instrumentation was completely removed. A rapid recovery of motor functions was observed. After 3 days, an MRI scan showed pronounced spinal canal stenosis at the level of T8–T10 segments. A week later, he was operated on again (T7–T11 laminectomy, posterior correction). There were no signs of neurological disorders during the 2-year postoperative follow-up.

Daniels et al. [66] described a rare complication that developed after surgery to correct Sheuermann's kyphosis with a Cobb angle of 106°. After a two-stage intervention carried out during one anesthesia, the patient was diagnosed with respiratory distress syndrome on the 5th day. He was reintubated. The X-ray showed free air in the abdominal cavity. Exploratory laparotomy: perforation of the antral part of the stomach with necrosis to the full depth, generalized peritonitis. On the 7th day, repeated laparotomy was done. The ischemia of the stomach, gallbladder, and pancreas was identified. The patient underwent gastrectomy, cholecystectomy, drainage of the common duct, splenectomy, eunostomy, peritoneal lavage. Long-term treatment, recovery. The main cause of the accident is the celiac artery occlusion. It developed as a result of kyphosis correction. The syndrome of celiac artery occlusion is the result of compression by the median arcuate ligament. It can be acute or chronic.

Llado et al. [67] described a case of thoracic disc herniation (T10-T11) in a 17-year-old patient at the time of surgical correction of juvenile kyphosis. The wake-up test showed a disorder of movements in the right leg. The patient was transported out of the operating room and was observed for some time. Due to the lack of positive dynamics, he was returned to the operating room. The tools were removed. After a few days, the movements recovered significantly. The

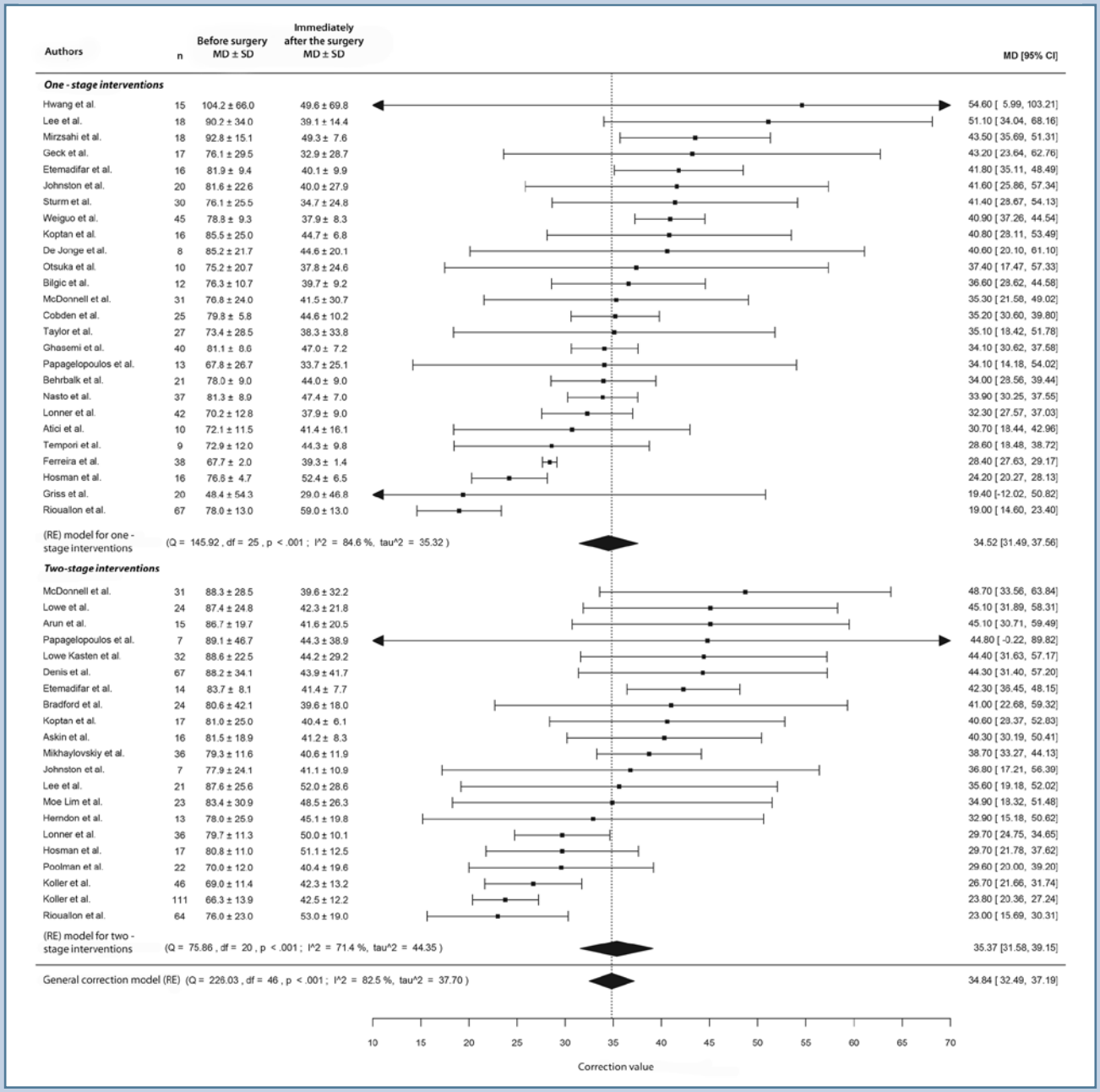

Fig. 1
A forest plot comparing postoperative correction with one-stage and two-stage interventions

MRI showed signs of a spinal disc herniation. The hernia was removed from the bone transversectomy access. The instrumentation integrity was restored. After 4 months, there was a complete restoration of the volume of movements; a decrease in sensitivity in the right lower extremity in the lower leg and below remained. The authors believe that the combination of pre-existing disc pathology with the use of a considerable corrective effort may exceed the strength of the fibrous ring and result in the formation of a typical hernia with neurological deficiency.

Lonneur et al. [68] compared the frequency of postoperative complications in groups of patients with Sheuermann's disease (97 patients) and idiopathic adolescent scoliosis (800 patients). Most of them had a postoperative follow-up period of more than two years. Among patients with Sheuermann's disease,

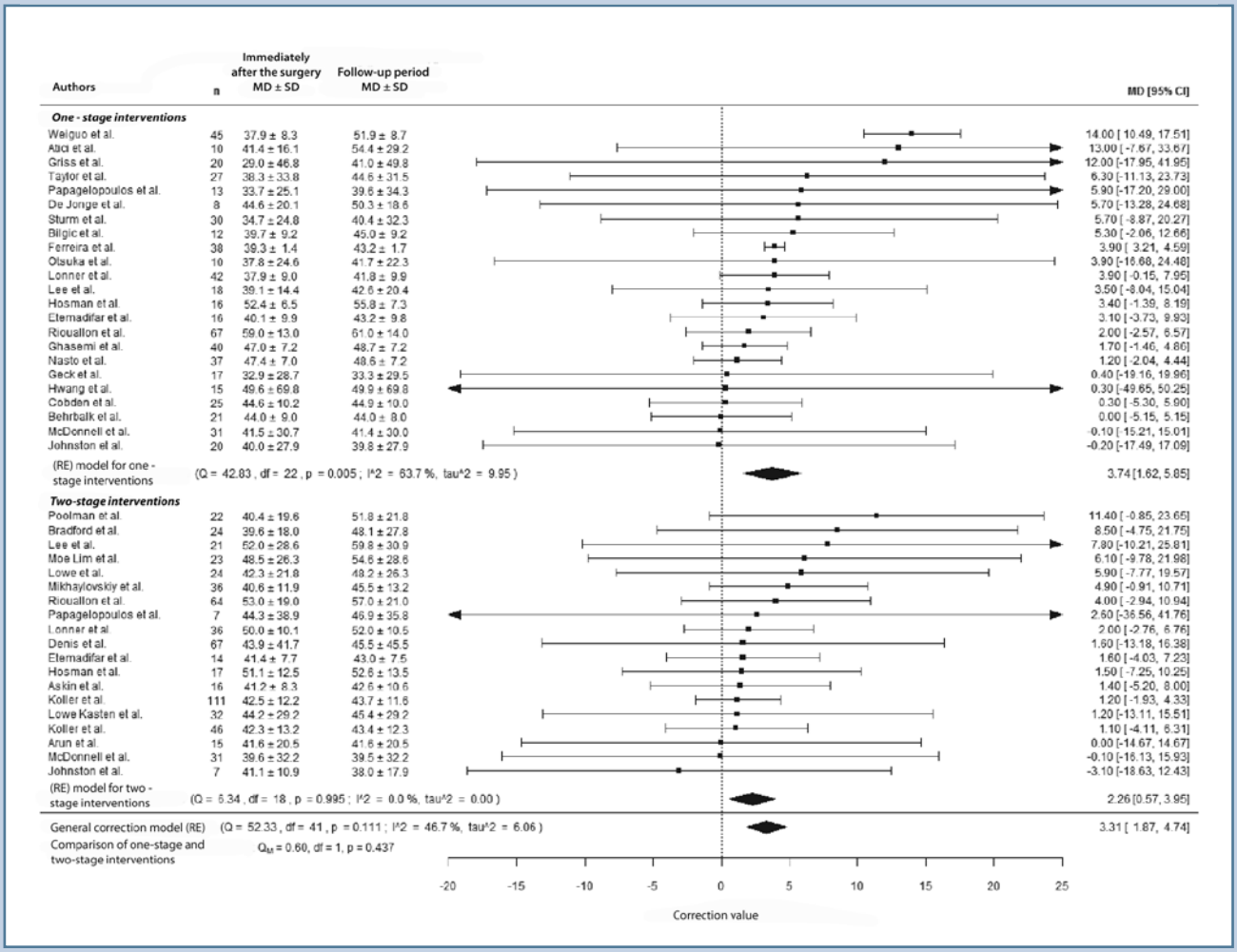

Fig. 2
A forest plot comparing correction losses with one-stage and two-stage interventions

there were 16 (16.3 %) severe complications: suppuration (10), instrumentation-associated (3), neurological complications (2), and resistant pain syndrome (1). The reoperations were required in 15 cases. According to all these indicators, the group with Sheuermann's disease demonstrates a greater number of complications than the group with idiopathic scoliosis. Generally, the risk of complications in patients with Sheuermann's disease surpasses that of idiopathic scoliosis by 3.9 times. The extent of the spinal fusion area is not a risk factor in terms of the development of severe complications.

The surgery duration and blood loss. Not all the authors found it essential to report on the time it took to perform one or another surgical intervention, and on the volume of intraoperative blood loss. There were 18 articles on this issue. The posterior correction and spinal fusion were carried out in 357 patients, two-stage intervention – in 152 (Table 3). The average blood loss during a one-stage posterior intervention was 1,092 ml (303 patients, 14 articles); the surgery duration was 257 minutes (253 patients, 12 articles). A two-stage posteroanterior intervention was followed by an average blood loss of 1533 ml (188 patients, 9 articles) and lasted 463 minutes (172 patients, 8 articles).

Health-related quality of Life (HRQOL). As far as we can tell from the literature sources, the first attempt to evaluate the life quality of patients with Sheuermann's disease after surgery was performed by Lowe and Kasten [20]. They did not identify the applied questionnaire, but stated a pronounced analgesic effect of the intervention. If before the surgery 27 out of 28 patients complained of severe pain in the spine, then in the postoperative period 18 noted only mild inconvenience. Meanwhile, 96 % of patients were satisfied with their appearance after surgery. Hosman et al. [25] used the Oswestry questionnaire and revealed a considerable improvement in patients

Table 2
Complications of Sheuermann's kyphosis surgical correction (according to the literature data)

Authors	Year	Number of patients, n		Suppuration (reoperations), n		Neurological complications (reoperations), n		IRC (reoperations), n		Other complications (reoperations), n	
		One stage	Two stages	One stage	Two stages	One stage	Two stages	One stage	Two stages	One stage	Two stages
Bradford et al. [6]	1975	22	–	3	–	–	–	5	–	19	–
Griss et al. [9]	1978	20	–	3	–		–	–	–		–
Taylor et al. [10]	1979	27	–	–	–	1 transient paresthesia	–	3	–	8	–
Bradford et al. [7]	1980	–	24	–	1	–	–	1	–	8	–
Herndon et al. [11]	1981	–	13	0	–	1 transient lack of foot extension	–	–	–	3 Death (coagulopathy) – 1	–
Heine et al. [13]	1984	–	11	–	–	–	–	–	–	6	–
Speck, Chopin [14]	1986	61		4	–	1 Brown-Sequard syndrome	–	8	–	–	–
Nerubay, Katznelsn [15]	1986	–	14	–	–	–	1 light paraparesis with significant recovery after removal of instrumentation	–	2 (1)	–	–
Lowe [16]	1987	–	24	–	–	–	The area of painful hyperesthesia	–	5	–	–
Otsuka et al. [17]	1990	10	–	–	–	–	–	2	–	–	–
Sturm et al. [19]	1993	30	–	3	–	–	–	8	–	–	(3)
Ferreira-Alves et al. [21]	1995	38	–	–	–	–	–	1	–	–	3
De Jonge et al. [22]	2001	8	–	1	–	–	–	1	–	–	–
Papagelopulos et al. [23]	2001	21	–	–	–	–	–	5	–	–	Death (*a. mesenterica sup.* syndrome) – 1 (2)
Poolman et al. [24]	2002	22	–	–	–	–	–	9 (9)	–	–	1
Hosman et al. [25]	2002	16	17	1	2	–	–	2 (2)	3 (3)	–	–
Atici et al. [27]	2004	10		2	–	0	–	–	–	–	–
Lim et al. [28]	2004	–	23	–	–	–	1 numbness and weakness in the hands (positioning)	–	3	–	10
Herrera-Soto et al. [29]	2005	–	19	–	–	–	2 light cases with full recovery	–	3	–	6 (1)
Arun et al. [31]	2006	–	15	–	3	–	–	–	1	–	(2)
Lee et al. [32]	2006	18	21	0	3	0	2 (1 – without recovery)	0	4	–	(2)
Lonner et al. [34]	2007	36	42	0	2	0	1	0	1	0	5
Geck et al.[35]	2007	17		1 (1)	–	–	–	–	1	–	2
Koptan et al. [36]	2007	16	17	–	3	Root pains (reoperation)	–	–		–	–
Cho et al. [38]	2009	–	31	–	4	–	1	–	5	–	–
Denis et al. [37]	2009	15	52	–		–	–	5		5 (1)	–
Tempori et al. [41]	2011	9	19	–	2 (1)	–	–	–	3	3 (1)	3
Koller et al. [43]	2013	–	–	–	6	–	0	2	12	–	(21)
Behrbalk et al. [44]	2014	21		1		Spastic paraplegia after reoperation	–	–	4	–	–
Etemadifar et al. [50]	2015	14	16	–	1	–	–	–	–	–	2
Graat et al. [52]	2016	17	16	–	–	–	–	20 (7)	–	–	–
Riouallon et al. [57]	2018	67	64	3	4	0	0	3	6	4 (13)	12 (16)
Hwang et al. [60]	2019	15	–	–	–	–	–	–	–	4	–
McDonnell et al. [8]	2020	31	31	3	6	0	0	1	4	–	1

operated with one- and two-stage interventions. It should be noted that there were no differences between the groups. Poolman et al. [24], who performed a two-stage strategy in their patients, used the SRS-24 questionnaire and received responses from 22 individuals. An abatement after surgery was found in 45% of them; the pain syndrome did not change – in 36 %, it became stronger – in 18 %. An improvement in appearance was observed by 45 %; absence of changes – by 41 % and deterioration – by 14 % of patients. With the application of ODI, Yang et al. [26], stated a change in this indicator from 6.4 to 37.3. Lee et al. [32] proposed the SRS-30 questionnaire to patients and observed an improvement in the overall indicator in both subgroups of their patients: with a one-stage intervention from 90 to 112, with a two-stage intervention from 115 to 146. The authors state that, if patients with severe complications are not considered, the differences between the groups are small. The same data was published by Koptan et al. [36]: with one-stage intervention, the overall indicator increased from 90 to 146, with two-stage intervention - from 90 to 132. Temponi et al. [41] evaluated the pain syndrome using the VAS tool. With one–stage intervention, the indicator was decreased from 6.6 to 0.6 (satisfaction with the result – 94.7 %), with two-stage intervention – from 5.6 to 0.5 (100.0 %). Koller et al. [43] applied ODI, SRS-24, ArM (Approach related Morbidity questionnaire), SF-36 to evaluate the life quality of patients operated using a two-stage intervention. There was a strong correlation between SRS-24 and ODI, SRS-24 and ArM, ODI and ArM data, as well as a distinct negative correlation between the extension of the spinal fusion area and self-evaluation of appearance according to SRS-24 data. In patients who underwent unplanned interventions, SRS-24, ODI, ArM indicators are decreased. Generally, 85.7 % of patients agree to the same surgery under the same conditions; 14.0 % disagree.

In the course of examination of patients operated on using one- and two-stage intervention, Etemadifar et al. [50] revealed a considerable improvement without any significant differences. The last was found using using ODI and SRS-30. A study by Grant et al. [52] is of special interest, since the duration of postoperative follow-up is on average 18 years. The VAS score was 2.5 points at the time of the last survey. Meanwhile, 68 % of patients reported pain in the spine during the last month, 43 % – in the neck, 21 % – persistent back pain, and 54 % – noted incapacity for work due to back pain over the past five years. The average ODI score is 12 at the time of the last survey. It was 21 before the surgery. Then, in the first 8 years after the surgery, it improved to 7, and later it grew to 19. The authors state that two-stage interventions provide slightly better results than one-stage ones. The EQ-5d indicators characterizing mobility, activity and pain were lower than in the general population. EQ VAS scores were better after two-stage interventions than after one-stage ones. The same is true for the EQ TTO and SF-36. 72 % of 29 patients were satisfied with the surgical treatment and would be ready to undergo it again under the same conditions. 62 % of patients reported that the results met their expectations. The authors state a discrepancy between a considerable loss of kyphosis correction and frequent pain syndrome, on the one hand, and a high level of patient satisfaction, on the other.

Cobden et al. [54] operated on patients through posterior approach. The individuals filled out the SRS-22 questionnaire. The obtained data showed that the patients rated their appearance the best, their mental state the worst, while almost all the patients would be ready for this surgery under the certain conditions. The only review dedicated to the quality of life of 82 patients with Sheuermann's disease was published by Toombs et al. [69]. The SRS-24 index increased across all domains with the greatest effect on self-evaluation of appearance. VAS indicators improved from 3.69 to 1.51 points. These data correlate with the dynamics of pain syndrome, mental health and the total indicator.

Conclusions

As far as can be judged, the vast literature describing Sheuermann's disease and its treatment does not have the findings of a multifactorial comparison of the outcomes of one- and two-stage interventions. We have done such an attempt, focusing on the following features: kyphotic deformity correction and its preservation in the postoperative period, postoperative complications, the volume of intraoperative blood loss and the duration of the operation as well as life quality of patients in the long-term postoperative period. It is difficult to analyze the differences in the length of inpatient stay in hospital and the cost of treatment due to the small amount of literature data. The challenge of junctional kyphoses and the extent of the spinal fusion area due to its special concern will be discussed in the second part of this review.

Both comparison groups had almost identical parameters of kyphotic deformity in the pre- and postoperative period. It means that anterior release (discectomy, interbody spinal fusion) does not give advantages in comparison with a one-stage posterior intervention. Nevertheless, some surgeons [8] believe that two-stage intervention has certain advantages. Regarding intra- and postoperative complications, two-stage intervention less frequently results in implant-associated complications. All the others: suppurative, neurological and etc. are less likely to follow one-stage interventions. The blood loss and surgery duration are expected and considerably longer when using two-stage interventions.

The research on the life quality of patients in the postoperative period, conducted using various questionnaires, shows that the type of intervention is not of great importance. The article by Graat et al. [52] is of particular interest. These authors examined patients with an average postoperative follow-up period of 18 years. The authors have observed a considerable loss of kyphosis correction, frequent pronounced pain syndrome and at the same time a high degree of satisfaction with the surgery outcomes.

Table 3

Blood loss and surgery duration during surgical correction of Sheuermann's kyphoses (according to the literature data)

Authors	Year	Number of patients, n		Blood loss, ml		Surgery duration, min	
		One stage	Two stages	One stage	Two stages	One stage	Two stages
Bradford et al. [6]	1975	22	–	1900 (250–4200)	–	234 (180–330)	–
Taylor et al. [10]	1979	27	–	1325 (600–3000)	–	–	–
Bradford et al. [7]	1980	24	–	1800	1100	–	–
Sturm et al. [19]	1993	30	–	1461 (350–3000)	–	–	–
Ferreira-Alves et al. [21]	1995	38	–	1000	–	180	–
Hosman et al. [25]	2002	16	17	1086 ± 584	2150	141.0 ± 27.1	166.0 ± 22.6
Lim et al. [28]	2004	23	–	1350 (400–1800)	1800 (600–3300)	–	–
Herrera-Soto et al. [29]	2005	19	–	–	1649 (400–3600)	–	680 (540–780)
Arun et al. [31]	2006	15	–	–	2233 (1100–5500)	–	300 (100–700)
Lee et al. [32]	2006	18	21	838 (400–2500)	1227 (800–3000)	378 (260–690)	662 (560–835)
Lonner et al. [34]	2007	42	36	1454 (325–5450)	1355 (500–3000)	342 (210–695)	575 (235–810)
Geck et al. [35]	2007	17	–	808 (350–1300)	–	270	–
Koptan et al. [36]	2007	16	17	620 (440–975)	910 (755–1295)	215 (185–325)	315 (245–505)
Nakamura et al. [42]	2011	35	27	1056	1515	410	623
Etemadifar et al. [50]	2015	14	16	760 (400–1200)	1380 (750–2800)	263 (185–310)	545 (425–655)
Padilla et al. [51]	2015	5	–	590 (300–1200)	–	218 (210–240)	–
Mirzashahi et al. [58]	2018	18	–	250	–	150 (140–200)	–
Hwang et al. [60]	2019	15	–	1403 (300–6500)	–	470 (210–950)	–
McDonnell et. al. [8]	2020	31	31	–	–	211 (160–300)	302 (220–480)

There is probably a need for new studies allowing the most objective evaluation of the findings of surgical correction of Sheuermann's kyphoses.

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