ENHANCED RECOVERY AFTER SURGERY IN PEDIATRIC SPINE SURGERY

Systematic review

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Objective. To conduct a systematic review of the literature on the use of enhanced recovery after surgery (ERAS) protocols in spinal surgery of children and adolescents to determine the existing evidence of the effectiveness of ERAS implementation in clinical practice.
Material and Methods. The authors conducted a systematic review of the literature on ERAS in spinal and spinal cord surgery in children and adolescents selected in the databases of medical literature and search resources of PUBMED/MEDLINE, Google Scholar, Cochrane Library and eLibrary according to the PRISMA guidelines and the PICOS inclusion and exclusion criteria.
Results. A total of 12 publications containing information on the treatment of 2,145 children, whose average age was 14.0 years (from 7.2 to 16.1), were analyzed. In the reviewed publications, the average number of key elements of the ERAS program was 9 (from 2 to 20), and a total of 23 elements used in spinal surgery in children and adolescents were identified. The most commonly used elements were preoperative education and counseling, prevention of infectious complications and intestinal obstruction, multimodal analgesia, refusal of routine use of drains, nasogastric probes and urinary catheters, standardized anesthesia protocol, early mobilization and enteral loading. The introduction of the ERAS protocol into clinical practice allowed to reduce the complication rate in comparison with the control group by 8.2 % (from 2 to 19 %), the volume of blood loss by 230 ml (from 75 to 427 ml), the operation time by 83 minutes (from 23 to 144 minutes), the duration of hospitalization by 1.5 days (from 0.5 to 3 days) and the total cost of treatment by 2258.5 dollars (from 860 to 5280 dollars). The ERAS program was implemented in pediatric clinics in the USA (75 %), France (8 %) and Canada (17 %).
Conclusion. The conducted systematic review of the literature allows us to conclude that the technology of enhanced recovery after surgery is a promising technology that improves surgical outcomes and is applicable in pediatric practice. There is a significant shortage of published studies evaluating the implementation of ERAS in pediatric surgical practice in general, and in spinal surgery in particular, which requires further prospective randomized studies to evaluate ERAS in spinal surgery in children and adolescents.
Key Words: enhanced recovery after surgery, ERAS, fast-track, spinal neurosurgery, spine surgery, children, vertebrology.
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The technology of Enhanced Recovery After Surgery (ERAS), previously known as Fast track surgery, Accelerated Recovery or Rapid Recovery Pathway, is a modern multimodal concept of perioperative management of patients grounded in evidence-based practices. The ERAS program (protocol) includes the following [1–4]:

– informing, education and active involvement of the patient in all treatment stages, as well as achieving a high compliance level;

– minimization of metabolic aftereffects and complications in response to surgical stress due to adequate pain control and active rehabilitation targeting the physical autonomy of the patient;

– planning and organization of discharge, as well as active postoperative follow-up.

The unification of evidence-based practices (elements of the ERAS program) into a single structure provides a capability to organize an overall system of medical care. It enables to achieve better functional outcomes, to increase satisfaction with the responses of treatment and the medical care quality, to reduce the hospitalization length and complications by 30–50 %. Additionally, such actions will minimize differences in the delivery of perioperative care in health care institutions, as well as reduce health expenditures [1, 2, 5–11].

It was Henrik Kehlet, a Danish professor, who developed and introduced the concept of ERAS in 1997. He laid and justified the principles of Fast Track in colorectal surgery [12]. In 2010, ERAS®Society was established (https://erassociety.org), which develops evidence-based ERAS protocols. They have already been actively implemented in many areas of surgery both in Europe and the USA. ERAS is a fairly recent paradigm for spine surgery. Therefore, in recent years there has been an increase in publications on this issue [7, 8, 13]. Studies have emphasized that the ERAS program is safe and effective for adults and children [2, 4–6, 14]. The first approved ERAS protocol for spine surgery in adults for lumbar interbody fusion was published in 2021 [2]. Nevertheless, the number of papers devoted to the ERAS program implementation in spine surgery in children is extreme-

ly limited. It requires need for further research in order to determine whether ERAS can be in demand and useful in pediatric spine surgery.

Objective: to conduct a systematic review of the literature on the use of enhanced recovery after surgery (ERAS) protocols in spine surgery of children and adolescents to determine the existing evidence of the effectiveness of ERAS implementation in clinical practice.

The study design is a systematic literature review. Level of evidence is 2a.

Material and Methods

The authors conducted a systematic review of the literature on ERAS in spine and spinal cord surgery in children and adolescents using main databases of medical literature and search resources of PUBMED/MEDLINE, Google Scholar, Cochrane Library and eLibrary (Table 1) according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [15].

At the first stage, the information retrieval (Fig. 1) was performed using the following keywords: “enhanced recovery after surgery”, “ERAS”, “spine/neurosurgery”, “children”, “technology of accelerated recovery after surgery”, “fast track”, “children”, “spine surgery/surgery of spine”. The last selection of publications was made on March 4, 2021. Only articles in Russian and English were considered. We gave consideration to the references in the selected papers. A total of 2418 articles for 1993–2021 were found on the first search stage. At the second stage, an analysis was performed by titles and abstracts of published works for compliance with the criteria for inclusion and exclusion of PICOS, as well as the exclusion of duplicate papers. At the third stage, the selected full-text articles were studied and analyzed. No papers on the topics we addressed here have been found in the Russian literature.

Results

Twelve publications were analyzed according to the inclusion and exclusion criteria (Table 2), considering the use of ERAS technology in spinal deformity surgery (n = 11) and in functional spinal neurosurgery (n = 1). Within literature search, there were no articles devoted to the use of ERAS in the surgery of infectious, tumor and degenerative lesions, as well as injury of the spine.

The findings included information on the treatment of 2,145 children, whose average age (Fig. 2) at the time of surgical treatment was 14.0 (from 7.2 to 16.1). The ERAS protocol has been applied in the treatment of children with adolescent idiopathic scoliosis [16–25], as well as with neuromuscular scoliosis [26] and infantile cerebral paresis [26, 27]. The chosen surgical approach was selective posterior rhizotomy [27] in one study, and in all the others – spinal deformity correction, spinal fusion and transpedicular fixation.

All the publications under consideration were non-randomized. They were published in the last 7 years (from 2014 to 2021). Most of the studies were retrospective, with a 3b level of strength of evidence (Fig. 3). The ERAS program was implemented in most cases in children’s hospitals in the USA [17–21, 23–27], as well as in France [22] and Canada [16, 19].

Key elements of ERAS. In the reviewed publications, the average number of key elements of the ERAS protocol was 9 (from 2 to 20). A total of 24 elements were identified (preoperative period – 6, intraoperative – 9, and postoperative – 9), which are used in spine surgery in children and adolescents (Fig. 4, Table 2). The most used elements (Table 3) became the following:

– preoperative period: preoperative education and counseling (58 %), prevention of infectious complications (25 %) and preventive multimodal analgesia – MMA (25 %);

– intraoperative period: refusal of routine use of drains, nasogastric tubes and urinary catheters (83 %), MMA (83 %) and standardized anesthesia protocol (50 %);

– postoperative period: immediate mobilization (83 %), postoperative MMA (83 %), early enteral nutrition and prevention of intestinal obstruction (67 %).

The effect of ERAS application on complications. The vast majority of researchers received a lower level of complications in the ERAS group compared to the control pre-ERAS group [17, 18, 20, 22–26] by 8.2 % – from 2 % [24] to 19 % [26], including a statistically significant decrease [18]. Pulmonary [26] and gastrointestinal complications were less common in the structure of complications for ERAS groups [22, 24]. Half of the authors received a comparable level of complications in the compared groups with regard to wound infection [16, 18, 19, 24, 25], as well as a smaller one in the ERAS group [22].

Some outcomes of ERAS application. Due to the introduction of the ERAS program into clinical practice, it was possible to achieve the following outcomes, as compared with the control group:

– reduction of blood loss by 230 ml: from 75 ml [18] to 427 ml [17], including statistically significant [17];

– reduction of the surgery duration by 83 min: from 23 min [25] to 144 min [19];

– providing a lower [19, 20, 22] or comparable pain level (the difference is less than 1 point according to VAS) [20, 23, 25];

– decrease in opioid consumption [21, 22], including statistically significant [27], as well as related side effects [20, 22];

– decrease in the hospitalization length by 1.5 days: from 0.5 [27] to 3 days [22] associated with a statistically insignificant increase in the ERAS group [25, 26] or a comparable readmission level [16, 20, 21];

– reduction of the total treatment cost by an average of $2,258.5: from $860 [27] to $5,280 [25];

– providing greater satisfaction and comfort [23], as well as comparable in quality and timing of social rehabilitation of children and their parents [19].

Discussion

Only 12 studies have been found on the implementation of the enhanced recovery after surgery protocol (ERAS) in spine surgery in children and adolescents. Furthermore, at the time of the literature search, we could not find

Table 1
PICOS – inclusion and exclusion criteria

PICOS elements	Inclusion criteria	Exclusion criteria
Patients	Children and adolescents under 18 after spine surgery	Adults over 18; injured patients without surgery
Intervention	Surgeries on the cervical, thoracic and lumbosacral spine departments; ERAS in the surgery of deformities, oncological, degenerative, infectious and traumatic injuries of the spine, as well as functional spinal neurosurgery	No less than two ERAS elements
Comparison	ERAS group and control group	
Outcome	Clinical (assessment of pain, complications, etc.) and economic (hospitalization length, costs, etc.); the use of ERAS in spine surgery in adults and children	
Study design	Randomized and non-randomized; prospective and retrospective	Clinical cases; historical research
Publications	Publications in English and Russian; full-text	Unpublished research; protocols; abstracts

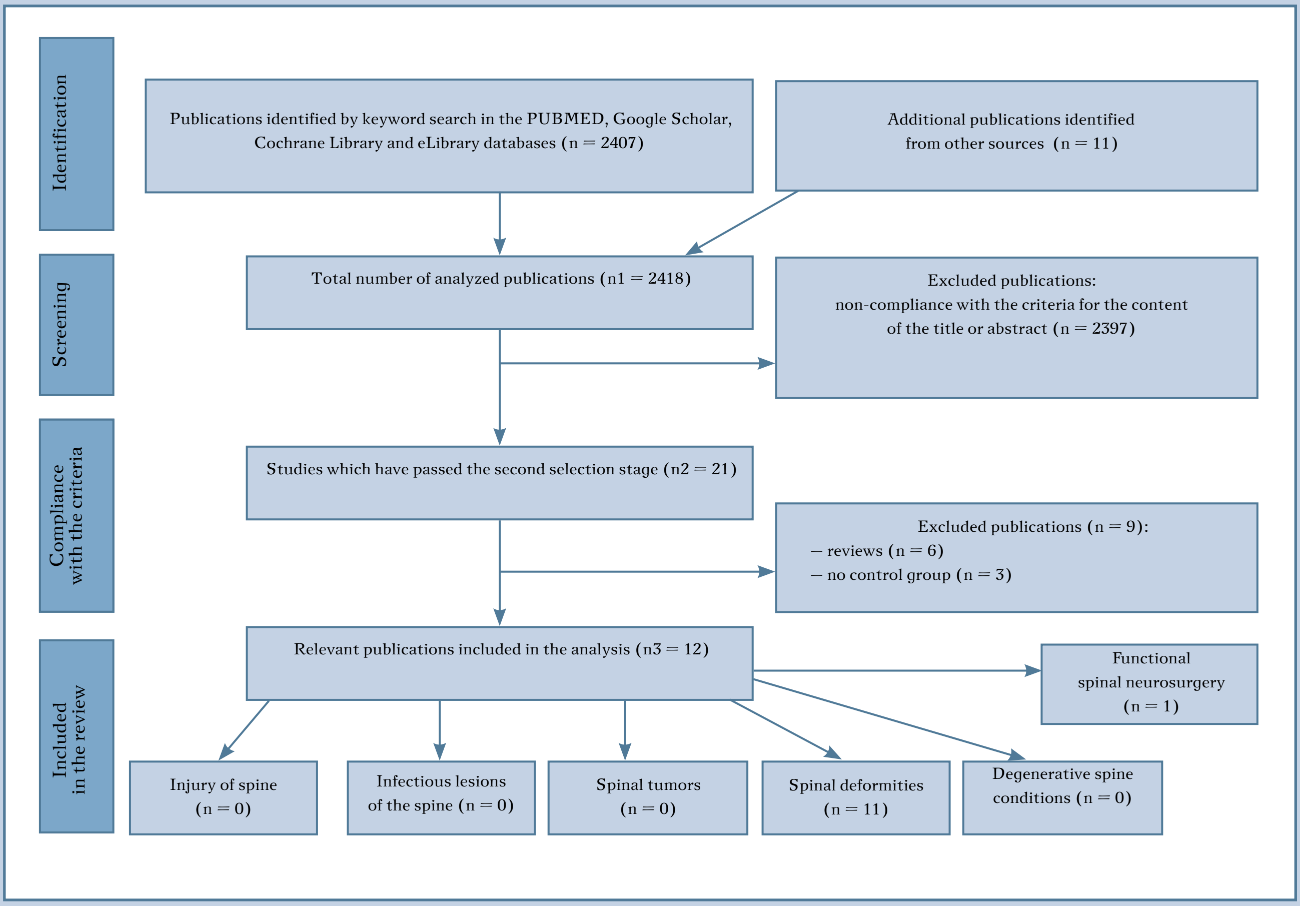

Fig 1
Flowchart of the PRISMA literature search

a single review in the world literature in which an analysis was conducted to evaluate the implementation of the ERAS protocol in spine surgery in children. The paper by Pennington et al. [28] can be considered as an exception. It analyzed the publications on ERAS only in the surgical treatment of spinal deformities in children. The authors have found that the introduction of the ERAS program is associated with a reduced hospitalization length by 1.1 days, fewer postoperative complications, lower pain levels, as well as an earlier discontinuation of patient-controlled analgesia [28]. The introduction of the ERAS program in the treatment of spinal deformities in children is another step in the treatment evolution of this challenging category of patients.

In pediatric surgery, the number of papers on the ERAS program is also small. Many authors explain this with the delay in the recognition of ERAS in this surgical industry [5, 6, 14, 29]. Though there is a small amount of research on ERAS, there is evidence that this program is feasible, safe and effective in pediatric surgical practice. Moreover, it helps to improve the satisfaction of patients and their parents with the treatment outcomes [2, 4–6, 14, 30].

In 2021, a whole team of authors led by Debono [2] for the first time in spine surgery in adults published the official guidelines of the ERAS®Society for operations with lumbar fusion. Within the framework of this agreement, not only 22 elements and their guidelines for inclusion in the protocol were identified, but also the quality of evidence and the level of the recommendation under consideration for the GRADE system were given [31].

Due to the fact that until now the ERAS®Society (https://erassociety.org) has not approved any protocol for pediatric spine surgery, as a result of the literature analysis, a table was synthesized for the first time (Table 3). It consists of perioperative periods, elements of the ERAS protocol, their justification and the frequency of inclusion in children [5–7, 14, 29, 32, 33]. A total of 24 elements of the ERAS program have been identified. According to the analysis, they are currently applied in spine surgery in children and adolescents. It is worth noting that some of the elements (prevention of infectious complications, audit, multimodal analgesia, etc.) are duplicated in the frames of different periods of medical care.

There was an average of 9 elements in the ERAS program, according to our review. As for spine surgery in adults, there were 13–19 elements [9, 34, 35]. There is a significant difference between children and adults in the type and possible scope of surgery, which is due to anatomical and physiological features, as well as different comorbid background and possible functional disorders. The nonuniformity of the age and stage of physiological and neurological development of children contribute even more to the direct comparison and extrapolation of the experience of implemented technologies in adults into children's practice. Comprehension of these differences will allow to define and adapt the «adult» ERAS protocols in the best way [5]. It is essential to understand that the features described above require the development of several ERAS programs

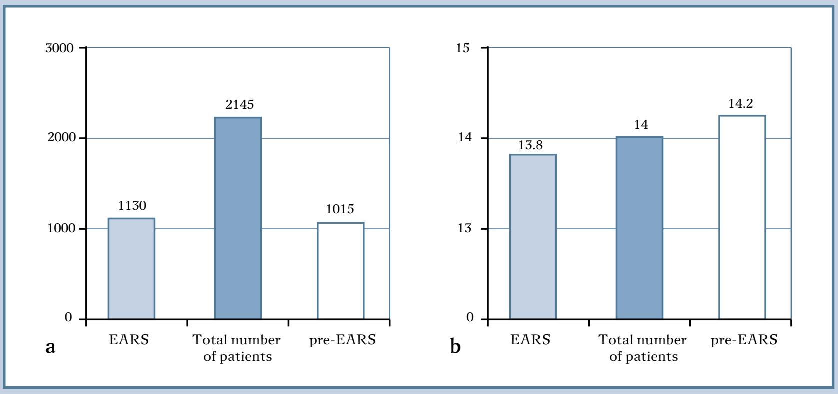

Fig 2
Distribution of the population: **a** – by groups (people); **b** – by average age in the group (y.o.)

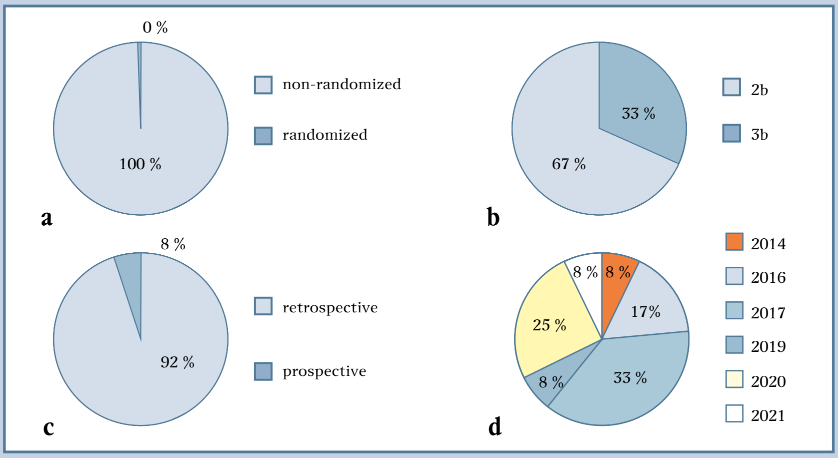

Fig 3
Distribution of studies: **a** – by randomization; **b** – by the data collection method; **c** – by the strength of evidence; **d** – by years

Table 2

Summary of studies implementing the ERAS protocol in spine surgery in children and adolescents

Authors	Year, country	Overview of the study	Number of people (group)	Age of patients, y.o.	Analyzed pathology	Operations performed	Elements of the ERAS protocol, n
Bellaire et al. [26]	2019, USA	Retrospective non-randomized case-control study – 3b	n = 29 (pre-ERAS)	12.7 ± 3.1	Neuromuscular scoliosis, infantile cerebral paresis (ICP)	Correction of spinal deformity, spinal fusion, transpedicular fixation (TPF)	9
			n = 42 (ERAS)	12.8 ± 3.1			
DeVries et al. [16]	2020, Canada	Retrospective non-randomized case-control study – 3b	n = 113 (pre-ERAS)	15.2 ± 2.0	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	9
			n = 131 (ERAS)	15.3 ± 1.9			
Fletcher et al. [17]	2014, USA	Retrospective non-randomized case-control study – 3b	n = 125 (pre-ERAS)	14.7 ± 2.3	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	9
			n = 154 (ERAS)	14.4 ± 1.9			
Fletcher et al. [18]	2017, USA	Retrospective non-randomized case-control study – 3b	n = 45 (pre-ERAS)	14.9 ± 1.8	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	14
			n = 105 (ERAS)	14.1 ± 1.6			
Fletcher et al. [19]	2021, USA, Canada	Retrospective non-randomized cohort study – 2b	n = 73 (pre-ERAS)	16.1 ± 2.1	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	6
			n = 203 (ERAS)	14.3 ± 2.1			
Gornitzky et al. [21]	2016, USA	Retrospective non-randomized cohort study – 2b	n = 80 (pre-ERAS)	15.0 ± 2.3	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	7
			n = 58 (ERAS)	14.8 ± 2.3			
Julien-Marsollier et al. [22]	2020, France	Retrospective non-randomized cohort study – 2b	n = 81 (pre-ERAS)	15.0 ± 2.0	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	20
			n = 82 (ERAS)	15.3 ± 1.8			

Hospitalization, days	Number and structure of complications, %	Other outcomes	Treatment cost
4.9 ± 1.4	A total of 33 % in the ERAS versus 52 % in the pre-ERAS group, including pulmonary — 21 % versus 38 %, respectively. There were no differences in wound complications and reoperations	Statistically significant decrease in length of hospitalization by 19 % in the ERAS group. Increasing frequency of readmission in the 30-day period in the ERAS group (23.8 % vs. 7.0 %). Reduction of blood loss in the ERAS group (526 ml vs. 850 ml)	No data available
4.0 ± 1.5			No data available
5.2	No differences were found in the frequency of wound complications (ERAS 3.05 % vs. 2.65 %), 30-day reoperations and hospitalizations between the groups ($p > 0.05$)	Less blood loss in the ERAS group (806 ± 418 ml vs. 994 ± 606 ml) affected by a larger correction (ERAS 45.8° ± 13.8° vs. 38.2° ± 12.1°)	No data available
3.4			No data available
4.3 ± 1.1	15.59 % (ERAS) vs. 10.4 % (pre-ERAS)	Reduction of the operation duration in the ERAS group (220 ± 45 vs. 312 ± 68 min, $p < 0.0001$). Significant decrease in blood loss in the ERAS group (336 ± 313 ml vs. 763 ± 556 ml, $p < 0.0001$). Lower incidence of osteotomies (5.2 vs. 30.1 %, $p = 0.03$) and implants in the ERAS group. Reduction of total treatment costs by 33 % in the ERAS group	$2779
2.9 ± 0.7			$1.885
4.2	7.6 % (ERAS) versus 20.0 % (pre-ERAS) is statistically significant. Comparable level of wound infections (1.1 % in the ERAS group versus 2.2 %) and medical complications	Lesser surgery duration in the ERAS group (187 min vs. 235 min) and blood loss volume (275 ml vs. 350 ml, respectively)	No data available
2.2			No data available
4.8	Wound complications - ERAS 1.5 % vs. 1.4 % in the pre-ERAS group	Lesser surgery duration (ERAS 2.8 h vs. 4.8 h, $p < 0.001$) and volume of blood loss (ERAS 240 ml vs. 500 ml, $p < 0.001$), with lower curve magnitude (ERAS 54° vs. 62°, $p < 0.001$), length of fixation (ERAS 10.1 ± 2.6 vs. 11.4 ± 1.6, $p < 0.001$) and frequency of osteotomies (ERAS 46% vs. 94 %). Lower pain level (ERAS 2.0 vs. 4.0 according to VAS). Comparable in terms of the recovery quality, for the time of return to school (ERAS 20.0 vs. 20.5), and for parents of children to work (ERAS 10.0 vs. 10.0)	No data available
2.2			No data available
5.0 ± 0.8	Reducing the frequency of side effects in the ERAS group associated with opioids	In the ERAS group, the average daily pain level was lower by 0 ($p = 0.027$), 1 ($p < 0.001$) and 2 ($p = 0.004$) POD. In the ERAS group, termination of patient-controlled analgesia occurred 34 % earlier. In the ERAS group, urinary catheters were removed 26 % earlier. No difference in readmission during the first 30 days	No data available
3.5 ± 0.8			No data available
7.0	The frequency of postoperative nausea and vomiting did not differ between the two groups, and the frequency of constipation reduced slightly, but significantly in the ERAS group on day 3 (56.8 % vs. 70.2 %). The frequency of wound infections within 30 days after surgery was slightly lower in the ERAS group — 4.9 % versus 7.3 %	The intensity of pain at rest and movement is lower in the ERAS group on the 2nd and 3rd day associated with lower opioid consumption (by 25 % and 35 % on the 2nd and 3rd day, respectively)	No data available
4.0			No data available

End of table 2

Authors	Year, country	Overview of the study	Number of people (group)	Age of patients, y.o.	Analyzed pathology	Operations performed	Elements of the ERAS protocol, n
Muhly et al. [20]	2016, USA	Retrospective non-randomized case-control study — 3b	n = 134 (pre-ERAS)	15.0	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	7
			n = 84 (ERAS)	14.0			
Rao et al. [23]	2017, USA	Retrospective non-randomized case-control study — 3b	n = 51 (pre-ERAS)	15.0	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	15
			n = 100 (ERAS-1)	14.9			
			n = 39 (ERAS-2)	13.5			
Raudenbush et al. [24]	2017, USA	Retrospective non-randomized case-control study — 3b	n = 50 (pre-ERAS)	15	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	4
			n = 30 (ERAS)	14			
Sanders et al. [25]	2017, USA	Retrospective non-randomized case-control study — 3b	n = 194 (pre-ERAS)	14.0	Adolescent idiopathic scoliosis	Correction of spinal deformity, spinal fusion, TPF	7
			n = 90 (ERAS)	14.3			
Shao et al. [27]	2020, USA	Retrospective non-randomized cohort study — 2b	n = 40 (pre-ERAS)	7.2 ± 3.6	ICP	Selective dorsal rhizotomy	2
			n = 12 (ERAS)	7.8 ± 5.1			

depending on the age of the child and the pathology under consideration [9].

The greater number of elements in ERAS protocols for adults is typical not only for spine surgery. Shinnik et al. [29] revealed that the average number of ERAS elements in pediatric surgery is 5.6 versus 23.8 in surgery protocols in adults. This may be due to the fact that ERAS elements in adults, for example thromboprophylaxis, are considered less relevant in pediatrics.

In our study, all the authors reported one of the main results: a reduction in the hospitalization length by an average of 1.5 days. Reducing the hospitalization length has many possible advantages. For example, a shorter exposure to nosocomial infection, an early return of children to home conditions and their parents to work. We suppose that these outcomes should encourage more active implementation of ERAS protocols in spine surgery in children [18, 22, 36, 37].

Meanwhile, attention should be paid to the paper of Bellaire et al. [26]. In the course of this study, it was found that ERAS, like any medical technology, is not a panacea and will be implemented for 90 % of patients. The remaining 10 % need a more personalized approach. We consider that in pediatric surgery in general, and in spine surgery in particular, it is essential to coordinate efforts, as well as to develop and implement scientifically-based elements of the ERAS pro-

Hospitalization, days	Number and structure of complications, %	Other outcomes	Treatment cost
5.7	Comparable pain syndrome scores with an improvement of 0 (3.8 vs. 4.9) and 1 (3.8 vs. 5) POD. No difference in the frequency of readmission during the first 30 days. No data available		No data available
4.0			No data available
98.4 ± 27.8 ч	Reducing the number of complications (pre-ERAS: ERAS-1: ERAS-2 = 12 : 1 : 3 %)	The average pain scores are comparable, but slightly lower in the ERAS group (>1 point according to VAS). Greater satisfaction comfort in ERAS-1 and ERAS-2 groups compared to pre-ERAS. Increased duration of surgery (pre-ERAS 2.9 ± 3.7 min vs. 4.7 ±1.0 min ERAS)	No data available
ERAS-1 = 97.4 ± 27.8 ч			No data available
ERAS-2 = 84.3 ± 27.7 ч			
4.2	Comparable level of complications: ERAS – 20 % (6 cases), including major – 3.3 % (1 deep wound infection) and minor – 16.7 % (2 progressions of non-structural curve, 1 implant-associated and 2 superficial wound infections). In the control group – 22 % (11 cases), where major complications – 6 % (1 hydropneumathorax, 1 deep wound infection and 1 superior mesenteric artery syndrome), minor – 16 % (1 urinary tract infection, 5 superficial wound infections (granulomas) and 2 implant-associated infections)		Reduction of total average costs by 9 % or by $2000/case
3.3			
5.0	Reduced complication rate (ERAS 12.9 % vs. 5.6 %, p = 0.060). Comparable level of wound complications (ERAS 3.3 % vs. 3.6%, p = 0.91). The frequency of early complications in ERAS 2.2 % versus 5.2 % in pre-ERAS and late complications – 3.3 % and 7.7 %, respectively	No statistically significant difference in readmission was found (ERAS 4.4 % vs. 1.5 %, p = 0.213). However, there were more frequent reoperations in the control group (9.29 % vs. ERAS 2 %). No significant differences (>1 point according to VAS) were found in the pain level assessment between the groups. Reduction of the timing of surgery (ERAS 275 min vs 252 min, p = 0.0398). Reduction of blood loss (ERAS 479 ml vs. 586 ml, p = 0.0281)	$23640
3.7			$18360
3.5	Statistically significant decrease in opioid consumption without increasing the total treatment cost. No statistically significant differences were revealed in the doses of antiemetics, the need for opioids at discharge, the hospitalization length, and the total treatment cost		$25050 ± 4564
3.0			$24190 ± 2476

gram in actual surgical practice. This is especially interesting, challenging and crucial for all sections of spine surgery in children and adolescents [38].

Limitations and prospects of the study. Our systematic review has several limitations:

– the publication biased error risk and possibly incomplete volume of the identified publications, since only the papers published in the main databases: PUBMED/MEDLINE, Google Scholar, Cochrane Library and eLibrary were analyzed;

– there were no randomized controlled studies among the analyzed publications;

– at the initial stage of the literature search, the process was performed by one researcher, which may influence the risk of biased error.

Nevertheless, our systematic review analyzes the available publications on the issue under consideration. In the course of analysis, a summary table of evidence-based elements of the ERAS protocol used in spine surgery in adults and children was made. These recommendations are crucial for generalizing heterogeneous studies in spine surgery in children, where the introduction of ERAS is in an embryonic state.

Our paper can help create a foundation for further standardized studies, as well as support healthcare officials in deciding on the ERAS protocol for spine

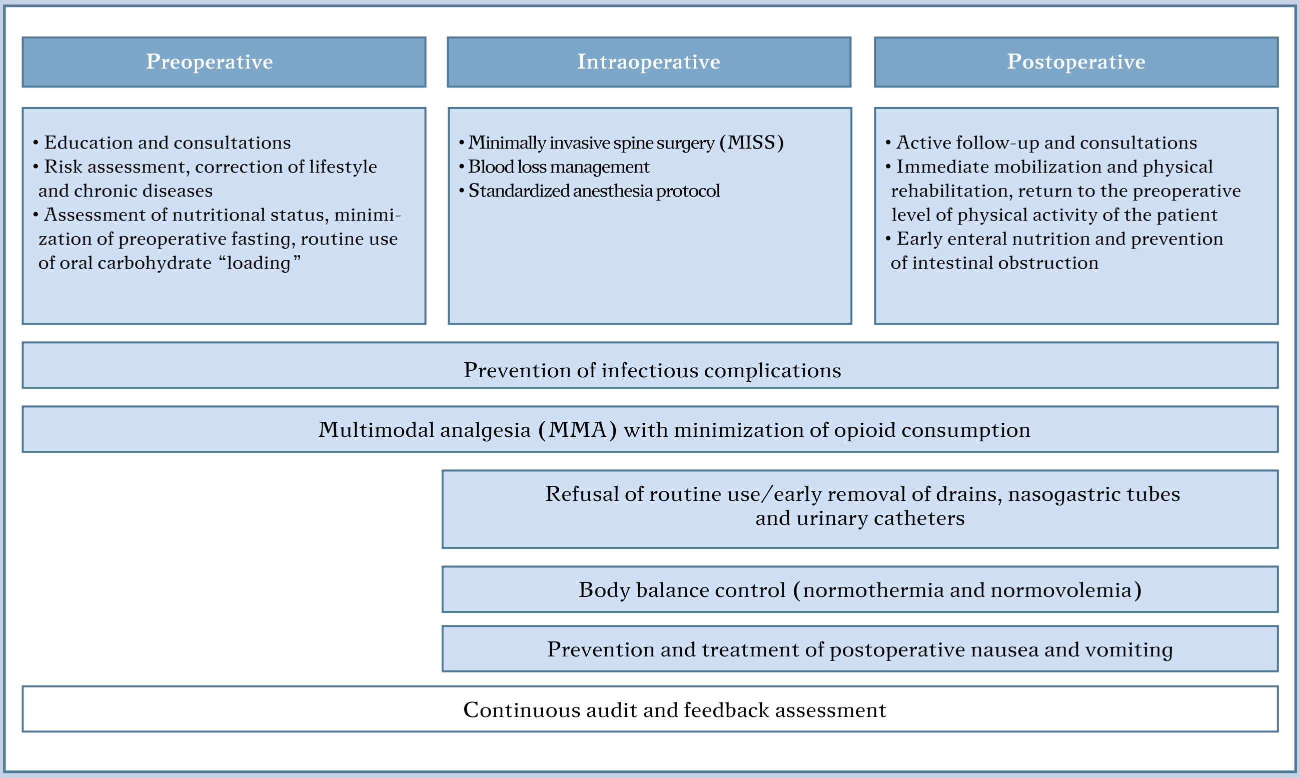

Fig 4
Protocol of recommended ERAS elements in spine surgery in children and adolescents according to the review

surgery in children and adolescents to be implemented in clinical practice.

Conclusions

The conducted systematic review of the literature allows us to conclude that the technology of enhanced recovery after surgery (ERAS) is a promising technology that improves surgical outcomes and is applicable in pediatric practice.

There is a significant shortage of published studies evaluating the implementation of ERAS in pediatric surgical practice in general, and in spine surgery in particular, which requires further prospective randomized studies to evaluate ERAS in spine surgery in children and adolescents.

Table 3

Recommended elements of the ERAS protocol in spine surgery in adults and children [2, 5–7, 14, 29, 32, 33]

ERAS protocol element	Justification of the required element	Recommendations of the ERAS®Society [2] for adults (≥18 years), lumbar fusion	Inclusion frequency in children (according to the review)
Preoperative period			
Preoperative education and consultations	A preoperative consultation is a basic element of ERAS, during which patients receive information concerning the upcoming surgical treatment and preparation for it, risk factors and possible complications, as well as specific features of the course of the postoperative period. All these actions promote emotional preparation of the patient, reduce preoperative anxiety and severity of postoperative pain. A well-informed patient has the most favorable outcome. Thence, realistic expectations should be set before surgery to avoid subsequent dissatisfaction [34, 39]. Children should be specifically informed, including the expected pain level [40]. Blount's prescriptive model advises communicating relevant information to children before planning the procedure and minimizing new information on the day/during the operation. The optimal time of provision of information is very important to reduce anxiety and negative dreams. Children over six should receive information more than five days in advance, and younger children – closer to the beginning of procedure [5]. Since the anxiety of parents on the day of surgery correlates with the elevated anxiety of the child, it is essential to include parents in the preoperative educational process [41]. Parents sign an informed consent and consent to be involved in the ERAS program. The criteria of the planned discharge are explained: a complete return to the previous level of nutrition, the administration of physical needs, successful mobilization of the patient and control of the pain syndrome with oral analgesics [14]	Preoperative education of patients is recommended. Evidence strength level (ESL) – low. Recommendation level (RL) – strong	58 % (7 out of 12) [16–18, 22, 23, 25, 26]
Risk assessment, correction of lifestyle and chronic diseases	It is important to evaluate the comorbid status, lifestyle and compensation of chronic diseases to prevent postoperative complications. For example, diabetes mellitus in a patient after spine and spinal cord surgery is associated with a high frequency of infectious and other complications, great health expenditures and repeated hospitalizations in the early postoperative period [42]. Preoperative anemia is related to an increased risk of blood transfusion, an increased hospitalization length and frequency of readmissions, infectious and other complications, as well as the total treatment cost [43, 44]. It is necessary to have a conversation with the patient regarding smoking and alcohol to give up these habits, since this is associated with better wound healing, improvement of late fates, reduction in the number of complications and mortality. It is required to consider the possibility of obligatory cessation of smoking and alcohol consumption in such patients 4 weeks before and after surgery with the use of appropriate adjunctive means and consultation [2, 45]. The continuation of smoking after spine surgery relates to increased recurrence of disc herniation, raised opioid consumption and pseudoarthrosis [46, 47]	Patients before lumbar fusion: assessment and correction of anemia (ESL – low, RL – strong). The combination therapy for smoking cessation is recommended at least 4 weeks before surgery (ESL – moderate, RL – strong). Abstinence 4–8 weeks before surgery may decrease postoperative complications (ESL – moderate, RL – strong)	8 % (1 out of 12) [22]

Continuation of table 3

ERAS protocol element	Justification of the required element	Recommendations of the ERAS®Society [2] for adults (≥18 years), lumbar fusion	Inclusion frequency in children (according to the review)
Optimization of nutritional status, minimization of preoperative fasting, routine use of oral carbohydrate "loading"	Nutrition optimization is an essential component of preoperative preparation, during which it is required to evaluate the nutritional status. Malnutrition, low levels of albumin, transferrin and lymphocytes are associated with an elevated risk of infections in the surgical site, postoperative complications, increased hospitalization length, 30-day readmission and mortality after spine surgery [2]. Fasting for days before surgery strengthens metabolic and immune responses, which cause a catabolic state that raises insulin resistance and potentially downsizes intravascular volume. Fasting from midnight until the general anesthesia administration is aimed at reducing the volume and acidity of stomach contents during surgery, which lowers the risk of pulmonary aspiration. Yet this belief has not been empirically confirmed, which has been demonstrated in many randomized clinical trials [2, 30, 48]. Preoperative oral carbohydrate therapy (carbonate loading) reduces anxiety, hunger, insulin resistance, protein degradation and the frequency of postoperative complications. A carbohydrate drink (for example, Gatorade or Pedialyte) supports glycogen storage, promotes wound healing, enhances overall muscle strength, restores bowel action and accelerates recovery. It is recommended to take the last meal 6 hours and liquids, including a carbohydrate drink, 2–3 hours before surgery to maintain the reserves of the body and reduce the physical exertion associated with prolonged anesthesia (from 10 ml/kg, but up to 200–350 ml) [6, 13, 14, 32, 49, 50]	The patient should undergo a preoperative nutrition evaluation for the addition of dietary supplements to the diet before performing lumbar fusion (ESL – low, RL – strong). For patients with low BMI – preoperative nutrition correction (ESL – low, RL – strong). Water intake should be allowed for 2 hours, and solid food for 6 hours before the induction of general anesthesia (ESL – high, RL – strong). There is not enough evidence regarding carbohydrate loading	17 % (2 из 12) [22, 26]
Avoiding routine mechanical bowel preparation	Contradictory outcomes are reported regarding bowel preparation. Nevertheless, researchers come to the conclusion that hyperosmotic enema should be avoided and isotonic enema should be performed in combination with perioperative antibiotic prophylaxis, which minimizes the infectious complications risk without worsening recovery [51]. Despite this result has not yet been replicated according to the literature in pediatrics, there are no obvious reasons why it cannot be extrapolated for pediatric practice [5]. Regarding the preoperative preparation of the intestine, there is also no strong belief in spine surgery. Liu et al. [52] included bowel preparation in their protocol, conducting a glycerin enema with chronic constipation or absence of bowel movements for more than 2 days. Other authors reject enemas before spine surgery and come to the conclusion that bowel preparation has a negative effect on recovery [53, 54]	The element is not included in the protocol at this stage	We did not find this element in the publications under consideration

Continuation of table 3

ERAS protocol element	Justification of the required element	Recommendations of the ERAS®Society [2] for adults (≥18 years), lumbar fusion	Inclusion frequency in children (according to the review)
Prevention of infectious complications	Surgical site infection is one of the most common complications in pediatric surgery, especially in colorectal and spine one [55]. Scientifically grounded ways to solve this problem are maintenance of normothermia, antiseptic dressing (chlorhexidine bath) before surgery, preoperative oral or intravenous antibiotics 60 minutes before incision and every 4 hours during long-term procedures, as well as treatment of the surgical area with chlorhexidine and step-by-step change of gloves [6, 29, 32, 56]	Antiseptic dressing before surgery (ESL – low, RL – moderate). Administration of a broad-spectrum antibiotic (covering *S. aureus*) with repeated administration during long-term procedures (ESL – high, RL – strong)	25 % (3 out of 12) [18, 22, 23]
Avoiding routine use of sedatives	Patients should not regularly take sedatives or anxiolytic drugs before surgery, as this slows down recovery, may cause neurocognitive disorders and other side effects [2, 6, 32, 57]	It is not recommended to have a routine sedative medication to reduce anxiety before surgery (ESL – low, RL – strong)	This element was not found in the considered publications
Thromboprophylaxis	There is no consensus on thromboprophylaxis for children under 10. However, children aged from 10 to 17 are offered thromboprophylaxis in procedures of more than 60 minutes and at high risk of venous thromboembolism (VTE) – with ≥ 1 risk factor (age ≥ 14, neurological impairment, VTE, oncology and the condition after surgery for injuries and spinal deformities in the anamnesis, BMI > 30). Such patients should use compression stockings and undergo regular pneumatic compression of the lower extremities. Also, they should be assigned anticoagulant therapy [5, 6, 32, 58–60]	The element is not included in the protocol at this stage	This element was not found in the considered publications
Preventive multimodal analgesia (MMA) with minimization of opioid consumption	Optimization of perioperative analgesia due to the inclusion of MMA is the standard for treatment in ERAS protocols. The stages of MMA within the preoperative (preventive or preemptive), intraoperative and postoperative periods have proven their efficiency for recovery in spine surgery. MMA promotes making the patient more functional, ready for immediate mobilization and physical rehabilitation in the postoperative period [12, 13, 61, 62]. The administration of non-opioid analgesics and regional analgesia before induction of anesthesia correlates with a reduced pain level and the need for anesthesia. The following non-opioid analgesics are administered to children: acetaminophen, midazolam, gabapentin, lidocaine, ketamine and NSAIDs. Intravenous administration of acetaminophen is preferable (the maximum daily dose is 75 mg/kg) compared with rectal (unreliable absorption and excessively high doses – 35–45 mg/kg). Depending on the procedure and the risk of postoperative bleeding, the possibility of intravenous administration of ketorolac may be considered. Its analgesic efficacy is comparable to that of morphine. Simultaneously, it reduces the frequency of postoperative nausea and vomiting associated with opioids [6, 13, 32, 63, 64]. It is worth noting that currently there is no convincing evidence of the negative effect of NSAIDs on bone healing. Moreover, it is known that short-term administration of NSAIDs for 2 weeks does not affect the bone block formation [65]. See Intraoperative period	The routine preoperative administration of paracetamol, NSAIDs and gabapentinoids under MMA is recommended (ESL – moderate, RL – strong)	25 % (3 out of 12) [20–22]

Continuation of table 3

ERAS protocol element	Justification of the required element	Recommendations of the ERAS®Society [2] for adults (≥18 years), lumbar fusion	Inclusion frequency in children (according to the review)
Prehabilitation	Prehabilitation — improving the body functional ability before surgery to accelerate the functional recovery after surgery. In surgery, Prehabilitation includes a set of exercises, diet therapy and psychological training. It has been proven that this element helps recovery in general surgery [66, 67]	This technique does not have enough evidence to be recommended to all patients	This element was not found in the considered publications
Continuous audit and feedback assessment	Monitoring and regular feedback assessment at all stages of treatment helps to evaluate the outcome satisfaction, pain severity and functional capacity of patients [9, 34, 35, 68]. Moreover, they guarantee the successful implementation of the ERAS protocol [69, 70]. The medical staff is in favor of ERAS implementation. Nevertheless, it considers this process difficult [71]. Thus, it is recommended to implement ERAS by a multidisciplinary team, adhering to strict compliance with ERAS recommendations for continuous improvement of the medical care quality [4, 72–75]	Regular audit and feedback assessment are essential for implementing ERAS protocols and improving the medical care quality (ESL – low, RL – strong)	8 % (1 out of 12) [23]
Intraoperative period			
Minimally invasive spine surgery (MISS), modern technologies	The use of MISS techniques helps patients recover quickly after surgery. It is one of the key elements of the ERAS program. The use of a standard posterior median approach with skeletonization of the spine ensures direct approach to its posterior column. Nevertheless, this contributes to the development of muscular atrophy and the formation of a long-term local pain syndrome in the postoperative period, which results in deterioration of functional outcomes and increases the complication risk [34, 76]	Surgical technique should be specified on a case-by-case basis, considering the mission objective, the surgeon's experience and the technical equipment of the in-patient facility (ESL – low, RL – strong)	42 % (5 out of 12) [16, 18, 22, 23, 25]
Intraoperative MMA	See *Preoperative period*. MMA allows to minimize the use of opioids in the postoperative period, which correlates with a reduced hospitalization, financial costs, the number of complications and side effects (nausea and vomiting, pruritus, hyperalgesia, constipation and postoperative ileus, acute tolerance to opioids, respiratory failure, etc.). Nevertheless, intravenous administration of opioids as part of patient-controlled analgesia (PKA) is still the basis of postoperative analgesia. Thus, in cases where the administration of opioids is still necessary, attempts may be made to include short-acting opioids (sufentanil) [13, 33, 61, 62]. Epidural (EPI) and intrathecal (IT) administration techniques are a more effective alternative to intravenous administration of opioids regarding analgesia, its duration and recovery. Caudal catheters are installed in infants and young children; epidural catheters are installed in children over 6, which is due to the anatomical position of the sacrum in relation to the lumbar vertebrae. For EPI, 10–20 g/kg of hydromorphone is bolus-injected through an epidural catheter, followed by an infusion of 20 g/ml of hydromorphone and 0.1 % bupivacaine at an initial rate of 0.1–0.2 ml/kg/h [6, 32, 77]. For EPI, Cohen et al. [78] injected epidural morphine with prolonged release (EREM) 150 mcg/kg. Morphine is also used for IT after induction of anesthesia before incision at a dose of 2–19 mcg/kg (on average 14 mcg/kg) with an effect of up to 12.0–18.8 hours. There is convincing evidence that IT administration of opioids can significantly decrease intraoperative blood loss. Nevertheless, this mechanism remains unclear [33, 79]	To reduce the severity of postoperative pain syndrome, intrathecal administration of morphine, epidural analgesia, locoregional blocks or wound infiltration with long-acting local anesthetics should be used (ESL – high, RL – strong)	83 % (10 out of 12) [16–24, 27]

Continuation of table 3

ERAS protocol element	Justification of the required element	Recommendations of the ERAS®Society [2] for adults (≥18 years), lumbar fusion	Inclusion frequency in children (according to the review)
	The addition of naloxone can improve the effectiveness of IT injection of morphine and reduce the number of complications [80]. Additionally, local infiltration of the surgical incision with local anesthetics (ropivacaine, bupivacaine) downgrades the pain syndrome and accelerates recovery [7, 54, 81, 82]. Detailed evidence-based guidelines for the use of multimodal anesthesia and its components with dosage in spine surgery in children are given in a recent review by Lee et al. [12]		
Homeostatic balance control (normothermia and normovolemia)	Intraoperative homeostatic balance control correlates with a reduction in postoperative complications and with a better recovery [4]. Normothermia and normovolemia can decrease postoperative respiratory, cardiovascular and intestinal complications, wound infections and hospitalization length, as well as improve the function of respiration and digestion after procedure. Normothermia is maintained in various ways in the range from 36 to 38 °C (heated fluid for infusions, blankets, circulating air heating devices); normovolemia is early enteral intake of fluids and restriction of intravenous administration by goal-directed fluid therapy (GDFT) in combination with hemodynamic monitoring. The goal of GDFT is to achieve euvolemia. It means zero fluid balance in the perioperative period to reduce complications and hospitalization length. The total volume of intravenous infusions is from 3 to 7 ml/kg/h under the control of hemodynamic parameters [6, 13, 32, 52, 54, 83–88]	Normothermia should be maintained in the perioperative period by active heating of patients intraoperatively (ESL – high, RL – strong). Intravenous infusions should promote and maintain euvolemia (ESL – moderate, RL – strong). GDFT is not required for 1-2-level lumbar fusion; it should be considered in the presence of serious related diseases (ESL – low, RL – strong)	17 % (2 out of 12) [22, 26]
Blood loss management	Minimizing blood loss can reduce the risk of hypotension, damage to target organs and the development of coagulopathy, as well as complications associated with blood transfusion. Tranexamic acid, preoperative arterial embolization in tumors with a high risk of bleeding, autotransfusion, as well as iron supplementation to patients with anemia in the preoperative period are used intraoperatively to control blood loss and prevent associated complications [5, 35, 89]	The element is not included in the protocol at this stage	25 % (3 out of 12) [16, 22, 26]
Refusal of routine use of drains, nasogastric tubes and urinary catheters	Long-term use of surgical drains is associated with the development of infectious complications [35, 52]; the installation of drain itself does not cause a decrease in the frequency of wound infection and postoperative epidural hematoma [90-94]. Nevertheless, Mirzai et al. [95] report that the installation of drain decreases both the frequency and the size of the hematoma on the first postoperative day, which is crucial for preventing postoperative fibrosis and improving the results of procedure. The use of a nasogastric tube is related to a slow recovery of bowel action [6, 32], and urinary catheterization is associated with postoperative urinary retention, urinary tract infections, the risk of sepsis, injuries to the urethra, bladder and kidneys, the onset of pseudopolypes. Conscious restriction of the use of drains, tubes and catheters can minimize side effects, simplify patient mobilization and reduce treatment costs [54, 61, 96–98]	The routine use of urinary catheters is not recommended. If they are used, the catheters should be removed within a few hours after the procedure (ESL – moderate, RL – weak)	83 % (10 out of 12) [16–23, 25, 26]

Continuation of table 3

ERAS protocol element	Justification of the required element	Recommendations of the ERAS®Society [2] for adults (≥18 years), lumbar fusion	Inclusion frequency in children (according to the review)
Prevention of infectious complications	See *Preoperative period*. The time of patient's skin preparation is very important. It has been proven that the number of bacteria on the skin is significantly decreased if povidone-iodine is used. It is true if the drug to be left to dry for a few minutes before spine surgery [99]	Patient's skin preparation by an alcoholic iodine solution or chlorhexidine (ESL – high, RL – strong)	See *Preoperative period*
Prevention and treatment of postoperative nausea and vomiting (PONV)	Prevention and treatment of PONV are essential for patients after any operative treatment, since PONV results in dehydration, delayed return to adequate nutrition, an increase in the volume of intravenous fluid, an enhanced hospitalization length and health care costs. PONV occurs in 50 % of patients after surgery; up to 80 % have a high risk of developing PONV. The main risk factors for PONV in women, people with PONV history or motion sickness, non-smokers using volatile anesthetics, nitrous oxide and opioids [100–102]. It is recommended to use a multimodal approach to the prevention of postoperative nausea and vomiting [6]. To this end, ondasetron and dexamethasone are administered intraoperatively [14]. Smith et al. [68] achieved a significant reduction in the intake of antiemetic drugs in the postoperative period, using intraoperative administration of dexamethasone (8 mg) and ondasetron (4 mg) in adults. Additionally, 40 mg of aprepitant was administered to high-risk patients	It is recommended to assess the PONV risk and routine use of multimodal prophylaxis under this evaluation, treatment of PONV with the help of various classes of antiemetics (ESL – high, RL – strong)	33 % (4 out of 12) [22, 23, 25, 27]
Standardized anesthesia protocol	There are conflicting high-quality studies in spine surgery that compare different anesthesia techniques. Wahood et al. [103] did not reveal a difference between general and other anesthetic techniques in terms of complications, the hospitalization length, and the frequency of readmissions. Yoshimoto et al. [104] showed a significant improvement in hemodynamic stability, severity of blood loss and pain relief using local anesthesia. The use of short-acting anesthetics (for example, sevoflurane) provides optimal anesthesia management and creates conditions for an early recovery after surgery. It reduces the number of side effects and complications of anesthesia, as well as downgrades the pain level in the first postoperative day [7, 54, 105]. Neuromuscular blockade decreases the airway pressure and the muscle damage risk associated with long-term retraction in spine surgery [106]. In randomized clinical trials, it has been proven that the combination of dexmedetomidine and ketamine ensures improved pain control. The administration of dexmedetomidine or clonidine is associated with a lower incidence of PONV and an enhanced action of local anesthetics during wound infiltration [107–110]	Modern general anesthesia, including neuromuscular blockades and neuraxial techniques, should be used as part of a multimodal anesthetic strategy in accordance with accessibility and local organizational characteristics (ESL – moderate, RL – strong)	50 % (6 out of 12) [16, 18, 22–24, 26]
Thromboprophylaxis	See *Preoperative period*	The element is not included in the protocol at this stage	See *Preoperative period*
Continuous audit	See *Preoperative period*	See *Preoperative period*	See *Preoperative period*

Continuation of table 3

ERAS protocol element	Justification of the required element	Recommendations of the ERAS®Society [2] for adults (≥18 years), lumbar fusion	Inclusion frequency in children (according to the review)
Postoperative period			
Immediate mobilization and physical rehabilitation, return to the preoperative level of physical activity of the patient	Immediate mobilization is the most crucial element of ERAS, correlating with early discharge. Immediate mobilization means the verticalization of the patient on the surgery day or the next day. However, it can more often be administered 2 hours after spine surgery under the specialist's supervision. It may involve physical rehabilitation and ergotherapy. Immediate mobilization decreases the hospitalization length with a reduction in the frequency and severity of pain syndrome and the development of complications (thrombosis, pneumonia, urinary tract infection, sepsis, heart attacks, strokes, etc.) [6, 111, 112]	Immediate mobilization is recommended (ESL – low, RL – strong)	83 % (10 out of 12) [16–23, 25, 26]
Early enteral nutrition and prevention of intestinal obstruction	It is a common element in the ERAS protocol in various surgical specialties. Patients are recommended to start eating and drinking within a few hours after surgery, which results in a faster recovery of bowel function and a shorter length of hospitalization, a lower rate of infectious complications, higher satisfaction with treatment and a reduced likelihood of developing postoperative ileus compared with late enteral or parenteral nutrition [34, 35, 54]	It is recommended to return to the regular diet as soon as possible (ESL – low, RL – moderate)	67 % (8 out of 12) [17–19, 21–23, 25, 26]
Postoperative MMA	See *Preoperative period* and *Intraoperative period*. Insufficient postoperative pain control is observed in 57% of patients after elective spine surgery [113]. Inadequate control of acute pain is connected with the development of chronic pain and a significant systemic inflammatory reaction causing dysfunction of internal organs and pain [114]. The standard perioperative MMA protocol results in adequate postoperative analgesia and improved outcomes [4]	Routine use of MMA is suggested to improve pain control and reduce opioid consumption (ESL – moderate, RL – strong)	83 % (10 out of 12) [16–24, 27]
Homeostasis balance control	See *Preoperative period*	See *Preoperative period*	See *Preoperative period*
PONV treatment	See *Preoperative period*	See *Preoperative period*	See *Preoperative period*
Early removal of drains and catheters, nasogastric tubes	See *Preoperative period*	During lumbar fusion on several segments, it is not recommended to use drains (ESL – moderate, RL – strong)	See *Preoperative period*
Prevention of infections	See *Preoperative period* and *Intraoperative period*	See *Preoperative period* and *Intraoperative period*	See *Preoperative period*
Blood glucose monitoring	Hyperglycemia is a risk factor for complications (see *Preoperative period*) and must be avoided in adult patients in spine surgery. This causes less concern in children, and thus regular monitoring of blood glucose is not performed in routine practice for all patients [6, 32, 42]	See *Preoperative period*	This element was not found in the considered publications

End of table 3

ERAS protocol element	Justification of the required element	Recommendations of the ERAS®Society [2] for adults (≥18 years), lumbar fusion	Inclusion frequency in children (according to the review)
Thromboprophylaxis	See *Preoperative period*	Immediate mobilization and use of compression prophylaxis (stockings, etc.) are recommended for all patients after spine surgery (ESL – moderate, RL – strong). Anticoagulant therapy is for people from risk groups. There is no recommendation regarding its routine use (ESL – low, RL – strong)	See *Preoperative period*
Continuous audit. Active postoperative follow-up and consultations	Today there are no uniform criteria determining early discharge after spine surgery. If there are no complications, the patient mobilizes and is quickly discharged home. Nevertheless, safety should have top priority. Thus, discharge on the operation day should not be a defining grade in ERAS principles [9, 34, 35, 68]	See *Preoperative period*	67 % (8 out of 12) [16–21, 23, 26]

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References

1. **Garin C.** Enhanced recovery after surgery in pediatric orthopedics (ERAS-PO). Orthop Traumatol Surg Res. 2020;106(1S):S101–S107. DOI: 10.1016/j.otsr.2019.05.012.
2. **Debono B, Wainwright TW, Wang MY, Sigmundsson FG, Yang MMH, Smid-Nanninga H, Bonnal A, Le Huec JC, Fawcett WJ, Ljungqvist O, Lonjon G, de Boer HD.** Consensus statement for perioperative care in lumbar spinal fusion: Enhanced Recovery After Surgery (ERAS®) Society recommendations. Spine J. 2021;21:729–752. DOI: 10.1016/j.spinee.2021.01.001.
3. **Liu VX, Rosas E, Hwang J, Cain E, Foss-Durant A, Clopp M, Huang M, Lee DC, Mustille A, Kipnis P, Parodi S.** Enhanced recovery after surgery program implementation in 2 surgical populations in an integrated health care delivery system. JAMA Surg. 2017;152:e171032. DOI: 10.1001/jamasurg.2017.1032.
4. **Ljungqvist O, Scott M, Fearon KC.** Enhanced recovery after surgery: a review. JAMA Surg. 2017;152:292–298. DOI: 10.1001/jamasurg.2016.4952.
5. **George JA, Koka R, Gan TJ, Jelin E, Boss EF, Strockbine V, Hobson D, Wick EC, Wu CL.** Review of the enhanced recovery pathway for children: perioperative anesthetic considerations. Can J Anaesth. 2018;65:569–577. DOI: 10.1007/s12630-017-1042-6.
6. **Rove KO, Edney JC, Brockel MA.** Enhanced recovery after surgery in children: Promising, evidence-based multidisciplinary care. Paediatr Anaesth. 2018;28:482–492. DOI: 10.1111/pan.13380.
7. **Licina A, Silvers A, Laughlin H, Russell J, Wan C.** Proposed pathway for patients undergoing enhanced recovery after spinal surgery: protocol for a systematic review. Syst Rev. 2020;9:39. DOI: 10.1186/s13643-020-1283-2.
8. **Venkata HK, van Dellen JR.** A perspective on the use of an enhanced recovery program in open, non-instrumented day surgery for degenerative lumbar and cervical spinal conditions. J Neurosurg Sci. 2018;62:245–254. DOI: 10.23736/S0390-5616.16.03695-x.
9. **Dietz N, Sharma M, Adams S, Alhourani A, Ugiliweneza B, Wang D, Nino M, Drazin D, Boakye M.** Enhanced Recovery After Surgery (ERAS) for spine surgery: a systematic review. World Neurosurg. 2019;130:415–426. DOI: 10.1016/j.wneu.2019.06.181.
10. **Debono B, Sabatier P, Garnault V, Hamel O, Bousquet P, Lescure JP, Plas JY.** Outpatient lumbar microdiscectomy in France: from an economic imperative to a clinical standard – an observational study of 201 cases. World Neurosurg. 2017;106:891–897. DOI: 10.1016/j.wneu.2017.07.065.
11. **Carr DA, Saigal R, Zhang F, Bransford RJ, Bellabarba C, Dagal A.** Enhanced perioperative care and decreased cost and length of stay after elective major spinal surgery. Neurosurg Focus. 2019;46:E5. DOI: 10.3171/2019.1.FOCUS18630.
12. **Kehlet H.** Multimodal approach to control postoperative pathophysiology and rehabilitation. Br J Anaesth. 1997;78:606–617. DOI: 10.1093/bja/78.5.606.
13. **Grasu RM, Cata JP, Dang AQ, Tatsui CE, Rhines LD, Hagan KB, Bhavsar S, Raty SR, Arunkumar R, Potylchansky Y, Lipski I, Arnold BA, McHugh TM, Bird JE, Rodriguez-Restrepo A, Hernandez M, Popat KU.** Implementation of an Enhanced Recovery After Spine Surgery program at a large cancer center: a preliminary analysis. J Neurosurg Spine. 2018;29:588–598. DOI: 10.3171/2018.4.SPINE171317.
14. **Modrzyk A, Pasierbek MJ, Korlacki W, Grabowski A.** Introducing enhanced recovery after surgery protocol in pediatric surgery. Adv Clin Exp Med. 2020;29:937–942. DOI: 10.17219/acem/121931.
15. **Moher D, Liberati A, Tetzlaff J, Altman DG.** Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6:e1000097. DOI: 10.1371/journal.pmed.1000097.
16. **DeVries Z, Barrowman N, Smit K, Mervitz D, Moroz P, Tice A, Jarvis JG.** Spine Deform. 2020;8:1223–1229. DOI: 10.1007/s43390-020-00146-w.
17. **Fletcher ND, Shourbaji N, Mitchell PM, Oswald TS, Devito DP, Bruce RW.** Clinical and economic implications of early discharge following posterior spinal fusion for adolescent idiopathic scoliosis. J Child Orthop. 2014;8:257–263. DOI: 10.1007/s11832-014-0587-y.
18. **Fletcher ND, Andras LM, Lazarus DE, Owen RJ, Geddes BJ, Cao J, Skaggs DL, Oswald TS, Bruce RW Jr.** Use of a novel pathway for early discharge was associated with a 48 % shorter length of stay after posterior spinal fusion for adolescent idiopathic scoliosis. J Pediatr Orthop. 2017;37:92–97. DOI: 10.1097/BPO.0000000000000601.
19. **Fletcher ND, Murphy JS, Austin TM, Bruce RW Jr, Harris H, Bush P, Yu A, Kusumoto H, Schmitz M, Devito DP, Fabregas JA, Miyanji F.** Short term outcomes of an enhanced recovery after surgery (ERAS) pathway versus a traditional discharge pathway after posterior spinal fusion for adolescent idiopathic scoliosis. Spine Deform. 2021. DOI: 10.1007/s43390-020-00282-3.
20. **Muhly WT, Sankar WN, Ryan K, Norton A, Maxwell LG, DiMaggio T, Farrell S, Hughes R, Gornitzky A, Keren R, McCloskey JJ, Flynn JM.** Rapid recovery pathway after spinal fusion for idiopathic scoliosis. Pediatrics. 2016;137:e20151568. DOI: 10.1542/peds.2015-1568.
21. **Gornitzky AL, Flynn JM, Muhly WT, Sankar WN.** A rapid recovery pathway for adolescent idiopathic scoliosis that improves pain control and reduces time to inpatient recovery after posterior spinal fusion. Spine Deform. 2016;4:288–295. DOI: 10.1016/j.jspd.2016.01.001.
22. **Julien-Marsollier F et al.** Enhanced recovery after surgical correction of adolescent idiopathic scoliosis. Paediatr Anaesth. 10 2020;30:1068–1076. DOI: 10.1111/pan.13988.
23. **Rao RR, Hayes M, Lewis C, Hensinger RN, Farley FA, Li Y, Caird MS.** Mapping the road to recovery: shorter stays and satisfied patients in posterior spinal fusion. J Pediatr Orthop. 2017;37:e536–e542. DOI: 10.1097/BPO.0000000000000773.
24. **Raudenbush BL, Gurd DP, Goodwin RC, Kuivila TE, Ballock RT.** Cost analysis of adolescent idiopathic scoliosis surgery: early discharge decreases hospital costs much less than intraoperative variables under the control of the surgeon. J Spine Surg. 2017;3:50–57. DOI: 10.21037/jss.2017.03.11.
25. **Sanders AE, Andras LM, Sousa T, Kissinger C, Cucchiaro G, Skaggs DL.** Accelerated discharge protocol for posterior spinal fusion patients with adolescent idiopathic scoliosis decreases hospital postoperative charges 22. Spine. 2017;42:92–97. DOI: 10.1097/BRS.0000000000001666.
26. **Bellaire LL, Bruce RW Jr, Ward LA, Bowman CA, Fletcher ND.** Use of an accelerated discharge pathway in patients with severe cerebral palsy undergoing posterior spinal fusion for neuromuscular scoliosis. Spine Deform. 2019;7:804–811. DOI: 10.1016/j.jspd.2019.02.002.
27. **Shao B, Tariq AA, Goldstein HE, Alexiades NG, Mar KM, Feldstein NA, Anderson RCE, Giordano M.** Opioid-sparing multimodal analgesia after selective dorsal rhizotomy. Hosp Pediatr. 2020;10:84–89. DOI: 10.1542/hpeds.2019-0016.
28. **Pennington Z, Cottrill E, Lubelski D, Ehresman J, Lehner K, Groves ML, Sponseller P, Sciubba DM.** Clinical utility of enhanced recovery after surgery pathways in pediatric spinal deformity surgery: systematic review of the literature. J Neurosurg Pediatr. 2020;27:225–238. DOI: 10.3171/2020.7.PEDS20444.
29. **Shinnick JK, Short HL, Heiss KF, Santore MT, Blakely ML, Raval MV.** Enhancing recovery in pediatric surgery: a review of the literature. J Surg Res. 2016;202:165–176. DOI: 10.1016/j.jss.2015.12.051.
30. **Smith I, Kranke P, Murat I, Smith A, O'Sullivan G, Soreide E, Spies C, in't Veld B**. Perioperative fasting in adults and children: guidelines from the European Society of Anaesthesiology. Eur J Anaesthesiol. 2011;28:556–569. DOI: 10.1097/EJA.0b013e3283495ba1.

31. **Guyatt GH, Oxman AD, Vist GE, Kunz R, Falk-Ytter Y, Alonso-Coello P, Schunemann HJ.** GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ. 2008;336:924–926. DOI: 10.1136/bmj.39489.470347.AD.
32. **Rove KO, Brockel MA, Saltzman AF, Donmez MI, Brodie KE, Chalmers DJ, Caldwell BT, Vemulakonda VM, Wilcox DT.** Prospective study of enhanced recovery after surgery protocol in children undergoing reconstructive operations. J Pediatr Urol. 2018;14:252.e1–252.e9. DOI: 10.1016/j.jpurol.2018.01.001.
33. **Lee CS, Merchant S, Chidambaran V.** Postoperative pain management in pediatric spinal fusion surgery for idiopathic scoliosis. Paediatr Drugs. 2020;22:575–601. DOI: 10.1007/s40272-020-00423-1.
34. **Corniola MV, Debono B, Joswig H, Lemee JM, Tessitore E.** Enhanced recovery after spine surgery: review of the literature. Neurosurg Focus. 2019;46:E2. DOI: 10.3171/2019.1.FOCUS18657.
35. **Tong Y, Fernandez L, Bendo JA, Spivak JM.** Enhanced recovery after surgery trends in adult spine surgery: a systematic review. Int J Spine Surg. 2020;14:623–640. DOI: 10.14444/7083.
36. **Master DL, Poe-Kochert C, Son-Hing J, Armstrong DG, Thompson GH.** Wound infections after surgery for neuromuscular scoliosis: risk factors and treatment outcomes. Spine. 2011;36:E179–185. DOI: 10.1097/BRS.0b013e3181db7afe.
37. **Omeis IA, Dhir M, Sciubba DM, Gottfried ON, McGirt MJ, Attenello FJ, Wolinsky JP, Gokaslan ZL.** Postoperative surgical site infections in patients undergoing spinal tumor surgery: incidence and risk factors. Spine. 2011;36:1410–1419. DOI: 10.1097/BRS.0b013e3181f48fa9.
38. **Subramanyam R, Muhly WT, Goobie SM.** Enhanced recovery: The evolution of pediatric spinal fusion care. Paediatr Anaesth. 2020;30:1066–1067. DOI: 10.1111/pan.13976.
39. **Burgess LC, Arundel J, Wainwright TW.** The effect of preoperative education on psychological, clinical and economic outcomes in elective spinal surgery: a systematic review. Healthcare (Basel). 2019;7:48. DOI: 10.3390/healthcare7010048.
40. **Fortier MA, Chorney JM, Rony RY, Perret-Karimi D, Rinehart JB, Camilon FS, Kain ZN.** Children's desire for perioperative information. Anesth Analg. 2009;109:1085–1090. DOI: 10.1213/ane.0b013e3181b1dd48.
41. **Chorney JM, Kain ZN.** Family-centered pediatric perioperative care. Anesthesiology. 2010;112:751–755. DOI: 10.1097/ALN.0b013e3181cb5ade.
42. **Epstein NE.** Predominantly negative impact of diabetes on spinal surgery: A review and recommendation for better preoperative screening. Surg Neurol Int. 2017;8:107. DOI: 10.4103/sni.sni_101_17.
43. **Nouri A, Matur A, Pennington Z, Elson N, Ahmed AK, Huq S, Patel K, Jeong W, Nasser R, Tessitore E, Sciubba D, Cheng JS.** Prevalence of anemia and its relationship with neurological status in patients undergoing surgery for degenerative cervical myelopathy and radiculopathy: A retrospective study of 2 spine centers. J Clin Neurosci. 2020;72:252–257. DOI: 10.1016/j.jocn.2019.11.027.
44. **Kansagra AJ, Stefan MS.** Preoperative anemia: evaluation and treatment. Anesthesiol Clin. 2016;34:127–141. DOI: 10.1016/j.anclin.2015.10.011.
45. **Mesfin FB, Hoang S, Ortiz Torres M, Ngnitewe Massa'a R, Castillo R.** Retrospective data analysis and literature review for a development of enhanced recovery after surgery pathway for anterior cervical discectomy and fusion. Cureus. 2020;12:e6930. DOI: 10.7759/cureus.6930.
46. **Hofler RC, Swong K, Martin B, Wemhoff M, Jones GA.** Risk of pseudoarthrosis after spinal fusion: analysis from the Healthcare Cost and Utilization Project. World Neurosurg. 2018;120:e194–e202. DOI: 10.1016/j.wneu.2018.08.026.
47. **Jackson KL 2nd, Devine JG**. The effects of smoking and smoking cessation on spine surgery: a systematic review of the literature. Global Spine J. 2016;6:695–701. DOI: 10.1055/s-0036-1571285.
48. Practice Guidelines for Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration: Application to Healthy Patients Undergoing Elective Procedures: An Updated Report by the American Society of Anesthesiologists Task Force on Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration. Anesthesiology. 2017;126:376–393. DOI: 10.1097/ALN.0000000000001452.
49. **Bohl DD, Shen MR, Mayo BC, Massel D,H, Long WW, Modi KD, Basques BA, Singh K.** Malnutrition predicts infectious and wound complications following posterior lumbar spinal fusion. Spine. 2016;41:1693–1699. DOI: 10.1097/BRS.0000000000001591.
50. **Wang P, Wang Q, Kong C, Teng Z, Li Z, Zhang S, Sun W, Feng M, Lu S.** Enhanced recovery after surgery (ERAS) program for elderly patients with short-level lumbar fusion. J Orthop Surg Res. 2020;15:299. DOI: 10.1186/s13018-020-01814-3.
51. **Holubar SD, Hedrick T, Gupta R, Kellum J, Hamilton M, Gan TJ, Mythen MG, Shaw AD, Miller TE.** American Society for Enhanced Recovery (ASER) and Perioperative Quality Initiative (POQI) joint consensus statement on prevention of postoperative infection within an enhanced recovery pathway for elective colorectal surgery. Perioper Med (Lond). 2017;6:4. DOI: 10.1186/s13741-017-0059-2.
52. **Liu B, Liu S, Wang Y, Zhao L, Zheng T, Chen L, Zhang Y, Xue Y, Lu D, Ma T, Zhao B, Gao G, Qu Y, He S.** Enhanced recovery after intraspinal tumor surgery: a single-institutional randomized controlled study. World Neurosurg. 2020;136:e542–e552. DOI: 10.1016/j.wneu.2020.01.067.
53. **Olsen U, Brox JI, Bjork IT.** Preoperative bowel preparation versus no preparation before spinal surgery: A randomised clinical trial. Int J Orthop Trauma Nurs. 2016;23:3–13. DOI: 10.1016/j.ijotn.2016.02.001.
54. **Li J, Li H, XvZK, Wang J, Yu QF, Chen G, Li FC, Ren Y, Chen QX.** Enhanced recovery care versus traditional care following laminoplasty: A retrospective case-cohort study. Medicine (Baltimore). 2018;97:e13195. DOI: 10.1097/MD.0000000000013195.
55. **Floccari LV, Milbrandt TA.** Surgical site infections after pediatric spine surgery. Orthop Clin North Am. 2016;47:387–394. DOI: 10.1016/j.ocl.2015.09.001.
56. **Ryan SL, Sen A, Staggers K, Luerssen TG, Jea A.** A standardized protocol to reduce pediatric spine surgery infection: a quality improvement initiative. J Neurosurg Pediatr. 2014;14:259–265. DOI: 10.3171/2014.5.PEDS1448.
57. **Gaulton TG, Wunsch H, Gaskins LJ, Leonard CE, Hennessy S, Ashburn M, Brensinger C, Newcomb C, Wijeysundera D, Bateman BT, Bethell J, Neuman MD.** Preoperative sedative-hypnotic medication use and adverse postoperative outcomes. Ann Surg. 2021;274:e108–e114. DOI: 10.1097/SLA.0000000000003556.
58. **Groot OQ, Ogink PT, Paulino Pereira NR, Ferrone ML, Harris MB, Lozano-Calderon SA, Schoenfeld AJ, Schwab JH.** High risk of symptomatic venous thromboembolism after surgery for spine metastatic bone lesions: a retrospective study. Clin Orthop Relat Res. 2019;477:1674–1686. DOI: 10.1097/CORR.0000000000000733.
59. **Fidelia I, Lamba N, Papatheodorou SI, Yunusa I, O'Neil K, Chun S, Wilson J, Maher T, Tafel I, Smith TR, Aglio LS, Mekary RA, Zaidi HA.** Adult spinal deformity surgery: a systematic review of venous thromboprophylaxis and incidence of venous thromboembolic events. Neurosurg Rev. 2020;43:923–930. DOI: 10.1007/s10143-019-01095-3.
60. **Mosenthal WP, Landy DC, Boyajian HH, Idowu OA, Shi LL, Ramos E, Lee MJ.** Thromboprophylaxis in spinal surgery. Spine. 2018;43:E474–E481. DOI: 10.1097/BRS.0000000000002379.
61. **Wang MY, Chang TY, Grossman J.** Development of an Enhanced Recovery After Surgery (ERAS) approach for lumbar spinal fusion. J Neurosurg Spine. 2017;26:411–418. DOI: 10.3171/2016.9.SPINE16375.
62. **Martini ML, Nistal DA, Deutsch BC, Caridi JM.** Characterizing the risk and outcome profiles of lumbar fusion procedures in patients with opioid use disorders: a step toward improving enhanced recovery protocols for a unique patient population. Neurosurg Focus. 2019;46:E12. DOI: 10.3171/2019.1.FOCUS18652.
63. **Hong JY, Kim WO, Koo BN, Cho JS, Suk EH, Kil HK.** Fentanyl-sparing effect of acetaminophen as a mixture of fentanyl in intravenous parent-/nurse-controlled

analgesia after pediatric ureteroneocystostomy. Anesthesiology. 2010;113:672–677. DOI: 10.1097/ALN.0b013e3181e2c34b.

64. **Rusy LM, Hainsworth KR, Nelson TJ, Czarnecki ML, Tassone JC, Thometz JG, Lyon RM, Berens RJ, Weisman SJ.** Gabapentin use in pediatric spinal fusion patients: a randomized, double-blind, controlled trial. Anesth Analg. 2010;110: 1393–1398. DOI: 10.1213/ANE.0b013e3181d41dc2.
65. **Sivaganesan A, Chotai S, White-Dzuro G, McGirt MJ, Devin CJ.** The effect of NSAIDs on spinal fusion: a cross-disciplinary review of biochemical, animal, and human studies. Eur Spine J. 2017;26:2719–2728. DOI: 10.1007/s00586-017-5021-y.
66. **Santa Mina D, Clarke H, Ritvo P, Leung YW, Matthew AG, Katz J, Trachtenberg J, Alibhai SMH.** Effect of total-body prehabilitation on postoperative outcomes: a systematic review and meta-analysis. Physiotherapy. 2014;100:196–207. DOI: 10.1016/j.physio.2013.08.008.
67. **Carli F, Scheede-Bergdahl C.** Prehabilitation to enhance perioperative care. Anesthesiol Clin. 2015;33:17–33. DOI: 10.1016/j.anclin.2014.11.002.
68. **Smith J, Probst S, Calandra C, Davis R, Sugimoto K, Nie L, Gan TJ, Bennett-Guerrero E.** Enhanced recovery after surgery (ERAS) program for lumbar spine fusion. Perioper Med (Lond). 2019;8:4. DOI: 10.1186/s13741-019-0114-2.
69. **Ripolles-Melchor J, Ramirez-Rodriguez JM, Casans-Frances R, Aldecoa C, Abad-Motos A, Logrono-Egea M, Garcia-Erce JA, Camps-Cervantes A, Ferrando-Ortola C, Suarez de la Rica A, Cuellar-Martinez A, Marmana-Mezquita S, Abad-Gurumeta A, Calvo-Vecino JM.** Association between use of enhanced recovery after surgery protocol and postoperative complications in colorectal surgery: The Postoperative Outcomes Within Enhanced Recovery After Surgery Protocol (POWER) Study. JAMA Surg. 2019;154:725–736. DOI: 10.1001/jamasurg.2019.0995.
70. **Hu QL, Liu JY, Hobson DB, Cohen ME, Hall BL, Wick EC, Ko CY.** Best practices in data use for achieving successful implementation of enhanced recovery pathway. J Am Coll Surg. 2019;229:626–632.e1. DOI: 10.1016/j.jamcollsurg.2019.08.1448.
71. **Cohen R, Gooberman-Hill R.** Staff experiences of enhanced recovery after surgery: systematic review of qualitative studies. BMJ Open. 2019;9:e022259. DOI: 10.1136/bmjopen-2018-022259.
72. **Currie A, Soop M, Demartines N, Fearon K, Kennedy R, Ljungqvist O.** Erratum to: Enhanced recovery after surgery interactive audit system: 10 years' experience with an international web-based clinical and research perioperative care database. Clin Colon Rectal Surg. 2019;32:e1. DOI: 10.1055/s-0039-1678573.
73. **Verrier JF, Paget C, Perlier F, Demesmay F.** How to introduce a program of Enhanced Recovery after Surgery? The experience of the CAPIO group. J Visc Surg. 2016;153:S33–S39. DOI: 10.1016/j.jviscsurg.2016.10.001.
74. **Ljungqvist O, Thanh NX, Nelson G.** ERAS-Value based surgery. J Surg Oncol. 2017;116:608–612. DOI: 10.1002/jso.24820.
75. **Elsarrag M, Soldozy S, Patel P, Norat P, Sokolowski JD, Park MS, Tvrdik P, Kalani YS.** Enhanced recovery after spine surgery: a systematic review. Neurosurg Focus. 2019;46:E3. DOI: 10.3171/2019.1.FOCUS18700.
76. **Goldstein CL, Macwan K, Sundararajan K, Rampersaud YR.** Comparative outcomes of minimally invasive surgery for posterior lumbar fusion: a systematic review. Clin Orthop Relat Res. 2014;472:1727–1737. DOI: 10.1007/s11999-014-3465-5.
77. **Milbrandt TA, Singhal M, Minter C, McClung A, Talwalkar VR, Iwinski HJ, Walker J, Beimesch C, Montgomery C, Sucato DJ.** A comparison of three methods of pain control for posterior spinal fusions in adolescent idiopathic scoliosis. Spine. 2009;34:1499–1503. DOI: 10.1097/BRS.0b013e3181a90ceb.
78. **Cohen M, Zuk J, McKay N, Erickson M, Pan Z, Galinkin J.** Intrathecal morphine versus extended-release epidural morphine for postoperative pain control in pediatric patients undergoing posterior spinal fusion. Anesth Analg. 2017;124:2030–2037. DOI: 10.1213/ANE.0000000000002061.
79. **Ibach BW, Loeber C, Shukry M, Hagemann TM, Harrison D, Johnson PN.** Duration of intrathecal morphine effect in children with idiopathic scoliosis undergoing posterior spinal fusion. J Opioid Manag. 2015;11:295–303. DOI: 10.5055/jom.2015.0278.
80. **Firouzian A, Baradari AG, Ehteshami S, Zamani Kiasari A, Shafizad M, Shafiei S, Younesi Rostami F, Alipour A, Ala S, Darvishi-Khezri H, Haddadi K.** The effect of ultra-low-dose intrathecal naloxone on pain intensity after lumbar laminectomy with spinal fusion: a randomized controlled trial. J Neurosurg Anesthesiol. 2020;32:70–76. DOI: 10.1097/ANA.0000000000000537.
81. **Ali ZS, Flanders TM, Ozturk AK, Malhotra NR, Leszinsky L, McShane BJ, Gardiner D, Rupich K, Chen HI, Schuster J, Marcotte PJ, Kallan MJ, Grady MS, Fleisher LA, Welch WC.** Enhanced recovery after elective spinal and peripheral nerve surgery: pilot study from a single institution. J Neurosurg Spine. 2019:1–9. DOI: 10.3171/2018.9.SPINE18681.
82. **Ortega-Garcia FJ, Garc a-Del-Pino I, Aunon-Martin I, Carrascosa-Fernandez AJ.** Utility of percutaneous catheters for local anaesthetics infusion for postoperative pain control in lumbar arthrodesis. A prospective cohort study. Rev Esp Cir Ortop Traumatol (Engl Ed). 2018;62:365–372. DOI: 10.1016/j.recot.2018.01.007.
83. **Lechat JP, Van der Linden P.** Fluid therapy in the intraoperative setting. Transfus Apher Sci. 2019;58:408–411. DOI: 10.1016/j.transci.2019.06.016.
84. **Koraki E, Stachtari C, Stergiouda Z, Stamatopoulou M, Gkiouliava A, Sifaki F, Chatzopoulos S, Trikoupi A.** Blood and fluid management during scoliosis surgery: a single-center retrospective analysis. Eur J Orthop Surg Traumatol. 2020;30:809–814. DOI: 10.1007/s00590-020-02637-y.
85. **Munch JL, Zusman NL, Lieberman EG, Stucke RS, Bell C, Philipp TC, Smith S, Ching AC, Hart RA, Yoo JU.** A scoring system to predict postoperative medical complications in high-risk patients undergoing elective thoracic and lumbar arthrodesis. Spine J. 2016;16:694–699. DOI: 10.1016/j.spinee.2015.07.442.
86. **Thiele RH, Raghunathan K, Brudney CS, Lobo DN, Martin D, Senagore A, Cannesson M, Gan TJ, Mythen MMG, Shaw AD, Miller TE.** Correction to: American Society for Enhanced Recovery (ASER) and Perioperative Quality Initiative (POQI) joint consensus statement on perioperative fluid management within an enhanced recovery pathway for colorectal surgery. Perioper Med (Lond). 2018;7:5. DOI: 10.1186/s13741-018-0085-8.
87. **Guest JD, Vanni S, Silbert L.** Mild hypothermia, blood loss and complications in elective spinal surgery. Spine J. 2004;4:130–137. DOI: 10.1016/j.spinee.2003.08.027.
88. **Pearse R, Dawson D, Fawcett J, Rhodes A, Grounds RM, Bennett ED.** Early goal-directed therapy after major surgery reduces complications and duration of hospital stay. A randomised, controlled trial [ISRCTN38797445]. Crit Care. 2005;9:R687–R693. DOI: 10.1186/cc3887.
89. **Chakravarthy VB, Yokoi H, Coughlin DJ, Manlapaz MR, Krishnaney AA.** Development and implementation of a comprehensive spine surgery enhanced recovery after surgery protocol: the Cleveland Clinic experience. Neurosurg Focus. 2019;46:E11. DOI: 10.3171/2019.1.FOCUS18696.
90. **Kanayama M, Oha F, Togawa D, Shigenobu K, Hashimoto T.** Is closed-suction drainage necessary for single-level lumbar decompression?: review of 560 cases. Clin Orthop Relat Res. 2010;468:2690–2694. DOI: 10.1007/s11999-010-1235-6.
91. **Lai Q, Song Q, Guo R, Bi H, Liu X, Yu X, Zhu J, Dai M, Zhang B.** Risk factors for acute surgical site infections after lumbar surgery: a retrospective study. J Orthop Surg Res. 2017;12:116. DOI: 10.1186/s13018-017-0612-1.
92. **Adogwa O, Elsamadicy AA, Sergesketter AR, Shammas RL, Vatsia S, Vuong VD, Khalid S, Cheng J, Bagley CA, Karikari IO.** Post-operative drain use in patients undergoing decompression and fusion: incidence of complications and symptomatic hematoma. J Spine Surg. 2018;4:220–226. DOI: 10.21037/jss.2018.05.09.

93. **Liu JM, Chen WZ, Fu BQ, Chen JW, Liu ZL, Huang SH.** The use of closed suction drainage in lumbar spinal surgery: Is It really necessary? World Neurosurg. 2016;90: 109–115. DOI: 10.1016/j.wneu.2016.02.091.
94. **Patel SB, Griffiths-Jones W, Jones CS, Samartzis D, Clarke AJ, Khan S, Stokes OM.** The current state of the evidence for the use of drains in spinal surgery: systematic review. Eur Spine J. 2017;26:2729–2738. DOI: 10.1007/s00586-017-4983-0.
95. **Mirzai H, Eminoglu M, Orguc S.** Are drains useful for lumbar disc surgery? A prospective, randomized clinical study. J Spinal Disord Tech. 2006;19:171–177. DOI: 10.1097/01.bsd.0000190560.20872.a7.
96. **Baldini G, Bagry H, Aprikian A, Carli F.** Postoperative urinary retention: anesthetic and perioperative considerations. Anesthesiology. 2009;110:1139–1157. DOI: 10.1097/ALN.0b013e31819f7aea.
97. **Altschul D, Kobets A, Nakhla J, Jada A, Nasser R, Kinon MD, Yassari R, Houten J.** Postoperative urinary retention in patients undergoing elective spinal surgery. J Neurosurg Spine. 2017;26:229–234. DOI: 10.3171/2016.8.SPINE151371.
98. **Jackson J, Davies P, Leggett N, Nugawela MD, Scott LJ, Leach V, Richards A, Blacker A, Abrams P, Sharma J, Donovan J, Whiting P.** Systematic review of interventions for the prevention and treatment of postoperative urinary retention. BJS Open. 2019;3:11–23. DOI: 10.1002/bjs5.50114.
99. **Yasuda T, Hasegawa T, Yamato Y, Kobayashi S, Togawa D, Arima H, Matsuyama Y.** Optimal timing of preoperative skin preparation with povidone-iodine for spine surgery: a prospective, randomized controlled study. Asian Spine J. 2015;9: 423–426. DOI: 10.4184/asj.2015.9.3.423.
100. **Nathan N.** Management of postoperative nausea and vomiting: The 4th Consensus Guidelines. Anesth Analg.2020;131:410. DOI: 10.1213/ANE.0000000000004996.
101. **Gan TJ, Diemunsch P, Habib AS, Kovac A, Kranke P, Meyer TA, Watcha M, Chung F, Angus S, Apfel CC, Bergese SD, Candiotti KA, Chan MT, Davis PJ, Hooper VD, Lagoo-Deenadayalan S, Myles P, Nezat G, Philip BK, Tramer MR.** Consensus guidelines for the management of postoperative nausea and vomiting. Anesth Analg. 2014;118:85–113. DOI: 10.1213/ANE.0000000000000002.
102. **Sarin P, Urman RD, Ohno-Machado L.** An improved model for predicting postoperative nausea and vomiting in ambulatory surgery patients using physician-modifiable risk factors. J Am Med Inform Assoc. 2012;19:995–1002. DOI: 10.1136/amiajnl-2012-000872.
103. **Wahood W, Yolcu Y, Alvi MA, Goyal A, Long TR, Bydon M.** Assessing the differences in outcomes between general and non-general anesthesia in spine surgery: Results from a national registry. Clin Neurol Neurosurg. 2019;180:79–86. DOI: 10.1016/j.clineuro.2019.03.021.
104. **Yoshimoto H, Nagashima K, Sato S, Hyakumachi T, Yanagibashi Y, Masuda T.** A prospective evaluation of anesthesia for posterior lumbar spine fusion: the effectiveness of preoperative epidural anesthesia with morphine. Spine. 2005;30:863–869. DOI: 10.1097/01.brs.0000158879.26544.69.
105. **Konstantopoulos K, Makris A, Moustaka A, Karmaniolou I, Konstantopoulos G, Mela A.** Sevoflurane versus propofol anesthesia in patients undergoing lumbar spondylodesis: a randomized trial. J Surg Res. 2013;179:72–77. DOI: 10.1016/j.jss.2012.09.038.
106. **Brown CH 4th, Jones EL, Lin C, Esmaili M, Gorashi Y, Skelton RA, Kaganov D, Colantuoni EA, Yanek LR, Neufeld KJ, Kamath V, Sieber FE, Dean CL, Edwards CC 2nd, Hogue CW.** Shaping anesthetic techniques to reduce post-operative delirium (SHARP) study: a protocol for a prospective pragmatic randomized controlled trial to evaluate spinal anesthesia with targeted sedation compared with general anesthesia in older adults undergoing lumbar spine fusion surgery. BMC Anesthesiol. 2019;19:192. DOI: 10.1186/s12871-019-0867-7.
107. **Song Y, Shim JK, Song JW, Kim EK, Kwak YL.** Dexmedetomidine added to an opioid-based analgesic regimen for the prevention of postoperative nausea and vomiting in highly susceptible patients: A randomised controlled trial. Eur J Anaesthesiol. 2016;33:75–83. DOI: 10.1097/EJA.0000000000000327.
108. **Hwang W, Lee J, Park J, Joo J.** Dexmedetomidine versus remifentanil in postoperative pain control after spinal surgery: a randomized controlled study. BMC Anesthesiol. 2015;15:21. DOI: 10.1186/s12871-015-0004-1.
109. **Li J, Yang JS, Dong BH, Ye JM.** The effect of dexmedetomidine added to preemptive ropivacaine infiltration on postoperative pain after lumbar fusion surgery: a randomized controlled trial. Spine. 2019;44:1333–1338. DOI: 10.1097/BRS.0000000000003096.
110. **Abdel Hay J, Kobaiter-Maarrawi S, Tabet P, Moussa R, Rizk T, Nohra G, Okais N, Samaha E, Maarrawi J.** Bupivacaine field block with clonidine for postoperative pain control in posterior spine approaches: a randomized double-blind trial. Neurosurgery. 2018;82:790–798. DOI: 10.1093/neuros/nyx313.
111. **Epstein NE.** A review article on the benefits of early mobilization following spinal surgery and other medical/surgical procedures. Surg Neurol Int. 2014;5(Suppl 3):S66–S73. DOI: 10.4103/2152-7806.130674.
112. **Staartjes VE, de Wispelaere MP, Schroder ML.** Improving recovery after elective degenerative spine surgery: 5-year experience with an enhanced recovery after surgery (ERAS) protocol. Neurosurg Focus. 2019;46:E7. DOI: 10.3171/2019.1.FOCUS18646.
113. **Yang MMH, Riva-Cambrin J, Cunningham J, Jette N, Sajobi TT, Soroceanu A, Lewkonia P, Jacobs WB, Casha S.** Development and validation of a clinical prediction score for poor postoperative pain control following elective spine surgery. J Neurosurg Spine. 2020;15:1–10. DOI: 10.3171/2020.5.SPINE20347.
114. **Walker CT, Gullotti DM, Prendergast V, Radosevich J, Grimm D, Cole TS, Godzik J, Patel AA, Whiting AC, Little A, Uribe JS, Kakaria UK, Turner JD.** Implementation of a standardized multimodal postoperative analgesia protocol improves pain control, reduces opioid consumption, and shortens length of hospital stay after posterior lumbar spinal fusion. Neurosurgery. 2020;87:130–136. DOI: 10.1093/neuros/nyz312.

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