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► To cite this version:

Julien Pico, Chrystelle Sola, Anne Charlotte Saour, Kevin Chapron, Lucie Coruble, et al.. Enhanced recovery after surgery (ERAS) for adolescent idiopathic scoliosis: Standardisation of Care Improves Patient Outcomes. *Anaesthesia Critical Care & Pain Medicine*, 2022, 41 (5), pp.101116. 10.1016/j.accpm.2022.101116 . hal-03711000

HAL Id: hal-03711000

<https://hal.science/hal-03711000v1>

Submitted on 21 Feb 2024

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Enhanced recovery after surgery (ERAS) for adolescent idiopathic scoliosis: Standardisation of care improves patient outcomes

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ABSTRACT

Introduction: Adolescent idiopathic scoliosis (AIS) surgeries are major paediatric procedures requiring multidisciplinary management. Enhanced recovery after surgery (ERAS) programs, with proven benefits in adults, remain poorly developed in paediatrics. The main objective of this Before/After study was to evaluate the impact of an ERAS program implementation for AIS on length of stay (LOS) and postoperative recovery.

Methods: The ERAS protocol included intrathecal morphine, standardised multimodal analgesia and multidisciplinary measures for early recovery. Retrospective data from adolescents operated between 2015 and 2017 ("Before ERAS" group) were compared with data from patients benefiting from the ERAS program ("After ERAS" group). Patients treated for neuromuscular scoliosis were not included. After a descriptive analysis, a propensity score matching defined two comparable populations. The main outcome was the LOS. The time to first solid food intake, first ambulation, first bowel movement and Foley removal were also analysed.

Results: During the "Before ERAS" period, 73 underwent PSF for AIS. Thereafter, 65 patients benefited from the ERAS protocol, including 35 for AIS. After propensity score application, 32 patients of the "After ERAS" group were matched with 32 patients of the "Before ERAS" group. The ERAS implementation was associated with 25% reduction in LOS (2.10 ± 1.60 days $p < 0.001$). All other enhanced recovery criteria were significantly reduced after ERAS implementation.

Conclusion: These results confirm the expected benefits of ERAS program in AIS with a significant impact on postoperative recovery and LOS. Patient adherence and the involvement of all caregivers are essential to the success of such a program.

Keywords:

Enhanced recovery after surgery
Adolescent idiopathic scoliosis
Posterior spinal fusion
Multimodal analgesia
Paediatric anaesthesia

Abbreviations: ERAS, enhanced recovery after surgery; AIS, adolescent idiopathic scoliosis; PSF, posterior spinal fusion; LOS, length of stay; CNIL, National Committee on Informatics and Liberty; PCA, patient-controlled analgesia; POD, postoperative day; PACU, post-anaesthesia care unit; ICU, intensive care unit; BIS, bispectral index; PONV, postoperative nausea and vomiting; NSAIDs, non-steroidal anti-inflammatory drugs; BMI, body mass index; EPO, erythropoietin; Hb, haemoglobin; IV, intravenous.

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Introduction

Scoliosis surgery is a major paediatric procedure requiring multidisciplinary management. Current data show an overall prevalence of adolescent idiopathic scoliosis (AIS) of 0.47–5.2% [1] and an incidence of approximately 3% in France. The main objective of the surgical treatment is to obtain a three-dimensional correction and to fuse the spinal segment with a bone graft to prevent further curve progression. The technique used in our centre is a classical posterior spinal fusion (PSF).

Spinal surgical procedures are associated with a high level of pain, a slow return of function and an extended hospital stay

among other complications, which can reach a rate up to 5%. The most common complications of posterior spinal instrumentation include infection (1.35%), pulmonary complications excluding pulmonary embolism (0.95%) and neurological injuries (0.32%) [2]. AIS surgery also leads to moderate to severe acute postoperative pain, opioid related side effects and delay in mobilisation. This can result in significant patient morbidity with a potential extended hospitalisation and delayed functional recovery at home [3]. The average length of stay (LOS) after PSF varies because it partly depends on the local conditions, on the day of surgery and on where the patient's rehabilitation (home vs. specialised centre) is foreseen.

Initially described to promote early recovery and to decrease the LOS, **enhanced recovery after surgery (ERAS)** has since evolved to focus on optimising the perioperative experience of surgical patients. The current definition includes a multidisciplinary and multimodal approach to improve surgical outcomes by using subspecialty and procedure-specific evidence-based protocols in the care of surgical patients. In adults, ERAS programs were introduced in 1997 by Henrik Kehlet [4,5]. As the earliest discipline to implement ERAS, colorectal surgery offers a substantial body of literature supporting its benefits. To date, ERAS has been implemented in various surgical specialties. The many published studies report a decrease in postoperative complications, a reduction of the LOS, an improvement of patient satisfaction and a significant cost reduction [6]. In light of the apparent success of ERAS programs in other surgical disciplines, they are currently implemented for spine surgery. However, it still remains poorly developed and evaluated in the paediatric population [7].

The purpose of this before/after study was to implement an ERAS program after spine surgery and to evaluate its impact on the LOS in our centre and postoperative recovery in surgery for adolescent idiopathic scoliosis.

Methods

After a two-year period of observation and analysis of every aspect of cares delivered to patients undergoing a PSF in our paediatric centre, a multidisciplinary reflection was initiated in order to develop and implement an ERAS protocol specifically designed for scoliosis surgery in the adolescent population.

Study design

Ethics

This study was approved by the Institutional Review Board (2018_IRB-MTP_10-03) and declared to the clinical trials registry (Clinicaltrial.gov - NCT04012528), according to French law.

Population

The "Before ERAS" group included the patients undergoing surgical scoliosis correction between January 2015 and January 2017. The patients of the "After ERAS" group were taken in charge after the implementation of the ERAS Protocol, from April 2018 to January 2020. Data of all the paediatric patients during these two study periods underwent a retrospective chart review ("Before ERAS" group) or a retrospective analysis of prospectively collected data ("After ERAS" group).

Collected data

Demographic data included age, sex, weight, height, degree of scoliosis and number of instrumented vertebral levels. Intraoperative data included perioperative analgesic modalities used, estimated blood loss, perioperative blood transfusion require-

ments and duration of surgery. Postoperative data included the duration of effective morphine patient controlled analgesia (PCA) placement, the resumption of feeding and bowel movements, the first mobilisation, the presence of vomiting within the first 24 h and the length of hospital stay (LOS).

The duration of surgery was defined, based on the anaesthetic records, from the incision to the end of surgical wound dressing. The LOS was defined from the day of the surgery (postoperative day - POD 0) until hospital discharge. Complications were determined on the basis of surgical reports and included any redo-surgery for septic or mechanical reasons or re-hospitalisation directly related to the scoliosis surgery. Although postoperative pain scores (numeric rating scale) were used to adapt postoperative analgesia, we could not retrieve them in the patient's files and they were thus not analysed in this study. However, the following data were recorded by the surgeons during the surgical follow-up visit one month, three months and one year after surgery: resumption of physical activity, presence of prolonged postoperative pain, pain physician consultation and occurrence any complication.

Objectives

The main outcome of this study was the difference in LOS following the implementation of an ERAS program after PSF surgery for AIS.

Secondary outcomes included prolonged postoperative pain, complications and optimal functional recovery, assessed on the return to a regular diet, the beginning of an oral analgesia regimen, the first bowel movement, the first ambulation and time of Foley catheter removal.

No standardised protocol was used in the "Before ERAS" group. The preoperative, intraoperative and postoperative patient's management were left at the discretion of the anaesthesiologist in charge.

Preoperative management

For all patients, a blood saving strategy with preoperative erythropoietin preparation, associated with oral iron supplementation, was implemented based on the preoperative haemoglobin level.

Preoperative pain was evaluated by a numeric rating scale on hospital admission. Painful patients were defined by a numeric rating scale > 3 on admission.

Pharmacological premedication (midazolam, hydroxyzine, pregabalin) was prescribed at the anaesthetist's discretion before the transfer to the operating theatre.

Intraoperative management

After ERAS program implementation, the intraoperative anaesthetic management was standardised.

Following placement of the standard monitoring, intravenous induction was conducted using a target-controlled infusion of propofol (Schnider model), remifentanyl (Minto model), a ketamine infusion (0.15 mg/kg/h), intravenous lidocaine (1 mg/kg) and magnesium sulphate (30 mg/kg), followed by endotracheal intubation. Intrathecal morphine injection (3-5 µg/kg - maximum dose 300 µg) was performed prior to incision. The maintenance of anaesthesia was performed intravenously and was monitored by a bispectral index (BIS™). Haemodynamic stability was monitored by transesophageal Doppler coupled with invasive arterial blood pressure measurement (CardioQ® ODM+, Deltex Medical).

Multimodal analgesia, included the use of dexmedetomidine (0.5 µg/kg/h).

Both cell salvage and a tranexamic acid infusion were used as part of perioperative blood-sparing strategy.

The prevention of postoperative nausea and vomiting (PONV) was also standardised (dexamethasone, droperidol and ondansetron).

Before skin closure, the surgeon placed, under visual control, two epidural catheters in the thoracic and lumbar areas.

The patient was extubated and monitored in the post-anaesthesia care unit (PACU) before transfer to the intensive care unit (ICU).

Postoperative management

After ERAS program implementation, the pain management protocol included a multimodal regimen associating systemic and regional analgesia:

- a systematic administration of paracetamol and non-steroidal anti-inflammatory drugs (NSAIDs) with the use of the oral route as soon as oral intake was tolerated;
- A continuous infusion of ketamine (1 mg/kg/d) and nefopam (1 mg/kg/d) for 24–48 hours;
- the use of a morphine PCA with rotation to oral opioid administration (Actiskenan[®], Laboratories BRISTOL-MYERS SQUIBB) at 48 h;
- the maintenance of double epidural catheters until the fourth postoperative day with continuous wound infusion of 2% ropivacaine (0.4 mg/kg/h) with clonidine (1 µg/ml) as adjuvant (**Appendix A**).

Patients were encouraged to start a regular diet as soon as the transfer from the PACU was initiated.

The resumption of transit was stimulated by a laxative prophylactic treatment combined with a high-fibre diet.

Physical therapy was standardised in the “After ERAS” group and started on the first postoperative day. The aim was an early verticalisation at the first or second postoperative day.

Patients returned at home immediately after leaving the hospital without being admitted in a rehabilitation centre.

Statistical analysis

The number of subjects required was calculated based on the main outcome defined by the LOS. Prior to the implementation of the ERAS protocol, the LOS was 9 days (+/-3). We estimated that after the implementation of the new ERAS protocol, a reduction in the LOS to 7 days (+/-3) would be clinically significant.

With a risk α of 5% and a power at 90%, 48 patients in each group would be needed. We chose to increase the number of subjects to 75 patients per group.

Qualitative variables were presented in numbers and percentages and quantitative variables in means (standard deviation) or medians (quartiles). The normality of the distribution was studied for each of the quantitative variables.

After a descriptive global analysis, patients were propensity matched into two equal and similar groups to reduce the potential bias of this non-randomised controlled trial. A multinomial logistic regression on the global population evaluated significant covariates that should be included in the propensity score estimation model. Finally, weight, BMI, thoracic scoliosis degree, erythropoietin (EPO) protocol, preoperative haemoglobin, preoperative pain and preoperative gabapentine were matched in the propensity score analysis. The selection process was done without replacement, subjects were not returned to the sample after being matched. The maximum allowable difference between propensity scores, the caliper, was equal to 0.1.

After a propensity score, data of the two groups were analysed by the paired student or Wilcoxon tests for quantitative data and the Mac Nemar test for qualitative data.

p Values below 0.05 were considered statistically significant.

The statistical analysis was carried out in collaboration with the medical information service of Montpellier using SAS software, SAS Institute.

Results

Demographic data

During the “Before ERAS” period, 95 patients benefited from a scoliosis surgery, including 73 who underwent a PSF for idiopathic scoliosis. During the “After ERAS” period, 65 patients benefited from the ERAS protocol. Patients who underwent PSF for neuromuscular scoliosis ($n = 30$) were not included in the present analysis (Fig. 1).

Demographic data were similar in the two groups, except for body mass index and preoperative gabapentin use (Table 1).

After propensity score matching, 32 patients in each group were analysed (Table 2).

Only the results of the propensity-matched groups are reported and discussed.

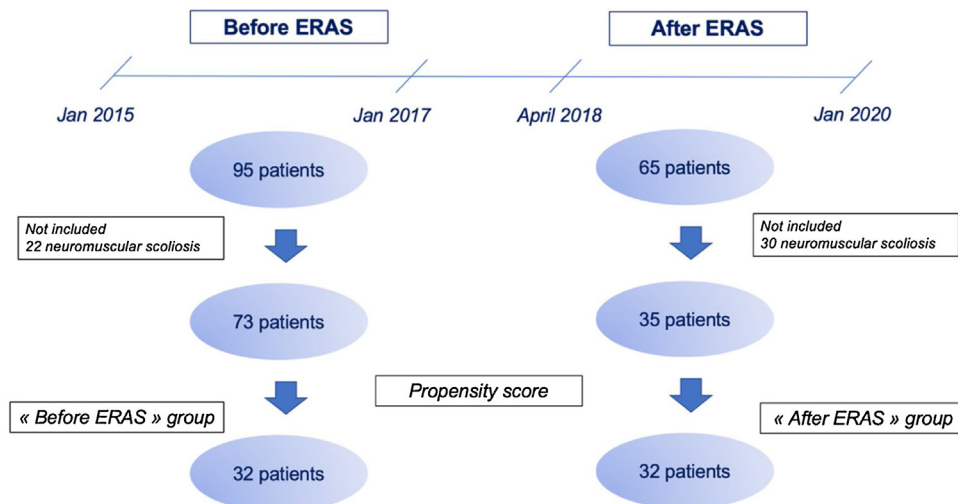


Fig. 1. Flow chart.

Table 1
Patient demographic characteristics.

ERAS protocol	Before (n = 73)	After (n = 35)	p Value
Age (y)	15.1 ± 1.9	15.1 ± 1.9	0.86
Female ratio	58 (79)	24 (69)	0.22
BMI (kg/m ²)	19.7 ± 3.7	21.1 ± 3.8	0.02
Nb levels fused	10.5 ± 1.8	10.5 ± 3.1	0.34
Thoracic curve (degrees)	54.4 ± 12.3	60.6 ± 18.4	0.02
Lumbar curve (degrees)	43.7 ± 10.6	46.5 ± 22.6	0.59
Reference haemoglobin	13.7 ± 1.1	13.8 ± 1.1	0.60
EPO protocol	44 (60.3)	19 (54)	0.22
Preoperative haemoglobin	14.4 ± 1.2	14.5 ± 1.1	0.70
Preoperative gabapentin	63 (84)	20 (57)	0.001
Preoperative pain	27 (37)	14 (46)	0.36

Values are reported as mean ± SD, total number (%), ratio female (%).
p Values < 0.05 are considered significant.

Primary outcome

The analysis of the primary outcome showed a significant decrease in the mean length of stay in the “After ERAS” group of 2.10 ± 1.60 days (95% CI, 1.65–2.35; *p* < 0.001) for total hospitalisation.

Multimodal analgesics

After the implementation of ERAS program, 94% of patients benefited from an intrathecal morphine administration. The average dose of morphine administered intrathecally was 3.39 ± 1.29 µg/kg. In addition, ketamine and dexmedetomidine infusion were reported in 100% of patients. These infusions were not associated with any side effects or complications.

The duration of morphine PCA was significantly decreased by 2.5 ± 2.08 days (95% CI, 1.28–2.72; *p* < 0.001) in the “After ERAS” group compared to the “Before ERAS” group.

There was no significant difference on the analgesics ordered at discharge from the ICU between the two groups, except for ketoprofen, which was more frequently prescribed in the “After ERAS” group (*p* < 0.001).

Blood management

In the two groups, an increase in the preoperative haemoglobin values secondary to the EPO protocol was noticed (+1.7 ± 1 g/dl; *p* = 0.001).

For all patients, in both groups, a cell saver processing and a tranexamic acid infusion were used.

In comparison to the “Before ERAS” group, an average decrease in blood loss of 722 ± 1450 ml (95% CI, 194–1250) was found in the “After ERAS” group (*p* = 0.012).

Table 2
Patient demographic characteristics after propensity score.

ERAS protocol	Before (n = 73)	After (n = 35)	p Value
Age (y)	15.1 ± 1.9	15.1 ± 1.9	0.86
Female ratio	26 (81)	22 (69)	0.25
BMI (kg/m ²)	19.7 ± 3.7	21.1 ± 3.8	0.02
Nb levels fused	10 ± 2	10.5 ± 3	0.26
Thoracic curve (degrees)	56.9 ± 13.3	60.3 ± 18.9	0.28
Lumbar curve (degrees)	47.1 ± 8.1	47.7 ± 20.4	0.90
Reference haemoglobin	13.5 ± 1.1	13.8 ± 1.1	0.29
EPO protocol	20 (63)	18 (56)	0.61
Preoperative haemoglobin	14.3 ± 1.3	14.6 ± 1.1	0.43
Preoperative gabapentin	27 (84)	19 (59)	0.03
Preoperative pain	15 (47)	11 (41)	0.64

Values are reported as mean ± SD, total number (%), ratio female (%).
p Values < 0.05 are considered significant.

No patient in the “After ERAS” group was transfused compared to 28% of patients in the “Before ERAS” group (9 of 32 patients) (*p* < 0.001) (Table 3).

Secondary outcomes

In the “After ERAS” group, we observed a decrease in the time to return to optimal functional autonomy: the time before the first solid food intake was significantly shorter (−0.69 ± 0.90 days (95% CI, 0.378–0.998); *p* < 0.001), as well as the time to rotation from IV to oral opioid administration (−2.5 ± 2.08 days (95% CI, 1.28–2.72), *p* < 0.001), the time to the first ambulation (−1.72 ± 1.69 days (95% CI, 0.654–1.35) *p* < 0.001) and the time to Foley catheter removal (−2.55 ± 1.27 days (95% CI, 1.64–2.36); *p* < 0.001). The time for the bowel movement was shorter in the “After ERAS” group but not statistically different between the two studied groups (−0.72 ± 2.02 days (95% CI, −0.728–0.728); *p* = 0.06) (Fig. 2).

Follow-up data

According to the surgical follow-up data, the incidence of preoperative and prolonged postoperative pain was not significantly different between the two groups although there was a trend for a decreased incidence in the “After ERAS” group (Fig. 3).

In the “After ERAS” group, we identified one postoperative complication. The patient presented an infection of the surgical site requiring a revision surgery. Comparatively, the rate of complications requiring a new hospitalisation was 15.6% (5 of 32 patients) in the “Before ERAS” group. There were four surgical site infections and one neurological deficit. The comparison of the complication rate did not reach statistical significance (*p* 0.19).

Discussion

This Before/After cohort study evaluated the implementation of an ERAS program after PSF surgery and the impact on the recovery of patients suffering from AIS. The results confirmed the expected benefits of such a program, with a significant reduction in the length of hospital stay of more than two days and the positive effects on postoperative recovery. Recently, Julien-Marsollier showed comparable results on the LOS [8]. More importantly, there was no increase in the number of unplanned readmissions related to LOS reduction in the post-ERAS period.

Length of stay

Our results are consistent with studies, which have demonstrated the safety and the economic impact of an accelerated discharge strategy in PSF surgeries for AIS after the implementation of an ERAS protocol [9,10].

The mean reduction of two hospital days per operated child has conducted to a significant total number of hospital days saved over the studied period in our institution. These encouraging results are

Table 3
Intraoperative data.

ERAS protocol	Before (n = 32)	After (n = 32)	p Value
Blood loss (ml) (mean ± SD)	1401 ± 1367	669 ± 530	0.01
Patients transfused	9 (28)	0 (0)	0.001
Intrathecal morphine	0 (0)	30 (94)	0.001
Fibrinogen	10 (31)	3 (9)	0.03
Number of levels fused	10 ± 2	10.5 ± 3	0.26
Duration of surgery (hours) (mean ± SD)	4.3 ± 0.9	5.9 ± 1.4	0.01

Values are reported as mean ± SD, total number (%).
p Values < 0.05 are considered significant.

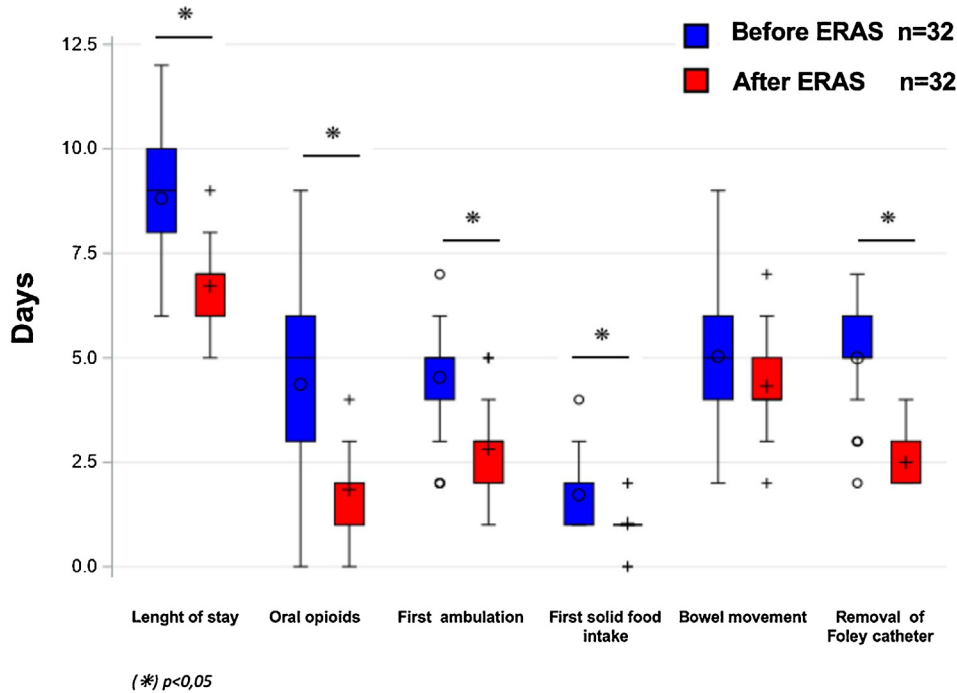


Fig. 2. Before/After ERAS protocol comparison on main ERAS criteria.

also consistent with those of ERAS protocols for other adult orthopaedic surgeries.

The ERAS protocol described in this study was initiated and designed to address three main objectives: to improve pain control, to reduce opioid-related adverse events and side effects and to promote early postoperative recovery.

Multimodal analgesics

The standardisation of multimodal postoperative analgesia was an important part of the ERAS protocol [11]. Indeed, PSF generates severe postoperative pain, with multiple and complex causes: an

extensive dissection of subcutaneous tissues, bones and ligaments and various noxious stimuli.

In our cohort, NSAIDs were consistently used postoperatively in the “After ERAS” group and more commonly continued after discharge from the ICU, compared to the “Before ERAS” group (81% vs. 34%, $p < 0,001$). In paediatric orthopaedic surgery, NSAIDs demonstrated a better analgesia and a decreased opioid consumption, while reducing both opioid-related gastrointestinal side effects and the length of stay [12].

Additionally, we noticed a high adherence of the team to the introduction of intrathecal morphine: 94% of patients in the “After ERAS” group benefited from an intrathecal opioid administration.

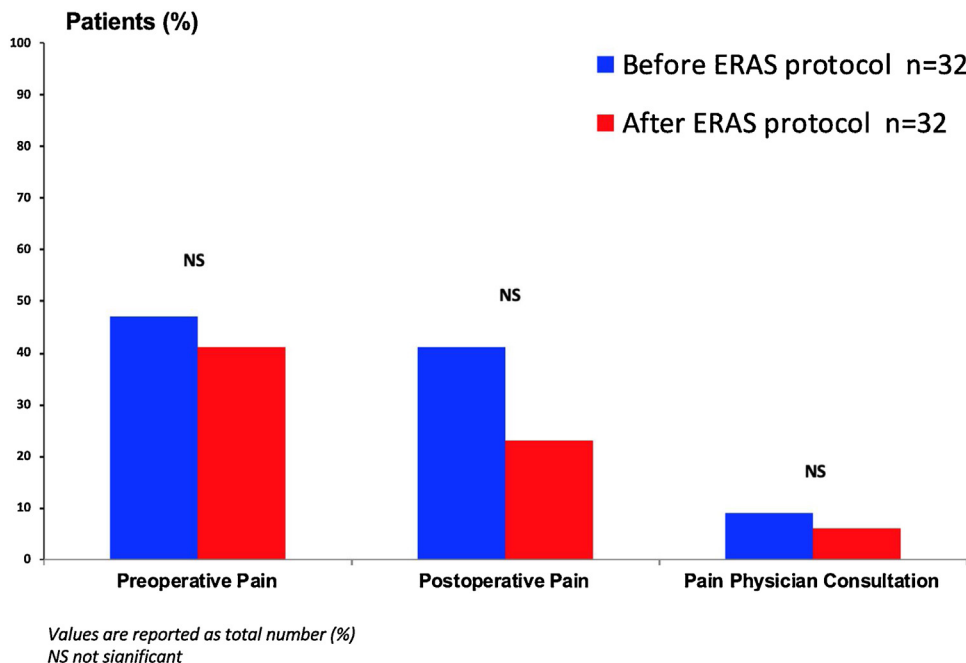


Fig. 3. Number of patients presenting with pre- and prolonged postoperative pain.

Previous studies have shown that intrathecal opioid administration was effective in reducing intraoperative opioid use, as well as early postoperative opioid use and pain scores [13,14]. Studies also showed that intrathecal opioid administration could decrease perioperative blood loss during idiopathic scoliosis surgery [15,16]. In concordance with these studies, we confirmed the benefits of intrathecal morphine in blood-saving management for PSF surgery. This study reported a significant decrease in intraoperative blood loss in the group with more frequent intrathecal opioid administration.

Earlier mobilisation observed in the "After ERAS" group could also be partially due to the benefit of intrathecal opioid administration on postoperative pain management.

As part of multimodal analgesia, Gabapentin has been studied for paediatric PSF, with conflicting results. Among two randomised controlled clinical trials, one reported an improvement in early pain scores and a reduced opioid consumption in the first 48 h after surgery with pre and postoperative gabapentin administration [17], whereas the other study found no difference in pain scores after a single preoperative dose [18]. As described in the Method section, gabapentin used in the current study was left to the discretion of the anaesthetist in charge of the patient.

We systematically used intraoperative intravenous ketamine infusion in the ERAS protocol. Intravenous ketamine was continued postoperatively for an average of two days in the "After ERAS" group. Studies have shown a decrease in pain scores and opioid consumption when used in patients undergoing various types of surgeries [19,20]. However, the postoperative analgesic effect of adjuvant ketamine in patients undergoing scoliosis correction surgery for AIS is controversial [21].

Double epidural analgesia has shown its effectiveness in pain management for scoliosis surgery [22,23]. However, centres implementing ERAS protocols have tended to abandon epidural analgesia, using only intrathecal morphine [24]. In addition, the Cochrane database published in 2019 concludes that there is medium and low quality evidence indicating a slight additional reduction in pain, up to 72 h after scoliosis surgery, with epidural analgesia, in comparison to systemic analgesia [25]. However, it is likely that the efficacy and safety of epidural analgesia depends on the experience of the healthcare team. We decided to combine intrathecal opioid administration with double epidural analgesia, historically used in our centre, to optimise postoperative pain management.

Complications

The results also showed a lower rate of postoperative complications, reported at follow-up, in the group having benefited from the ERAS protocol but without reaching significance. We confirm that it appears safe to reduce the length of stay without compromising readmission rates.

It is important to recognise that the role of the ERAS protocols cannot be limited to simply reducing the overall cost of care. It should also take into consideration the experience that patients and their families go through once a decision to proceed with an operation is taken. Many indicators could be used to measure the quality of care. Postoperative pain can be a reliable indicator, as it is a major concern for patients undergoing surgery [26].

Limits

Several limitations are to be discussed. First, there is a potential lack of power on the primary outcome. Therefore, we used a propensity score to compensate for this lack of number and to obtain two equal comparable groups. The design is also a limitation due to the use of a Before/After study, which is both retrospective

and prospective. It is conceivable that the healthcare team having participated in the design of the ERAS protocol was enthusiastic to demonstrate the success of the new approach when managing patients in the "After ERAS" group. However, the discharge criteria did not change between the two groups and are strictly based on the patient's performance and his return to a functional autonomy.

The duration of the operation was indeed longer in the ERAS group. Surgeons changed their surgical technique over time with new equipment and the technique of monitoring evoked potentials. There was a learning curve, which limited our results.

Another limitation is the lack of assessment of postoperative pain scores and postoperative morphine consumption. The literature confirms [8–27] the interest of multimodal analgesia in reducing morphine consumption and pain scores in PSF surgeries for AIS.

Another limitation is the lack of a validated outcome in terms of patient and family satisfaction. Specific patient satisfaction surveys with a longer follow-up may reveal areas of further improvement. The SRS (Scoliosis Research Society) score appears to be the gold standard satisfaction score after PSF surgery for AIS [28].

Conclusion

This study confirms the expected benefits of an ERAS program after PSF surgery for AIS. The implementation of this program resulted in a faster mobilisation and an earlier discharge. The quality of pain management also appeared to be improved. Overall, the development of such healthcare services serves as one of the most cost-effective ways to improve both the value and the quality of care delivered. In the future, it will be important to assess not only how such strategies improve immediate postoperative recovery, but also how they affect the patient's rehabilitation and the quality of life during the long-term follow-up.

Human and animal rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans as well as in accordance with the EU Directive 2010/63/EU for animal experiments.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s).

The authors declare that they obtained a written informed consent from the patients and/or volunteers included in the article. The authors also confirm that the personal details of the patients and/or volunteers have been removed.

Disclosure of interest

The authors declare that they have no known competing financial or personal relationships that could be viewed as influencing the work reported in this paper.

Funding

This work did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.accpm.2022.101116>.

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