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Enhanced recovery after adolescent idiopathic scoliosis surgery care pathway: Perioperative strategy to improve outcome

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ABSTRACT

Intro: AIS surgery generates a high inflammatory stress response which might influence the outcome in the perioperative period. Enhanced Recovery After Surgery (ERAS) is a global multidisciplinary care pathway aimed to improve patient's recovery.
Research question: The purpose of this article is to expose our actual ERAS protocol for AIS surgery and compare it with the earlier non ERAS management in our institution.Our primary outcome focus on the re-hospitalisation and complications rates at 30 and 90 days postoperatively. Our secondary outcomes focus on the overall morphine consumption, pain scores and side effects during the hospitalisation.
Material: We compare the results of the ERAS group (2019–2022) with the previous existing classical care pathway (2017–2019). The data were collected in our standard medical files.
Results: Our ERAS care pathway for AIS surgery lead to consequently improve the outcome regarding the VAS scores, the morphine consumption, the LOS and the complication and re hospitalisation rates.
Discussion: Regarding our results, ERAS care pathway for AIS surgery appears to be efficient in terms of benefits on complications rates, LOS and opioid consumption.
Intrathecal morphine and "anti-inflammatory" anaesthesia provides a good quality of pain management and allows the patient to get up early.
A superiority trial might be interesting to highlight the role of the ERAS pathway in AIS surgery.

1. Introduction

Posterior spinal fusion (PSF) surgery for adolescents with idiopathic scoliosis (AIS) generates a high inflammatory stress response which might influence the outcome in the perioperative period.

The prevalence of AIS is up to 2% among schoolchildren and 15% among the adolescent population (Trobisch et al., 2010). Curves over 40° occur less than 1/1000 (Rogala et al., 1978).

Aetiology is unknown but AIS is multifactorial and probably genetic. Girls tend to be more affected (sex ratio 6:1 above 10 years old).

It is an exclusion diagnosis once no specific aetiology is found (congenital, neuromuscular, myopathic, traumatic, neuropathic, tumoral)

The degree of curvature is defined by the Cobb angle. Surgical correction is indicated for AIS with Cobb angle above 45° but trigger for surgical decision depends on multiple factors such as speed of progression, maturity, severity of the curve and its type.

The aim of the surgical intervention is to stop the evolution of the pathology, reduce the pain and re-center the axis of the spine.

Evolution without treatment is a reduction in vital pulmonary capacity, chronic pain and loss of autonomy.

Enhanced Recovery After Surgery (ERAS) is a multimodal approach for improving a patient's outcome using evidence-based protocols in the perioperative period.

It is a global multidisciplinary care pathway.

Many studies have highlighted the benefits of ERAS care pathways in several specialties in reducing length of stay (LOS) and improving outcome. ERAS protocols may also have a positive financial impact in some specialties.

The purpose of this article is to expose our ERAS protocol for AIS surgery and compare the results retrospectively with the earlier non ERAS management. The data were prospectively collected in our

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medical files and retrospectively analysed.

2. Research question

Has the implementation of our ERAS care pathway a positive impact on post opérative management of PSF for AIS.

Our primary outcome is the rate of rehospitalization for complications related to surgery at 30 and 90 days.

Our secondary outcomes are the overall morphine consumption, the pain scores and side effects during the hospitalisation.

We compare the results of the ERAS group (2019–2022) with the previous existing classical care pathway (2017–2019).

AIS surgery carries a high level of pain intensity in the post-operative period, typically resulting in a high consumption of opioids with its load of side effects. These might have a negative impact on the recovery after surgery and the occurrence of complications, increasing consequently the global morbidity. Patient-controlled analgesia (PCA) is the standard of care for controlling the pain after PSF for AIS. The goal of the analgesic strategy for AIS surgery is an early satisfactory recovery of autonomy, including deambulation. But side effects due to high opioid consumption led to a reflection for an update in the global strategy in our institution.

A multimodal approach to control the pain has been proved to be efficient using different methods including PCA, epidural analgesia, intrathecal opioids, ketamine, iv lidocaine, NSAID, Gabapentinoïds, Glucocorticoïds, wound infiltration (Lamperti et al., 2017) (Choudhry et al., 2019) (Cohen et al., 2017) (De Bie et al., 2020)

One of the consistent side effects after AIS surgery is the post-operative ileus.

Regarding this, reducing opioid consumption is of most importance after AIS surgery.

Uncontrolled inflammatory response resulting from major surgery might have clinical consequences on pain and other systems. We hypothesised that by minimising the inflammatory response during the perioperative period and consequently limiting the overactivation of the immune system, side effects and complications might be lowered.

For instance, Kurz and all (Ehab Farag et al., 2013) showed that an infusion of 8h postoperative iv lidocaine for adults undergoing spine fusion reduces the opioid requirements during 48h after surgery and decreases the incidence of nausea and vomiting as well as reducing the length of stay and improving the quality of recovery at 3 months after hospitalisation.

Due to its anti-inflammatory effects, iv lidocaine is part of the strategy to control the stress response (Dunn and Durieux, 2017). Local anaesthetics act as antihyperalgesic and analgesic medications, by interacting with the NMDA receptors and increasing interleukin-1 receptor antagonist consequently modulating the cytokine stress response.

ERAS care pathways appear to be of most importance in controlling the overall stress response and limiting the overall morbidity.

Gadiya et al. (2021a) concluded that the use of an ERAS protocol for AIS surgery results in a significant reduction in LOS compared with traditional protocol. No other differences were highlighted in this review neither in complications nor for readmission rates.

Many studies have highlighted the benefits of ERAS in many specialties in reducing LOS (Elsarrag et al., 2019) and improving outcome.

3. Method

This study is a monocentric retrospective comparative non-inferiority review of patients undergoing AIS surgery in our institution between 2017 and 2023.

The patients were divided in two groups, ERAS group from 2019 until 2023 and non-ERAS group from 2017 until 2019.

4. Material

4.1. Data sources: Selection of the patients

The study was approved by our institutional Ethical Board (reference number: B0432021000013).

Patients were identified using our billing database for AIS surgery.

Inclusion criteria were patient age <24, idiopathic scoliosis.

Exclusion criteria were age above 24, non-idiopathic scoliosis, surgery prior to 2017, ASA 3 or more.

4.2. Data collection

Data were collected using our medical care programs (H+, Omnipro, Innovian Case Recorder). We extracted some of the data from our database hosted on the Grace Asso Society audit file (www.grace-asso.fr) (Table 1 details data collected for each patient) (Table 2 patient's demographics)

4.3. Statistical analysis

Data were analysed using SPSS SigmaPlot 13.0 software. As all the analysed data did not conform to a normal distribution and variance equality, they are all expressed in terms of median and interquartile ranges (Q1-Q3). Statistical inference was performed using nonparametric tests. We assessed the homogeneity of the two groups (non ERAS vs ERAS) in terms of demographic and clinical data at baseline. The effect of non ERAS vs ERAS management on anaesthesia medication data, secondary outcomes (pain, PCA consumption, PONV), ERAS outcomes, and on blood loss management data was compared using a Mann-Whitney *U* test. The complication rate in each group was compared using the chi-square test. The significance level was set at 0.05.

4.4. ERAS protocol

4.4.1. Surgery

AIS patients scheduled for PSF are all included by one of the two senior paediatric spine surgeons in our institution. All patients are assessed by standard preoperative imaging protocol including, plain film full spine (antero-posterior and lateral) to define curve pattern, maturity (Risser and acetabular triradiate cartilage closure), bending and traction (15 kg) films to asses curve flexibility, whole spine MRI to exclude neurologic abnormality, CT scanner for surgical planning in specific cases based on surgeon preferences and basal evoked potentials

Table 1
List of Data collected for each patient.

Age	Date of surgery	Weight-Height-BMI
Duration of surgery	Anaesthetic medications *	Time spent in recovery room
Morphine in the recovery room	Overall Morphine consumption	PONV
Return of bowel function	First deambulation	Duration of Urinary drainage
Readmission rate at 30 days	Readmission rate at 90 days	Complications
Side effects	Duration of postoperative iv lidocaine	LOS
First meal	Number of vertebral levels	Blood loss
Transfusions	VAS scores at 0, 1, 2, 3, 4, 5 days postoperatively	pre and post operative haemoglobin

Table 1Anaesthetic ERAS protocols for AIS surgery were elaborated in collaboration with all practitioners involved. Extensive detailed protocols were accessible online. The per-operative anaesthetic protocols were followed heterogeneously regarding the medications given per-operatively, but always focused on reducing the stress response and limiting the use of iv opioids.

Table 2
Patients' demographics.

	NON-ERAS (n = 34)	ERAS (n = 37)	P value
Age (years)	16,3	15,34	0.178
BMI	20,6	19,8	0.139
Weight (kg)	55,5	54,4	0.41
Height (com)	162,3	164,5	0.592
Sex ratio (boys/girls)	1/11	1/6	1
Fusion levels	11.1	11.8	0.802
Cobb angle (degrees)	61.3	59.6	0.526
Surgery duration (min)	205	180	**0.019**

monitoring.

Instrumentation planning follows Lenke principles.

All surgeries are conducted by one of the two senior surgeons with one intern and one scrub nurse under laminar flow.

Patients are positioned in supine position by the surgical team. Evoked potentials are monitored during every procedure by a neurophysiology technician.

Lower instrumented vertebrae are localised on C-arm film prior double dermal preparation with hydro-alcoholic solution (isobetadine 5%) and draping.

Incision of the epiderma is processed by a cold blade. Afterward infiltration of subcutaneous tissues is made with adrenaline solution to control subcutaneous bleeding before true dermal and subcutaneous incision.

The spine is exposed by a sub periosteum median approach and respect of interspinous ligament in the upper and lower last three instrumented vertebras.

After exposition, articular processes are sharpened in every level to fuse. Ponte osteotomy is only used in severe rigid curves. The number of instrumented levels in the segment to correct depends on the rigidity of the curve. Our principles are to instrument as few levels as necessary.

Pedicle uni-axial screws using the free hand technique are used in the lower levels. Pedicle and transverse hooks are used in the upper (thoracic) levels and at the apex of deformity when possible. The lower instrumented vertebra is controlled on C-arm film. Before reduction, cortical bone surfaces are sharpened using a high-speed burr.

Reduction is processed on a hand bended CrCo rod, mainly via rod rotation, translation, compression – distraction technique, and when required via derotation, cantilever and in situ bending.

To avoid proximal junction kyphosis (PJK), interspinous ligament is preserved at the extremities of the construct, in between spinous processes are removed and added to a massive, lyophilized allograft to enhance fusion.

Fascia is closed by cross stitches with Vicryl 2 V34. Subcutaneous is closed by suture laying with Vicryl 0 CP1. Skin is closed by intradermal suture laying with 3.0 Monocryl, without any wound drainage and simple adhesive bandage.

4.4.2. Anaesthesia

The ERAS protocol for AIS surgery in our institution was elaborated after a multidisciplinary consensus involving the surgeons, paediatricians, physiotherapists, nursing supervisors and anesthesiologists.

Our ERAS protocol 's main feature include.

- Full ERAS prehabilitation, (immunonutrition, mental preparation, preoperative extended information using quality supports (institutional ERAS logbook), dedicated medical and nurse ERAS consultation, respiratory preparation, nutritional evaluation and support).
- Reducing fasting time to 2 h for the liquids and 6 h for the solids
- Preoperative carbohydrate loading
- "Anti-inflammatory" anaesthesia (Low Opioids Anaesthesia (LOA) or Opioids Free Anaesthesia (OFA), corticoids, ketamine, alpha2-agonists, continuous iv lidocaine, NSAID, propofol)
- Single bolus intrathecal morphine prior to incision
- Multimodal pain management
- Strict temperature control during the surgery
- Iv fluids monitoring
- Neuro-monitoring to adjust the depth of anaesthesia.
- Alveolar recruitment manoeuvres and protective ventilation using driving pressure.
- Control of blood losses and avoidance of heterologous transfusions by using a cell saver device
- Avoidance of systematic drainage
- Spontaneous ventilation as soon as feasible
- Early extubation at the end of the plasters
- Systematic Prevention of PONV
- Early oral hydration in the recovery room

The aim was to achieve a maximum of those items but practically there were few cases with 100% adhesion. This must be improved in the future to reach our goal.

4.4.3. ERAS pathway

4.4.3.1. Preoperatively. The care pathway starts with the patient and his family visiting the surgical team where an extensive orthopaedic physical examination is performed. This includes the Risser testing, the Lenke classification and evaluation of the degree of deformity with a full spine tomodensitometry including the Cobb ankle measurement. The patient is invited to fill up the Spine Tango form prior to surgery.

The patient is later invited to contact the anaesthesia team to start the ERAS care pathway. During this first step, called "prehabilitation", the medical team and ERAS nurses are consulted to provide cardio-respiratory evaluation and preparation, nutritional and biological evaluation and extended informative support (Table 3).

4.4.3.2. Per operatively and recovery. General anaesthesia is performed by intravenous infusion of propofol (AIVOC Schnider Site effect Agilia Fresenius Kabi) + dexmedetomidine (1,4mcg/kg/h) + continuous iv lidocaine (2 mg/kg/h) + S-ketamine 0.5 mg/kg single dose. Muscular relaxant Rocuronium 0.5 mg/kg single dose prior to intubation as needed. Maintenance of anaesthesia is achieved by propofol (AIVOC Schnider Site effect), dexmedetomidine degressive doses (1 - 0,3 mcg/kg/h) stopped 45 min before the end of the procedure, continuous iv Lidocaine 2 mg/kg/h.

Classical monitoring is used (electrocardiogram 3 derivations, plethysmography (SpO2), non-invasive blood pressure) with control of the depth of anaesthesia (EEG Sensor Entropy General Electric). One or two large bore peripheral catheters are inserted and an arterial radial line 20 gauge is sometimes needed. Temperature control management is performed by fluid warmer (Asthoterm Plus Stihler Electronic) and warming blanket (Bair Hugger 3M).

Early postoperative pain management consists of an intrathecal low-dose Morphine Sulphate 1 μg/kg prior or after induction (89). The blood

Table 3
Prehabilitation.

Nutritional evaluation (NRS, 2002 scoring)	Preoperative oral carbohydrates to reduce insulin resistance.
Protein supplementation (1 g/kg/d)	Reducing fasting time to its minimum (6h for solids 2h for fluids)
Immunonutrition (vitamin C, D, Omega 3, melatonin)	Preoperative measurement of haemoglobin
Cobb angle: - > 50° Pulmonary Function Test - > 70° Transthoracic Echocardiography	Patient Blood Management in the presence of anaemia
Incentive Volumetric Spirometer (Respiflo Sissel)	Anxiety scoring: Amsterdam score (Annex 1.)
Physiotherapy focusing on physical capacity	Gestion of anxiety focusing on Coherent breathing using an app for smartphones

loss management consists of using autotransfusion unit cell saver Sorin Xtra and a single dose of Tranexamic Acid (20 mg/kg).

The analgesics drugs used are Ketorolac 0,5 mg/kg, Dexamethasone 0,2 mg/kg and paracétamol 15 mg/kg.

Prevention of PONV is supported by a single dose of Ondansetron 4 mg prior to awakening.

At the end of surgery early extubation is carried out as soon as possible (in the operating room).

Oral hydration is encouraged in the recovery room, in sitting position in bed.

Patient-controlled analgesia is explained to the patient before discharge towards the paediatric ward.

4.4.3.3. Hospitalisation. Follow-up is ensured by the ERAS coordinator nurse or physician (daily visit) and paediatric nurse team. Daily checklists of ERAS outcomes (Table 4) are followed, and multimodal pain treatment is prescribed (Table 5).

In collaboration with orthopaedic and paediatric teams, and based on the literature, we have drawn up various checklists for the post-operative period. These checklists represent a chronological line to be followed by the patient during the ERAS pathway. The patient can apply this information on a daily basis during hospitalisation, in the logbook handed out at the consultation. Table 4 represents all items in the checklists.

Table 4
Postoperative checklists.

Post-operative check list on **the day of surgery**
Continuous cardio-respiratory monitoring
Blood Pressure every 2h
Checking urinary output (>0,5 ml/kg/h)
Resumption of oral fluids in the recovery room
Chewing gum to stimulate bowel transit
Incentive Volumetric Spirometer
First meal H+6, light meal in absence of nauseas
Neurologic monitoring of the lower limbs
First rise with the help of physiotherapists
Post-operative check list DAY1
Continuous cardio-respiratory monitoring
Blood Pressure every 3h
Oral hydration: 1000 ml water/24h
Protein supplementation 18g twice daily
Resumption of enteral diet (light meals)
Incentive Volumetric Spirometer
Withdrawal of Bladder catheter
Sitting position for minimum 2h twice daily
Walk with the help of physiotherapists
Wound control
Complete blood sample
Neurologic monitoring of the lower limbs
Post-operative check list DAY 2
Oral hydration: >1000ml/24h
Normal enteral diet
Protein supplementation 18g twice daily
Incentive Volumetric Spirometer
Walk minimum 20 m with the help of physiotherapists
Wound control
Stop iv fluids
Withdrawal of PCA
Post-operative check DAY3
Free oral hydration
Normal enteral diet
Protein supplementation 18g twice daily
Incentive Volumetric Spirometer
Walk minimum 50 m with the help of physiotherapists
Wound control
Full spine radiography
Withdrawal of iv catheter
Post-operative check list DAY 4
Free oral hydration
Normal enteral diet
Protein supplementation 18g twice daily
Incentive Volumetric Spirometer
Wound control
Discharge

Table 5
Postoperative medications.

Paracétamol	0,15 mg iv 4 times daily for 24h, then orally 0,15 mg/kg 4 times daily
Ketorolac	0,5 mg/kg iv 3 times daily for 48h
Ibuprofen	400 mg orally 3 times daily starting >48h
Dexamethasone	iv 5 mg/8h, 2 doses
Clonidine	75 µg orally twice daily, if necessary
Lidocaine	iv continuous infusion 1,3 mg/kg/h during 24h
Piritramide	PCA starting on day 1 (IT Morphine) or on day of surgery if VAS pain score >6
Oxycodone	5 mg orally every 4h for 48h if necessary, when PCA is out
Passiflore Extract	400 mg orally 3 times daily
Tranexamic Acid	20 mg/kg orally/8h, 2 doses
Cefazolin	Iv 30 mg/kg/8h, 2 doses
Alizapride	50 mg/8h iv on demand
Ondansetron	4 mg/12 h iv on demand

5. Results

Pain intensity: Visual Analog Scale (VAS)
MAX (/10)

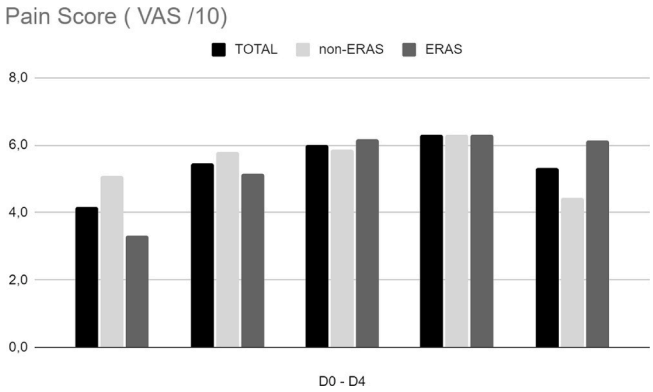
	J0	J1	J2	J3	J4
non-ERAS	5.1 ± 2.2	5.8 ± 1.8	5.9 ± 2.3	6.3 ± 2.3	4.4 ± 1.9
ERAS	3.3 ± 2.7	5.1 ± 2.3	6.2 ± 1.5	6.3 ± 1.4	6.1 ± 1.4
P value	**0.019**	0.401	0.444	0.822	0.4

insufficient data for analysis: Day 5.

PCA consumption (Piritramide) (mg)

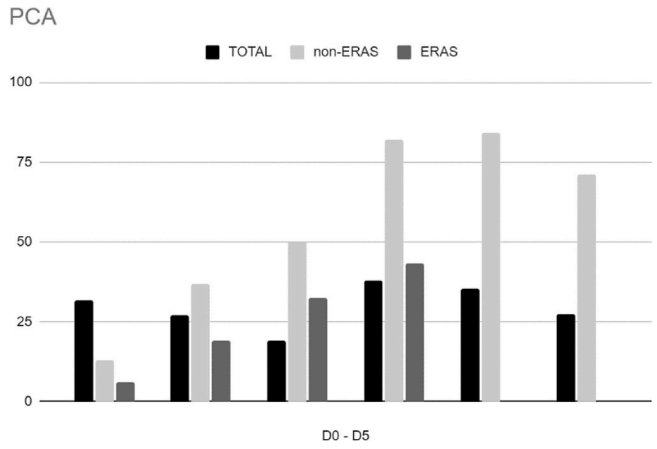
	J0	J1	J2	TOTAL (average)
Non-ERAS	12,9	37	50,2	40,5
ERAS	6,15	19	32,6	28,5
P value	**0,001**	**<0,001**	**0,018**	**0,025**

PCA: Patient Controlled Analgesia/insufficient data for analysis day 3,4,5.



Postoperative nauseas and vomiting (PONV)

PONV	TOT	Non-ERAS	ERAS
no PONV	33,30%	30%	36%
1 episode	34,80%	36,40%	33,30%
>1 episode	34,80%	36,40%	33,30%



Anaesthesia medications.

	Non-ERAS	ERAS	P value
Oxycodone (mg)	0,6	8,7	**<0,001**
Oxycodone/naloxone (mg)	0	2,6	0,06
Tramadol (mg)	155	63,7	**<0,001**
Dexmedetomidine (%)	0	66,6	**<0,001**
Per operative clonidine (mcg)	161,5	62,5	**<0,001**
Post operative clonidine (mcg)	30,9	108,6	**<0,001**
NSAID (%)	100	100	1
Dexamethasone (mg)	4	9,4	0,941
Duration continuous IV lidocaine (h)	0	21.1	**<0,001**
Ketamine (%)	48,5	69,4	**<0,001**
Sufentanyl (µg)	26,7	10,4	**<0,001**
Intrathecal morphine sulphate (%)	0	83	**<0,001**
Intrathecal morphine sulphate (mcg)	0	42,6	**<0,001**
Intrathecal morphine sulphate (mcg/kg)	0	0,81	**<0,001**

NSAID non-steroidal anti-inflammatory drug.

ERAS outcome.

	Non-ERAS	ERAS	P value
Duration recovery room (min)	177,8	172,3	0,934
Timing to sand up (day)	1	0,6	NA
Duration bladder drainage (day)	2,4	1,4	**<0,001**
Stool transit (day)	4	3	**0,014**
Gaz transit (day)	1,5	2	NA
Length of stay (day)	5,4	4,2	0,449
Pre-op Carbohydrate load (%)	2,9	62	**<0,001**

insufficient data for analysis for timing of stand up and gas transit.

Blood loss management.

	Non-ERAS	ERAS	P value
Circulating blood (ml)	4160,3	4081,6	0,41
Blood loss (ml)	360,8	352	0,717
Blood loss (ml/kg)	6,6	6,4	0,401
Heterogenous transfusion (%)	3	0	0,324
Autologous Blood Cell saver (ml)	142,2	126,7	0,421

Complications.

	Non-ERAS	ERAS	P value
90 days re-hospitalisation (%)	8/28	0/36	**0,005**
Abscess/wound infection	4	0	0,115
Hematoma	2	0	0,493
Neurologic complication	1	0	1
Wound dehiscence	1	0	1
Heterologous transfusion	1	0	1

The demographic details of the 71 patients are shown in Table 2. There were no statistically significant differences between patients in the two groups with regard to demographic data. Surgery duration is lower in the ERAS group (median 180 min $p = 0,019$ vs 205 min in the non-ERAS) probably because these patients benefited from a more experienced surgical team due to the timescale of the study and the indirect benefits of the ERAS protocol on the blood losses.

Medications used for anaesthesia were heterogeneous over time in the ERAS group because not all anesthesiologists strictly followed the per-operative medication protocol due to their own practices and beliefs. The "sparing opioid strategy" includes: continuous infusion of lidocaine during the surgery at a dose of 2 mg/kg/h; S-ketamine (single dose or continuous); lowering or avoiding synthetic opioids; a single dose (1 µg/kg) of Morphine intrathecally (IT) prior to surgery.

The strategy of low-dose IT morphine is interesting, allowing the use of Piritramide PCA iv to be postponed until 24 h after the surgery in most cases. Some PCA had to be connected on the day of surgery because of imperfect analgesia or other discomforts linked to the operative position (headaches, etc.). The majority of patients in the ERAS group who received their PCA on the day of surgery were still present in the recovery room. The PCA is stopped after 48 h, and oxycodone (median 5 mg $p < 0,01$) is preferred to tramadol (median 0 mg $p < 0,01$) as a third level analgesia medication.

Total dose and daily doses of PCA Piritramide are lower in the ERAS group (median 28,5 mg $p = 0,025$) than the non-ERAS (median 40,5 mg $p = 0,025$).

VAS data are significantly lower on the day of surgery in the ERAS group (VAS median 4 ERAS vs 5,7 non-ERAS $p = 0,019$). There is no significant difference in our sample for VAS on other postoperative days.

More patients in the ERAS group report no PONV compared to the non-ERAS group.

Fewer patients report PONV in the ERAS group in comparison with the non-ERAS group. But these differences are not statistically significant.

Regarding our secondary outcome, the duration of urinary drainage is shorter in the ERAS group (median 1 day vs 2 days in the non-ERAS group, $p < 0,001$) and the return of the bowel function is reduced in that group (median 3 days vs 4 days in the non-ERAS $p = 0,014$)

The length of stay is shorter of 1,2 days in the ERAS group but due to the small size of our sample, this difference is not significant.

There is no difference in the blood management results because the same protocols were applied in the two groups.

In the ERAS group there is no surgical complication reported as no re-hospitalisation reported but the statistical power of our study is not high enough to allow a significant difference in terms of surgical complications. But regarding the re-hospitalisation levels, there is a high significant difference in the ERAS group (non-ERAS 8/28 vs ERAS 0/36 $p = 0,005$).

6. Discussion

Several studies evaluating an ERAS protocol for AIS highlighted a significant reduction in LOS and side effects (Sanders et al., 2017) (Young et al., 2019) (Seki et al., 2018) (Gornitzky et al., 2016) (Hong et al., 2017)

In our institution, the application of a multimodal ERAS perioperative approach for AIS surgery led to several positive outcomes.

The statistical power of our study is low but the application of a dedicated anaesthetic protocol associated with a multidisciplinary standardised follow up led to improve the outcome in terms of pain scores, return of bowel function, duration of urinary drainage and LOS. Consequently we reported a decrease in postoperative complications and re hospitalisation.

There is no related scientific evidence of a link between the use of anti-inflammatory drugs like Lidocaine, Alpha2 agonists, ketamine, and those outcomes.

It is proven that the reduction of the production of cytokines is effective with such "anti-inflammatory" drugs.

We postulate that by using a variety of anti-inflammatory drugs and consequently reducing pro-inflammatory cytokines production, there might be an impact on bowel function as seen in our study.

The heterogeneous adherence to the anaesthetic per-operative protocol makes it difficult to conclude more precisely about the link between the use of a variety of anti-inflammatory drugs and the outcome. The association of an IT dose of morphine and the use of dexmedetomidine and continuous iv lidocaine might be responsible for the improvement of the outcome in terms of pain scores.

It is interesting to note that we didn't record any respiratory side effects related to the use of a single low dose of IT morphine.

It is as noted that a slightly higher dose of IT morphine could help to increase the duration of analgesia in the early recovery time without major side effects and regarding our study, we have already modified our protocol.

The study of de Bie et al. (De et al., 2020) was focused on post-operative opioid consumption, pain level and complications and it appears that low dose of ITM reduces the morphine-related complication rate.

Hydrophilic morphine acts on opioid receptors with the brain and substantia gelatinosa of the spinal cord.

Dhaliwal et all. (Dhaliwal et al., 2018) concluded in a recent single centre, double blind, placebo-controlled trial that an injection of 0.2 mg of morphine intrathecally for lumbar fusion surgery was safe and reduced postoperative pain scores.

Pain intensity was lower in the ERAS group but joined the non ERAS group on day 3.

Morphine consumption was lower in the ERAS group. No major side effects were noted with the intrathecal injection of Morphine.

No heterologous transfusions were noted in the ERAS group compared to the non -ERAS (1 case)

A recent meta-analysis by Gadiya et al. (2021b) concluded that ERAS protocols applied to surgery for AIS reduce the LOS (average 1.44 days) with no change in readmission rates or complications rates compared to conventional protocols.

LOS was shorter in the ERAS group (1.2 days = 22% reduction) but not significantly. A more homogenous application of the protocol might lead to more accurate results.

As highlighted in several studies, it is feasible to implement a multidisciplinary peri operative protocol for AIS.

Between 2016 and 2018, Tondevold et al. evaluated a new protocol for AIS surgery (Tøndevold et al., 2021).

They recorded a reduction in LOS, postoperative nauseas and vomiting and pruritus compared to the control group. The time spent in the recovery room was reduced.

No other differences were seen in terms of pain or side effects.

In our review, PONV seems to be slightly lower in the ERAS group compared with the non-ERAS.

De Vries et al. (DeVries et al., 2020) described retrospectively the feasibility of implementing a rapid recovery pathway in their canadian centre between 2010 and 2019. They concluded at a significant reduction in LOS and implementing the new protocol was feasible.

Martin et al. analysing a multicenter registry determined that the 30 day readmission rate for AIS patients was 2.66%, and most frequently due to G-I disorders (Martin et al., 2015).

Overall minor and major complications incidence in adult spine fusion is up to 16% (Deyo et al., 2010)

The rate of complications following spinal fusion for AIS ranges from 5% to 23% (Murphy et al., 2016). Highest rate is reported when transfusions are considered as a complication of surgery (Vigneswaran et al., 2015).

In our study we do not report any major side effects in the ERAS group necessitating a re hospitalisation.

The re-hospitalisation rate is stunningly zero in the ERAS group at 30 and 90 days post-surgery. Overall complication rate is 26% in the non-ERAs group and zero for the ERAS group.

The main complications described in the literature are neurologic injury, infections, venous thromboembolism, G-I complications, blood loss requiring transfusion (Lykissas et al., 2013).

Our main complications in the non-ERAS group are: wound infections, hematoma, neurologic disorder,wound dehiscence, heterologous transfusion.

In a very recent retrospective analysis, Kwan et al. (2021) found a complication rate of 1.32% for minor complications (superficial infection, lung atelectasis, intraoperative seizure) and 0.95% for major complications (neurological deficit, deep infection, massive blood loss, SMAS (superior mesenteric artery syndrome) for AIS treated with single-staged PSF.

7. Conclusions

Our ERAS care pathway for AIS surgery involving experienced surgeons but with an heterogeneous application of anaesthesia protocol lead to improve consequently the outcome regarding the VAS scores, the morphine consumption, the LOS and the complication and re hospitalisation rates.

Regarding our results, ERAS care pathway for AIS surgery appears to be efficient in terms of benefits on complications rates, LOS and opioid consumption.

Intrathecal morphine and "anti-inflammatory" anaesthesia provides a good quality of pain management and allows the patient to get up early.

No major side effects were recorded using a low dose of 1 μg/kg intrathecal morphine.

Extended prehabilitation appears to be essential in the success of the protocol.

ERAS pathway seems to become a standard of care in AIS surgery. The efficiency of a defined ERAS care pathway involving all practitioners led to an early satisfactory recovery and a positive outcome after such a major surgery.

A superiority trial might be interesting to highlight the role of the ERAS pathway in AIS surgery.

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Competing interests

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