Original manuscript

Enhanced recovery following posterior spinal fusion for adolescent idiopathic scoliosis: a medical and economic study in a French private nonprofit pediatric hospital

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Abstract

Introduction

Little data exist on the efficacy of enhanced recovery after surgery (ERAS) protocols in patients undergoing posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS).

Hypothesis: ERAS reduces hospital costs (HC) and length of stay (LOS) without increasing pain or complications.

Materials and methods

This was a retrospective comparative medical and economic study of 2 cohorts of patients who underwent PSF for AIS: a prospective group who underwent surgery with an ERAS protocol without a specially assigned care coordinator from 2020 to 2021 (N = 30) and a retrospective group (control) who received standard care from 2017 to 2018 (N = 30). The key amendments to the ERAS protocol were reduced preoperative investigations, opioid-sparing analgesia, ambulation starting on postoperative day (POD) 1, early resumption of oral diet, and early transition to oral analgesics. Moreover, an intensive care unit (ICU) stay, surgical drainage, and the postoperative CT scan were no longer routine. The discharge criteria were the same for both groups: normal bowel function, independent walking, pain visual analog scale (VAS) < 3 without strong opioids, and no signs of complications. The endpoints were: decreased HC (calculated by subtracting the costs of hospital days and complementary exams that were not carried out) and LOS, complications, and postoperative pain according to the VAS on POD 1, POD 3, and discharge. All means were reported with the standard deviation.

Results

The mean age of patients undergoing surgery (14.5 ± 1.7 years), sex ratio, curve type according to the Lenke classification, mean Cobb angle (54 ± 12°), and the number of instrumented vertebrae (9 ± 2) were similar in both groups (p > 0.5).

The HC decreased on average by €3,029 per patient. The mean LOS was 5 ± 0.9 days in the ERAS group versus 6.5 ± 0.6 days in the control group (p < 0.001). The VAS scores on POD 1 and POD 3 were lower in the ERAS group. One postoperative complication was noted in each group.

Conclusion

Implementing an ERAS protocol without a specifically assigned care coordinator for patients with AIS undergoing PSF significantly decreased HC, LOS, and early postoperative pain.

Keywords: ERAS, adolescent idiopathic scoliosis, costs, length of stay, intensive care.
Level of evidence: III; Retrospective comparative study.

Abbreviations:

ERAS: enhanced recovery after surgery

LOS: length of hospital stay

HC: hospital costs

AIS: adolescent idiopathic scoliosis

PSF: posterior spinal fusion

IRB: institutional review board

POD: postoperative day

VAS: visual analog scale for pain

ICU: intensive care unit

Introduction

Over the past several years, healthcare developments have improved care and reduced hospital length of stay (LOS). Enhanced recovery after surgery (ERAS) is integral to this process [1]. This comprehensive, evidence-based care strategy facilitates early recovery after surgery. It is based on the patient's active participation in a predefined care pathway [1,2]. A care coordinator, usually the preoperative consultation nurse, is often tasked with implementing the patient pathway [2–7]. The key components of ERAS, as defined by the French national authority for health (HAS), are preoperative patient education about the procedure and recovery period, coordination of the different stages of perioperative care and patient discharge, reduction of surgical stress, optimal pain management, and stimulation of patient autonomy [8]. The benefits of ERAS in knee and hip arthroplasty have been well documented in the literature: accelerated functional recovery, reduced morbidity and anxiety, and improved subjective patient experience [1–3]. The principles and effects of ERAS following posterior spinal fusion (PSF) have recently been described [4–7]. However, few studies have focused on the reduction of hospital costs (HC) following the implementation of an ERAS protocol for adolescent idiopathic scoliosis (AIS) surgery. A direct reduction of HC has been observed in the USA and Australia, but their healthcare funding system differs from the ones in France and continental Europe [9–11].

The primary objective of this study was to assess the decrease in HC at a private nonprofit pediatric hospital following the implementation of an ERAS protocol for patients with AIS treated with PSF. The secondary objectives were to compare LOS and postoperative pain. We hypothesized that the ERAS protocol would reduce HC and LOS without increasing complications or early postoperative pain.

1) **Materials and Methods**

2.1) Patients

Starting in 2020, all patients undergoing PSF for AIS followed an ERAS protocol (Appendix 1). After receiving institutional review board approval (IRB no. 13.003), we prospectively enrolled a cohort of

30 consecutive patients who underwent PSF for AIS with an ERAS protocol between January 2020 and July 2021, out of a total of 67 spinal instrumentations. The data for the control group was obtained retrospectively from 30 consecutive patients who underwent PSF for AIS with standard care between July 2017 and the end of 2018, out of a total of 60 spinal instrumentations. The exclusion criteria were as follows: 1) patients who were operated during the rollout phase in 2019, 2) secondary scoliosis or other forms of spinal deformity (kyphosis, spondylolisthesis), 3) revision surgery, 4) osteotomy and/or thoracoplasty, and 5) patients who went to a rehabilitation facility after the surgery. Age at surgery, sex, type of AIS curve according to the Lenke classification, Cobb angle, and the number of instrumented vertebrae were recorded and compared between groups.

2.1) Protocol

A working group within our hospital developed the ERAS protocol. This group of experts, comprised of anesthesiologists, spine surgeons, and health managers from the various departments involved, based these guidelines on HAS recommendations [8] and the recent literature [2, 4-7]. As a result, the following amendments were made to the standard protocol:

Preoperative phase:

- Limit the number of laboratory, radiologic, and diagnostic studies ordered (Table 1, details in Appendix 1)

- Optimize preoperative hemoglobin levels with iron supplementation ± erythropoietin if the patient is anemic

- Assess whether the patient is prone to constipation and give them a bowel preparation pamphlet.

Intraoperative phase:

- Avoid routine placement of central venous catheters and invasive blood pressure monitoring

- Intraoperative opioid-sparing analgesia (spinal anesthesia with intrathecal morphine and the introduction of ketamine and dexamethasone)

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- Surgical drainage is to be carried out on a case-by-case basis.

Postoperative phase:

- Liquid diet resumed in the post-anesthesia care unit

- Transfer to the intensive care unit (ICU) after surgery is not systematic

- Starting on POD 1: mobilization defined here as standing and walking; multimodal analgesia with a transition to oral pain medication, and removal of urinary catheter as soon as possible

- The postoperative CT scan is no longer performed systematically, but only if there is a clinical or radiologic suspicion about the positioning of an implant.

Our protocol did not call for a specifically assigned care coordinator or distinct post-discharge care pathways, but we continued to provide standard nursing care and physical therapy. The surgeon was the protocol coordinator, and the anesthesiologist and physical therapists were the primary team members. These committed actors explained the key elements of our protocol to patients: early mobilization, the shortest possible hospital stay, and prevention of constipation.

2.3) Surgical procedure and postoperative care

All PSFs were performed either in tandem or individually by 2 attending surgeons (JLC, FS) in a pediatric orthopedic operating room. The AIS was corrected by simultaneous translation on 2 rods with high-density implant constructs [12, 13].

Drainage of the surgical site was systematically performed in the control group and left to the surgeon's discretion in the ERAS group. The discharge criteria were the same for both groups: no signs of complications, resumption of gastrointestinal motility, ability to negotiate stairs independently, and pain visual analog scale (VAS) < 3 without strong opioids (e.g., morphine).

2.4) Endpoints

The primary endpoint was the reduction of HC (Table 1), which was calculated by adding the savings associated with the following:

- The cost of items not used in the ERAS group: consumables, complementary exams, etc.

- The decrease in LOS and the number of days spent in the ICU.

The total unspent amount was then divided by 30 to estimate the mean decrease.

The secondary endpoints were:

- LOS

- Pain intensity measured by VAS at 8:00 a.m. on POD 1, POD 3, and day of discharge

- Gastrointestinal motility on POD 5

- Complications before POD 30

- Family satisfaction in the ERAS cohort was collected with the following direct question: "Are you satisfied with your child's overall care?" The possible answers were: very satisfied, somewhat satisfied, fairly satisfied, and unsatisfied.

2.5) Statistical analysis

The number of subjects required was calculated based on the primary clinical outcome (i.e., decreased LOS). The mean LOS was 6 days in the ERAS group. We estimated the mean LOS of the control group to be 7 days based on our historical data and considered a decrease of 1 day in LOS to be clinically relevant. The level of significance (α) and the power (1-β) were set at 0.05 and 0.95, respectively. This resulted in 27 subjects per group, which we rounded to 30. No data was missing. The qualitative variables were compared with Fisher's exact test, and the quantitative variables were compared with the t-test. A multiple linear regression was used to assess the influence of the different parameters on the LOS.

2) **Results**

Both groups had similar pre- and intraoperative characteristics (Table 2).

The HC was reduced on average by €3,029 per patient. The mean LOS was 6.5 ± 0.6 days in the control group versus 5 ± 0.9 in the ERAS group (p < 0.001). The multivariate analysis showed that LOS was only affected by the ERAS protocol (Table 3).

Families in the ERAS group responded that they were "very satisfied" in 27 cases and "somewhat satisfied" in 3 cases.

All other findings are presented in Tables 1 and 2. Two complications were reported: a distal screw malposition in the intradiscal space in the control group, with no clinical consequences, and a recatheterization on POD 2 (urinary catheter removed on POD 1) in the ERAS group.

3) Discussion

The ERAS protocol reduced HC by around €3,000 per patient without adversely affecting clinical parameters, thus validating our working hypothesis. This saving is consistent with the findings of Dass et al., who reported a decrease of approximately €2,400 [11]. However, our estimate did not consider the reduction in nursing time associated with the expedited removal of various catheters and lines or their total absence.

The elimination of complementary exams carried out during hospitalization accounts for about 1/8 of the total savings for the hospital, which collects the same flat-rate revenue while consuming fewer resources. For instance, except for exceptional cases, pulmonary function tests and echocardiograms are no longer recommended [14, 15]. Although noninvasive, these exams added an extra step in the preoperative pathway that was sometimes difficult to complete because of the shortage of providers. The elimination of the CT scan warrants a separate mention. While CT scans were performed in the control group to measure vertebral rotations [13], they were removed from our ERAS protocol because it is no longer conceivable to perform this radiation-producing exam outside an IRB-approved study.

Finally, decreased LOS for pediatric patients resulted in reduced societal costs associated with the accompanying parent's professional inactivity.

In our study, LOS in the ERAS pathway was reduced by a mean of 1.5 days. This is in the lower limit of results found in the literature, with studies reporting decreases between 1.7 and 3 days [6, 16–18]. However, in the study conducted by Fletcher et al., the perioperative data were not comparable between the 2 groups, which could explain the greater reduction in LOS than in our study [16].

The incidence of anxiety disorders is greater in AIS patients than in the general population, which may lengthen the LOS following a PSF [19–22]. However, the stress associated with hospitalization and discharge home is probably lessened by the improved preoperative education and the reduction of unnecessary care: continuous monitoring, surgical drainage, infusions, CT scans, etc. [20].

Dass et al. demonstrated the direct impact of eliminating the stay in an ICU after surgery with a mean reduction in LOS of 1.8 days [11]. The fact that our study reported no respiratory depression or other signs of opioid overdose associated with a direct transfer to the surgical unit also confirmed the current trend in the literature [11].

Estimating each parameter's effect on the LOS is difficult. Among the modifiable criteria, a higher cumulative dose of morphine and more intense pain on POD 1 negatively impact LOS [23, 24]. This notion supports our "maximalist" intraoperative analgesic protocol, consisting of spinal anesthesia with intrathecal morphine, which lasts up to 30 hours after injection [25]. The various operative times and the different number of instrumented levels reported in the published studies [2, 6, 16, 17] could explain the variations in LOS.

Multimodal analgesia and early mobilization help decrease the systemic morphine dose and reduce its side effects: nausea, constipation, opioid-induced hyperalgesia, and opioid misuse after discharge [18, 23]. In the ERAS group, the pain scores were lower on POD 1 and POD 3, thus confirming how important this approach is for the well-being of these patients [11]. A prospective study on the erector spinae block, which could further reduce opioid use, is currently underway in the USA.

While accelerating recovery is important, it should not come at the expense of quality and safety of care, which remains our priority. Consequently, we decided not to amend our discharge criteria or

impose discharge if the families did not feel ready. Unfortunately, a minor complication (acute urinary retention) occurred in the ERAS group because the bladder catheter was removed too soon.

The prevention of constipation is paramount. The screening for patients prone to constipation during the anamnesis and preventive and curative measures have limited the onset of this condition and, indirectly, decreased LOS. Unfortunately, we could not find the exact date of the first bowel movement, but the gastrointestinal motility on POD 5 was significantly better in the ERAS group.

For some authors, ERAS requires a specifically assigned care coordinator [2]. However, the ERAS concept involves all caregivers and our protocol broadly complies with its guidelines (Appendix 1). We are also convinced of the benefits of a dedicated caregiver, which, unfortunately, was, and still is unavailable in our hospital.

The main limitation of this study was the retrospective analysis of the control group. However, most studies on this topic employ a similar methodology. The small sample size could also have been a limitation; however, the power was optimal ($1-\beta > 95\%$) since it was previously defined.

Due to a lack of data, we did not analyze the parents' social, occupational, and economic status and could not assess its impact on LOS and HC. However, in the French study by Michel et al., the most disadvantaged patients only had an increase in LOS of 3% (odds ratio: 1.03) compared to the national average [26].

Conclusion

Implementing an ERAS protocol without a specifically assigned care coordinator for patients with AIS undergoing PSF significantly decreased HC, LOS, without increasing postoperative pain or complications.

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Table 1:   Items removed or unused in the ERAS protocol and balance sheet

	Items	R or U*	Cost per unit (€)	N	Cost per item (€)	Exam performed only if:
Preoperative workup	Blood tests**	R	31	30	930	
	Urinalysis	U	17.55	30	526.5	If clinical signs or history
	Echocardiogram	U	96.49	30	2,894.7	If clinical signs or history
	Chest X-ray	R	21.28	30	638.4	If the anteroposterior full spine X-ray is not sufficient
	X-ray of the hand for bone age	U	19.95	27	538.65	If a Risser stage 0 or 1, or if uncertain
	X-ray of the gibbus	R	31.92	30	957.6	
	Sinus X-ray	R	19.95	30	598.5	If clinical signs of sinusitis
	Pulmonary function test	U	76.8	29	2,227.2	If dyspnea, history, or Cobb angle > 70°
	CT scan of the spine	R	25.27	30	758.1	
Intraoperative invasive blood pressure monitoring		U	21.3	24	511.2	Left to the discretion of the anesthesiologist, depending on the fixation and the patient's preop condition
Bone substitute		U	151	29	4,379	Left to the discretion of the surgeon, depending on the construct solidity
Surgical drain		U	13.1	7	91.7	Depending on the intraoperative blood loss
Postoperative CT scan of the spine		U	25.27	29	732.83	If presenting warning signs of implant malposition
Days of hospitalization in the intensive care unit		U	350	10	3,500	Depending on how the procedure went and the pain level upon waking
Days of hospitalization in the surgical unit			1,556.1	46	71,580.6	
TOTAL (€)					90,865	
MEAN COST PER PATIENT = TOTAL/30					3,028.83	

* Removed (R) or Unused (U)

** Deleted tests: AST, ALT, GGT, Prothrombin ratio, Cl-, Na+, K+, Ca++, Phosphate, and Urea.

Table 2: Characteristics and results.
The quantitative variables are presented as follows: mean [min-max]

Parameters	Control group	ERAS* group	p
Number of patients	30	30	-
Age (years)	14.5 [11–18]	14.7 [12–17]	0.7
Lenke curve type (N per type from 1 to 6)	19, 3, 1, 0, 6, 1	17, 4, 2, 0, 5, 2	0.8
Number of levels fused	9.1 [5–12]	9.0 [5–12]	0.7
Implant density (%)	73 [55–100]	75 [58–100]	0.8
Preoperative Cobb angle (°)	54 [38–92]	54 [39–86]	0.6
Coronal curve correction (%)	71 [48–95]	69 [52–89]	0.6
Drainage (N)	30/30 (100%)	23/30 (77%)	**0.001**
Length of stay (nights)	6.5 [5–8]	5.0 [4–7]	**E-5**
Stays in an intensive care unit (N)	30/30 (100%)	20/30 (67%)	**E-5**
1st mobilization (POD)	2.2 [1–4]	1.0 [1–2]	**E-4**
Urinary catheter removed (POD)	2.6 [2–4]	2.1 [1–3]	**0.01**
Morphine infusion stopped (POD)	2.9 [2–5]	2.2 [1–3]	**0.001**
Pain on POD 1 (VAS**)	3.6 [0–7]	2.4 [0–6]	**0.008**
Pain on POD 3 (VAS**)	5.3 [0–8]	4 [1–7]	**0.005**
Pain at discharge (VAS**)	1.6 [0–3]	1.3 [0–3]	0.3
Gastrointestinal motility on POD 5 (N per category***)	2, 6, 11, 11	1, 7, 1, 22	**0.003**
Complications (N)	1	1	1

*ERAS: enhanced recovery after surgery
**VAS: visual analog scale
***No bowel movements, flatus, stools with enema, spontaneous stools
   In bold, p < 0.05

Table 3: Multivariate linear regression (length of stay)

Independent variable	Coefficient	Standard error	p	95% confidence interval	
Constant	7.712	0.882	**E-12**	5.945	9.479
Age (years)	-0.088	0.060	0.144	-0.207	0.031
Number of instrumented vertebrae	0.000	0.000			
Preoperative Cobb	0.000	0.000			
Drainage (yes/no)	0.000	0.000			
Intensive care unit (yes/no)	0.000	0.000			
ERAS pathway	-1.435	0.198	**E-9**	-1.831	-1.039
Standard pathway	0.000	0.000			

The equation for the model:
Length of stay (POD…) = 7.7-8.8E-02*age-1.43*ERAS pathway
$R^2 = 0.49$
In bold, p < 0.05