



Enhanced Recovery After Surgery Protocol in Minimally Invasive Lumbar Fusion Surgery Reduces Length of Hospital Stay and Inpatient Narcotic Use

Isabelle C. Band¹, Altan O. Yenicay², Tina D. Montemurno², Jenny S. Chan², Alfred T. Ogden^{3,4}

BACKGROUND: The application of enhanced recovery after surgery (ERAS) has the potential to improve outcomes, hasten patient recovery, and reduce costs. ERAS has been applied to spine surgery for several years, but data are limited around the impact of ERAS on minimally invasive spine surgery, specifically. The authors report their experience implementing a multimodal ERAS protocol for patients receiving minimally invasive transforaminal lumbar interbody fusion.

METHODS: The ERAS protocol was implemented at The Valley Hospital Hospital in Ridgewood, New Jersey in January 2020. Following implementation, all patients receiving minimally invasive transforaminal lumbar interbody fusion by a single surgeon were studied. The authors analyze the impact of the protocol on length of stay (LOS), disposition post discharge, and opioid consumption postoperatively in the inpatient and outpatient settings.

RESULTS: Sixteen patients were enrolled in the protocol and compared with 17 historical controls. LOS was significantly shorter in the ERAS cohort (1.6 vs. 2.4 days, $P = 0.022$). There was no significant difference between the groups with respect to disposition; the majority of patients were discharged to home without need for in-home medical services. Patients in the ERAS cohort consumed significantly fewer opioid analgesics postoperatively in the inpatient setting (51 mg morphine milligram equivalents vs. 320 mg morphine milligram equivalents, $P = 0.00016$). On average, patients in the ERAS cohort were prescribed fewer opioids analgesics post discharge.

CONCLUSIONS: ERAS application to minimally invasive transforaminal lumbar interbody fusion was safe and effective, significantly reducing LOS and inpatient opioid consumption. These data reflect the importance of uniformly applying a multimodal ERAS protocol to accelerate recovery and reduce narcotic use.

INTRODUCTION

The concept of enhanced recovery after surgery (ERAS), otherwise known as “fast track surgery,” refers to a multidisciplinary, multimodal perioperative care approach that aims to accelerate patient recovery after surgery, improve functional outcomes, and maintain high standards of care.¹ ERAS was first outlined by Danish anesthesiologist Dr. Henrik Kehlet in 1997.² Since then, the movement has been adopted in multiple surgical specialties including gynecology, hepatobiliary, urology, colorectal, head and neck, breast, and bariatric surgery.³ As the earliest discipline to adopt ERAS, colorectal surgery offers substantial literature supporting its benefit,⁴ including evidence that ERAS results in significant reductions in morbidity, length of stay (LOS) and cost, and improvements to patient satisfaction.^{5,6}

ERAS has been applied to spine surgery over the past several years. The ERAS Society, formed in 2010, has proposed a range of consensus guidelines for a number of surgeries.⁷ In 2021, the group published evidenced-based recommendations for lumbar fusion surgery according to the Grading of Recommendations,

Key words

- Enhanced recovery after surgery
- Fast-track surgery
- Minimally invasive surgery
- Spine surgery

Abbreviations and Acronyms

ERAS: Enhanced recovery after surgery

LOS: Length of stay

MIS-TLIF: Minimally invasive—transforaminal lumbar fusion

MME: Morphine milligram equivalents

From the ¹Icahn School of Medicine, Mount Sinai Hospital, New York, New York; and the Departments of ²Anesthesiology and ³Neurosurgery, The Valley Hospital, Ridgewood, New Jersey, and ⁴Neurosurgery, NYU Langone Hospitals, New York, New York, United States

To whom correspondence should be addressed: Isabelle C. Band, B.A.
[E-mail: isabelle.band@icahn.mssm.edu]

Isabelle C. Band, Altan O. Yenicay, and Tina D. Montemurno contributed equally to this work.

Citation: *World Neurosurg.* X (2022) 14:100120.

<https://doi.org/10.1016/j.wnsx.2022.100120>

Journal homepage: www.journals.elsevier.com/world-neurosurgery-x

Available online: www.sciencedirect.com

2590-1397/© 2022 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Assessment, Development, and Evaluation (GRADE) system.⁷ Twenty-eight recommendations were included, but the guidelines lack specificity, particularly around anesthetic techniques and opioid use postoperatively.⁷

While existing literature suggests that ERAS has the potential to improve outcomes and speed up recovery in spine surgery, the literature is limited. Only a handful of studies examine the role of ERAS in minimally invasive spine surgery.^{8–16} Four studies specifically investigate the impact of ERAS in minimally invasive—transforaminal lumbar interbody fusion (MIS-TLIF).^{13–16} Of those studies, all 4 showed that an ERAS protocol significantly reduced LOS and 2 showed that it reduced in-hospital opioid usage.^{15,16} While this study also examines the impact of ERAS on LOS and inpatient opioid usage in MIS-TLIF, it is the only study to also look at whether the implementation of ERAS can reduce the amount of opioids used in the outpatient setting post-discharge, as well as whether it can increase the number of patients that can be discharged to their homes rather than to a rehabilitation facility or home health center. Compared with existing literature, this study also provides a more detailed description of the ERAS anesthetic protocol, such that it could be easily reproduced at other institutions. The goal of this study is to provide practical, detailed recommendations for an ERAS protocol in patients receiving a specific, uniform spinal surgery, MIS-TLIF.

MATERIALS AND METHODS

Study Design

This is a prospective cohort analysis to evaluate the impact of an ERAS protocol for patients undergoing single-level MIS-TLIF. The control and study groups consist of consecutive patients undergoing single MIS-TLIF by the same attending neurosurgeon (A.O.) at The Valley Hospital in Ridgewood, New Jersey from February 26, 2019 to January 26, 2021, immediately before and after the implementation of an ERAS protocol, on January 11, 2020. The protocol was adapted from the protocol used at the Department of Neurological Surgery at Rush University (John O'Toole, M.D.) after discussions between the Departments of Neurological Surgery and Anesthesiology at The Valley Hospital (Figure 1).

Inclusion and Exclusion Criteria

The following inclusion criteria were used: any patient undergoing single-level MIS-TLIF for degenerative disease by a single surgeon at a single institution between the study dates. The following exclusion criteria were used: chronic opioid use as defined by opioid use for >90 days on most days or the preexisting diagnosis of chronic neurologic disease (multiple sclerosis, Parkinson disease).

Control (Pre-ERAS) Group

A historical cohort of the last 18 consecutive patients before implementation of the ERAS protocol from February 26, 2019 to January 10, 2020 was identified as meeting the study criteria. One patient was excluded due to chronic opioid use. A second patient was excluded from the analysis for 2 endpoints—opioids prescribed in first postoperative prescription and opioids prescribed in first postoperative prescription plus subsequent refills—because the data were not available.

ERAS Group

Seventeen consecutive patients from January 11, 2020–January 26, 2021 were identified as meeting study criteria. All were enrolled in the ERAS protocol. One patient was excluded due to a diagnosis of multiple sclerosis.

Preoperative Outpatient Phase

All patients underwent a preoperative medical assessment and intervention that included optimization of chronic disease management (diabetes, hypertension), a discussion regarding weight loss when appropriate, a cessation of all nicotine products for tobacco users as evidenced by a negative preoperative urine cotinine test, and a preoperative education, counseling, and hospital orientation session by a nurse practitioner. Although this kind of multidisciplinary preoperative protocol is a key element in any ERAS protocol, it should be noted that the protocol outlined earlier was already in place as part of the surgeon's regular practice before implementation of the in-patient ERAS protocol and was therefore available to all patients in the study.

Preoperative Inpatient Phase

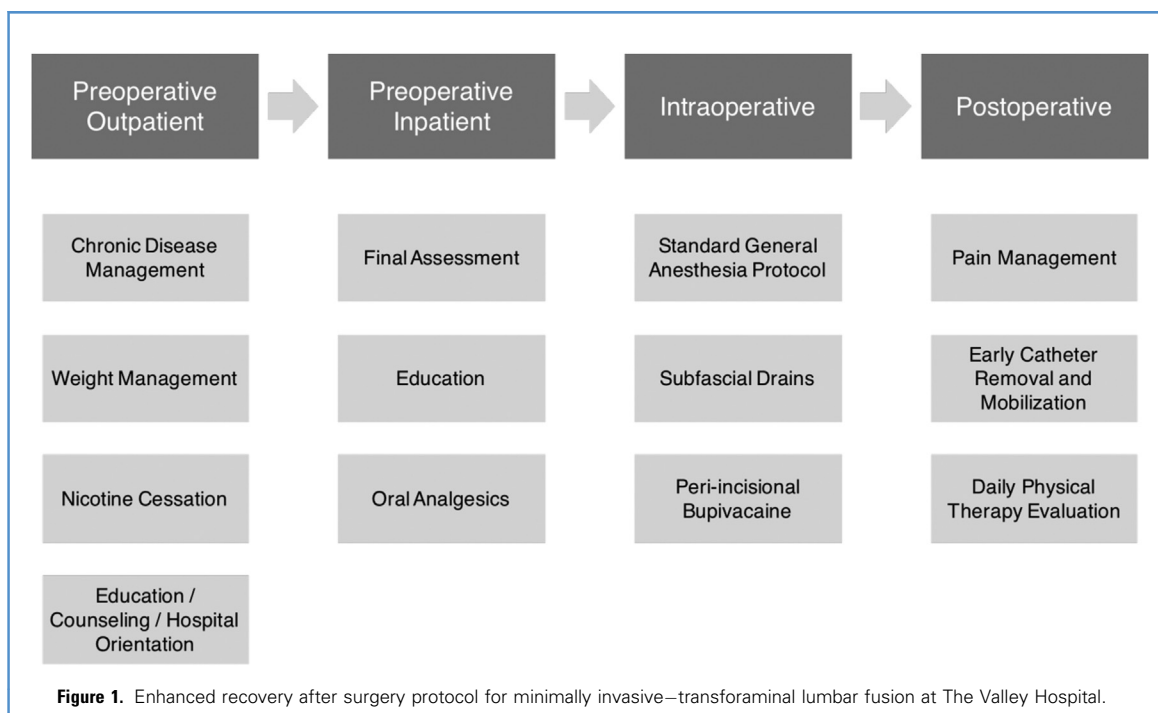
All patients, control and ERAS, received a final assessment and education from the attending surgeon, anesthesiologist, and neurophysiologist the day of surgery. The key difference between the ERAS and control cohorts during this phase involved the preoperative administration of oral analgesics to patients in the ERAS cohort. Each ERAS patient received the following medicines in the preoperative area: acetaminophen 1 gm, baclofen 10 mg, oxycontin 20 mg, and gabapentin 300 mg.

Intraoperative Phase

All patients received general anesthesia and were given periincisional bupivacaine 0.5% 20 mL on wound closure. All patients received subfascial drains, which were removed 1 day postoperatively. In the control group, there was no standard general anesthesia protocol other than the usual constraints necessary to permit intraoperative monitoring. In the ERAS cohort, the following anesthesia protocol was followed:

The following 5 elements were essential to the ERAS protocol and were included in all cases:

1. Ketamine and/or dexmedetomidine infusion for the duration of the case. Ketamine 0.5 mg/kg bolus up to max of 50 mg, followed by 0.5 mg/kg/hour. Use 0.6 mg/kg/hour for opiate-dependent patients.
- OR
- a. Dexmedetomidine 0.4 mcg/kg/hour. Range can be 0.25–0.5 mcg/kg/hour with lower doses used for older patients.
2. Dexamethasone 10 mg IVP.
3. Zofran 4 mg IVP.
4. Limit or eliminate long-acting narcotics.
5. Minimize short-acting opioids derivatives. Intraoperative and postanesthesia care unit use of fentanyl are left to the discretion of the anesthesiologist.



- Avoid remifentanyl infusion due to data revealing that it can cause postoperative opioid-induced hyperalgesia.
- Low or minimal dose of fentanyl can be used as part of the anesthesia induction phase to assist with intubation.
- Low or minimal dose of hydromorphone (Dilaudid) can be given before surgical incision.

To allow for a quick emergence for the postoperative neurologic checks, ketamine or dexmedetomidine infusions were tapered down and then stopped approximately 45 minutes before the completion of surgery. This allows adequate time for medication clearance. Given that dexmedetomidine can suppress the amplitude of motor evoked potentials at higher doses, a bolus before starting the infusion or an infusion rate above 0.5 mcg/kg/hour were both avoided. Ketamine drip can falsely increase the amplitude of motor evoked potentials. Midazolam was also used in conjunction with ketamine to limit emergence phenomena.

Postoperative Phase

Postoperatively, all patients were prescribed baclofen 10 mg orally 3 times daily as needed, gabapentin 300 mg every night at bedtime, and acetaminophen (Tylenol) 650 mg orally every 4–6 hours as needed. In addition, an escalating opioid protocol was followed: tramadol → hydrocodone → oxycodone → Dilaudid PCA. If a patient experienced nausea/vomiting with hydrocodone/oxycodone that did not respond to Zofran, Dilaudid 2 mg orally every 6 hours was prescribed. If oral opioids did not sufficiently address a patient's pain complaints, a Dilaudid PCA was ordered. Fentanyl was minimally used intraoperatively or postoperatively.

All patients received intraoperative urinary catheters. In the ERAS group, urinary catheters were removed and patients were mobilized on the day of surgery. In the control group, no specific protocol was followed.

All patients received a daily physical therapy evaluation and, with the exception of 1 patient, were discharged to home. The day of discharge was determined by medical need, daily physical therapy assessments, pain control, assessment by social work, and patient input.

New Jersey state law limits postoperative outpatient prescriptions of controlled substances to a 5-day supply. At discharge, prescriptions for a 5-day supply were estimated after reviewing the patient's in-house opioid intake. Patients were also prescribed gabapentin, baclofen, and acetaminophen and encouraged to use these medicines before using opioids. A second prescription renewing for opioids was only provided if necessary.

Study Parameters

Study outcomes included the following: hospital LOS (days), disposition post hospital stay (e.g., to rehab, home health service or home), opioid consumption postoperatively in hospital, opioids in the first postoperative prescription, and opioids in the first postoperative prescription plus in any subsequent refills.

The amount of opioids ingested or prescribed was calculated by converting to morphine milligram equivalents (MME) using standard conversion formulas.^{17–20} Although there is some debate as to whether tramadol is an opioid, the FDA defines it as such and thus it was factored into the calculation of total opioid use.²¹ A subanalysis of patients who received only tramadol was performed.

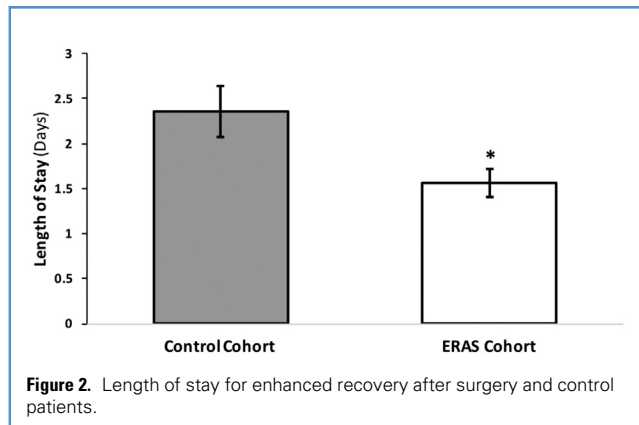


Figure 2. Length of stay for enhanced recovery after surgery and control patients.

Statistical Analysis

Comparisons among various patient characteristics and outcomes for the 2 patient groups (control vs. ERAS) were performed with independent 2-sample t-tests.

RESULTS

The control (pre-ERAS) group consisted of 17 analyzable patients for 3 endpoints (LOS, disposition post-hospital stay, opioids consumed in hospital post surgery) and 16 analyzable patients for 2 endpoints (opioids received in first postoperative prescription and opioids received via subsequent refills). The ERAS group included 16 analyzable patients across all endpoints. The 2 groups were similar (ERAS mean vs. control mean) in age, body mass index, history of prior spine surgery, preoperative narcotic use, and smoking status. Medical comorbidities in the 2 groups were not significantly different.

Statistically significant results were seen for 2 parameters: LOS and opioid consumption postoperatively in hospital. LOS was significantly reduced in the ERAS group versus the control group (1.6 vs. 2.4 days, $P = 0.022$) (Figure 2). There was no significant difference between the 2 groups with respect to disposition. In both groups, most patients were discharged to home without the need for in-home medical services (14 patients in ERAS vs.

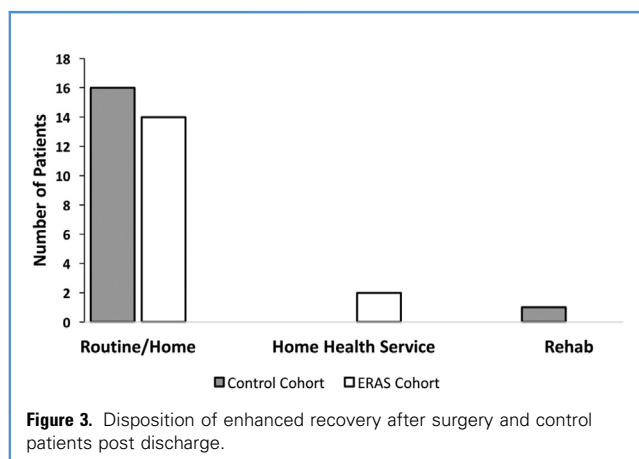


Figure 3. Disposition of enhanced recovery after surgery and control patients post discharge.

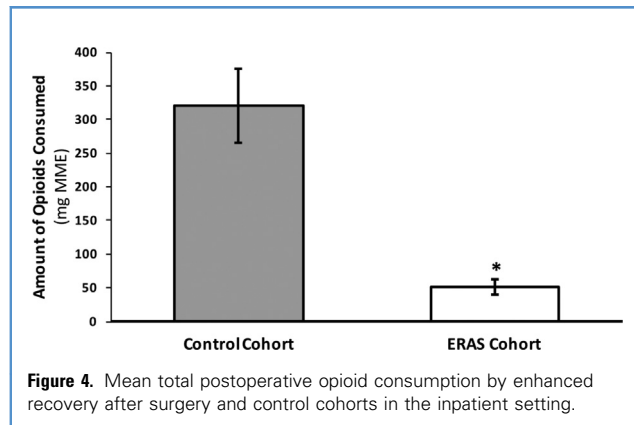


Figure 4. Mean total postoperative opioid consumption by enhanced recovery after surgery and control cohorts in the inpatient setting.

16 in control) (Figure 3). Two patients in the ERAS cohort were discharged with home health services versus zero in the control group. One patient in the control group was discharged to a rehabilitation center versus zero in the ERAS group.

Postoperative in-hospital opioid consumption was significantly reduced in the ERAS cohort versus the control group (51 mg MME vs. 320 mg MME, $P = 0.0002$) (Figure 4). The patients in the ERAS cohort received, on average, fewer MME in their first postoperative prescription versus the control group (329 mg MME vs. 452 mg MME, $P = 0.2$) (Figure 5) and in their first postoperative prescription plus subsequent refills (387 mg MME vs. 667 mg MME, $P = 0.14$) (Figure 6). Four patients in the ERAS group were managed on tramadol only in their first postoperative prescription and subsequent refills versus only 1 patient in the control group. On average, patients in the ERAS cohort who received tramadol only received fewer milligrams of morphine equivalents in their first postoperative prescription and subsequent refills versus patients in the control cohort (150 mg MME vs. 230 mg MME).

DISCUSSION

After the implementation of a multimodal ERAS protocol at The Valley Hospital, 16 consecutive patients were enrolled in the ERAS protocol and were compared with 17 consecutive historical

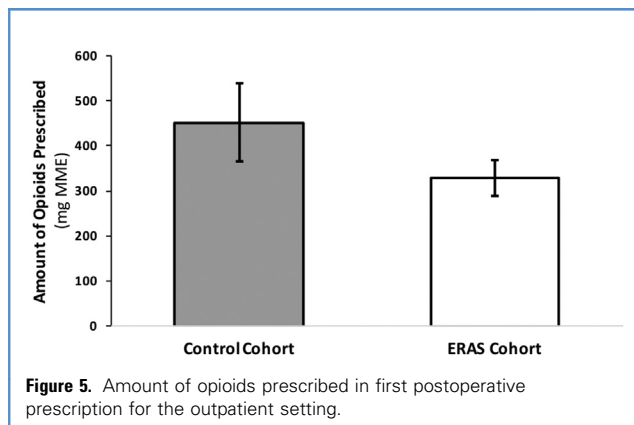
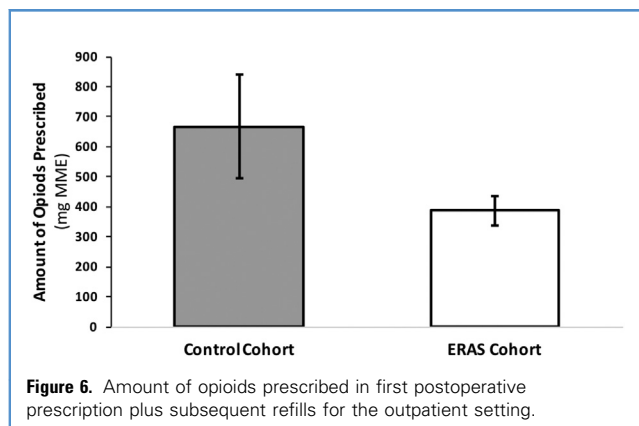


Figure 5. Amount of opioids prescribed in first postoperative prescription for the outpatient setting.



controls. LOS was significantly shorter in the ERAS cohort than in the control cohort (1.6 vs. 2.4 days, $P = 0.022$). Though there was no significant difference between the 2 groups with respect to disposition, most patients in both groups were discharged to home without the need for in-home medical services (14 patients in ERAS vs. 16 in control).

With respect to pain management, the ketamine drip was found to be oversedating in a subset of patients and was thus largely abandoned with preference for dexmedetomidine drip. The dexmedetomidine drip reduced the need for extra narcotics. Remifentanyl was avoided in most patients due to findings that it can cause postoperative opioid-induced hyperalgesia, especially in chronic pain management patients. In ERAS patients, regular fentanyl was used sparingly during the surgery and after the surgery in the postanesthesia care unit. Postoperatively in the inpatient setting, the ERAS cohort consumed significantly fewer opioids versus the control cohort (51 mg MME vs. 320 mg MME, $P = 0.0016$). On average, patients in the ERAS cohort were prescribed fewer opioids post discharge, but outpatient opioid consumption was not significantly reduced. Outpatient pill counting was not feasible in this study, which may have accounted for the lack of statistically significant results for this endpoint.

The demand for lumbar fusion surgery is increasing worldwide; however, variability in postoperative pain, LOS, patient satisfaction, and functional outcomes is widely observed.¹³ The implementation of an ERAS protocol has been proposed as an approach to improving outcomes, reducing cost, and increasing patient satisfaction in spine surgery. Over the past several years, evidence has demonstrated the multiple potential benefits that ERAS offers to the field of spine surgery. For one, ERAS has been shown to be more cost effective than traditional care approaches.^{3,13,19,20} It has also been found to significantly reduce LOS,^{3,8-10,13,14,19,21-26} length of intensive care unit stay,^{3,19} postoperative pain scores,^{9,20,21} amount of opioids used postoperatively in the hospital,^{9,12,21-23,27,28} and postoperative catheterization.^{22,26,27} Evidence also suggests that ERAS in spine surgery may reduce the amount of rescue antiemetic medications used,²⁹ readmission rate,^{25,30} and reoperation rate.²⁵ Finally, ERAS has been shown to significantly increase patient and staff satisfaction,⁹ allow patients to mobilize/ambulate sooner or better,^{9,21-23,25-28,31} and take food sooner.²⁶

Despite a growing body of evidence on the impact of ERAS protocols in spine surgery, there are limited data on the impact of a comprehensive ERAS protocol MIS-TLIF specifically. Such studies are important because they have the ability to separate the impacts of a less invasive surgical approach from the impacts of other aspects of the ERAS protocol. The primary interventions that distinguished the ERAS group from the control group were the preoperative administration of oral analgesics, the intraoperative administration of ketamine or dexmedetomidine, a focus on earlier mobilization, and a postoperative analgesic protocol that consciously sought to promote the use of nonopioid medications while reducing the use of opioids. Ketamine or dexmedetomidine, as intraoperative adjuvant anesthesia for multimodal analgesia, was used as a nonnarcotic option for pain control. This resulted in a statistically significant reduction in LOS and in-hospital opioid use and nonstatistically significant trends in lower outpatient opioid intake.

Limitations

This study is limited due to the fact that it is a before-and-after cohort analysis; no randomization or blinding was performed. The control group was historical, and data were gathered retrospectively from medical records of patients who received surgery before the implementation of the ERAS protocol. However, comparisons between the 2 groups remain valid and the results are likely generalizable, due to the nonstandardized nature of spine surgery before ERAS implementation.

Future Directions

Future studies may look at opioid use post discharge in more detail. While we collected data on the amount of pain medication patients were prescribed at discharge and in subsequent refills, we were not able to follow up with patients on how much pain medication they actually chose to take. Collecting such data would allow us to develop a more accurate understanding of the impact of the ERAS protocol on pain medication intake post surgery (e.g., at 1 week post surgery, 1 month post surgery, 3 months post surgery).

Other directions for future research include investigating the use of NSAIDs and drains and liposomal bupivacaine versus unbound bupivacaine.

Over time, we will also be able to study long-term outcomes associated with ERAS protocols. We also hope to confirm our current findings with a prospective, randomized clinical trial, which would allow for better comparison between cohorts and reduce reporting biases.³¹

CONCLUSIONS

We have created and implemented a practical, detailed ERAS protocol targeting patients receiving MIS-TLIF. Data have shown a significant reduction in LOS and inpatient opioid use postoperatively and an increase in the number of patients who can return home, rather than to a rehabilitation facility or home health center, post discharge. We hope that, as prospective controlled or randomized trials generate additional evidence supporting the efficacy of ERAS approaches in spine surgery, this protocol will be applied in a standardized manner where possible.

CRedit AUTHORSHIP CONTRIBUTION STATEMENT

Isabelle C. Band: Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Altan O. Yenicay:** Methodology, Writing – review & editing. **Tina D. Montemurno:** Methodology, Writing – review & editing. **Jenny S. Chan:** Methodology, Writing – review & editing. **Alfred T. Ogden:**

Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision.

ACKNOWLEDGMENT

The ERAS protocol was derived from a Rush University protocol (John O'Toole, M.D.).

REFERENCES

- Corniola MV, Debono B, Joswig H, Lemée JM, Tessitore E. Enhanced recovery after spine surgery: review of the literature. *Neurosurg Focus.* 2019;46:E2.
- Kehlet H. Multimodal approach to control postoperative pathophysiology and rehabilitation. *Br J Anaesth.* 1997;78:606-617.
- 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.
- Elsarrag M, Soldozy S, Patel P, et al. Enhanced recovery after spine surgery: a systematic review. *Neurosurg Focus.* 2019;46:E3.
- Greco M, Capretti G, Beretta L, Gemma M, Pecorelli N, Braga M. Enhanced recovery program in colorectal surgery: a meta-analysis of randomized controlled trials. *World J Surg.* 2014;38:1531-1541.
- Visioni A, Shah R, Gabriel E, Attwood K, Kukar M, Nurkin S. Enhanced recovery after surgery for noncolorectal surgery? A systematic review and meta-analysis of major abdominal surgery. *Ann Surg.* 2018;267:57-65.
- Debono B, Wainwright TW, Wang MY, et al. Consensus statement for perioperative care in lumbar spinal fusion: enhanced recovery after surgery (ERAS) society recommendations. *Spine J.* 2021;21:729-752.
- Debono B, Corniola MV, Pietton R, Sabatier P, Hamel O, Tessitore E. Benefits of enhanced recovery after surgery for fusion in degenerative spine surgery: impact on outcome, length of stay, and patient satisfaction. *Neurosurg Focus.* 2019;46:E6.
- Liu VX, Rosas E, Hwang J, et al. Enhanced recovery after surgery program implementation in 2 surgical populations in an integrated health care delivery system. *JAMA Surg.* 2017;152:e171032.
- Staatjes VE, de Wispelaere MP, Schröder ML. Improving recovery after elective degenerative spine surgery: 5-year experience with an enhanced recovery after surgery (ERAS) protocol. *Neurosurg Focus.* 2019;46:E7.
- Wang MY, Chang PY, Grossman G. Development of an enhanced recovery after surgery (ERAS) approach for lumbar spinal fusion. *J Neurosurg Spine.* 2017;26:411-418.
- Soffin EM, Wetmore DS, Beckman JD, et al. Opioid-free anesthesia within an enhanced recovery after surgery pathway for minimally invasive lumbar spine surgery: a retrospective matched cohort study. *Neurosurg Focus.* 2019;46:E8.
- Feng C, Zhang Y, Chong F, et al. Establishment and implementation of an enhanced recovery after surgery (ERAS) pathway tailored for lumbar minimally invasive transforaminal lumbar interbody fusion. *World Neurosurg.* 2019;121:e317-e323.
- Yang Y, Wu X, Wu W, et al. Enhanced recovery after surgery (ERAS) pathway for microendoscopy-assisted minimally invasive transforaminal lumbar interbody fusion. *Clin Neurol Neurosurg.* 2020;196:106003.
- Kerolus MG, Yerneni K, Witiw CD, et al. Enhanced recovery after surgery pathway for single-level minimally invasive transforaminal lumbar interbody fusion decreases length of stay and opioid consumption. *Neurosurgery.* 2021;88:648-657.
- Chang HK, Huan M, Wu JC, Huang WC, Wang MY. Less opioid consumption with enhanced recovery after surgery transforaminal lumbar interbody fusion (TLIF): a comparison to standard minimally-invasive TLIF. *Neurospine.* 2020;17:228-236.
- Centers for Medicare and Medicaid Services. Morphine equivalency conversion factors. Available at: <https://www.cms.gov/medicare/prescription-drug-coverage/prescriptiondrugcovcontra/downloads/opioid-morphine-eq-conversion-factors-march-2015.pdf>. Accessed July 8, 2021.
- FDA. Tramadol information. Available at: <https://www.fda.gov/drugs/postmarket-drug-safety-information-patients-and-providers/tramadol-information>. Accessed July 8, 2021.
- Dagal A, Bellabarba C, Bransford R, et al. Enhanced perioperative care for major spine surgery. *Spine.* 2019;44:959-966.
- Tarıkcı Kilic E, Tastan NC, Sarıkaya C, Naderi S. The application of an enhanced recovery after spine surgery to lumbar instrumentation. *Turk Neurosurg.* 2020;30:707-713.
- Brusco GD, Kolcun JPG, Heger JA, et al. Reductions in length of stay, narcotics use, and pain following implementation of an enhanced recovery after surgery for 1- to 3-level lumbar fusion surgery. *Neurosurg Focus.* 2019;46:E4.
- Flanders TM, Ifrach J, Sinha S. Reduction of postoperative opioid use after elective spine and peripheral nerve surgery using an enhanced recovery after surgery program. *Pain Med.* 2020;21:3283-3329.
- Young R, Cottrill E, Pennington Z, et al. Experience with an enhanced recovery after spine surgery protocol at an academic community hospital. *J Neurosurg Spine.* 2021;34:680-687.
- d'Astorg H, Fièrè V, Dupasquier M, Vieira TD, Szadkowski M. Enhanced recovery after surgery (ERAS) protocol reduces LOS without additional adverse events in spine surgery. *Orthop Traumatol Surg Res.* 2020;106:1167-1173.
- Garg B, Mehta N, Bansal T, Shekhar S, Khanna P, Baidya DK. Design and implementation of an enhanced recovery after surgery (ERAS) protocol in elective lumbar spine fusion by posterior approach: a retrospective, comparative study. *Spine.* 2020;46:E679-E687.
- Li J, Li H, Xv Z, et al. Enhanced recovery care versus traditional care following laminoplasty: a retrospective case-cohort study. *Medicine (Baltimore).* 2018;97:E13195.
- Ali ZS, Flanders TM, Ozturk AK, et al. Enhanced recovery after elective spinal and peripheral nerve surgery: pilot study from a single institution. *J Neurosurg Spine.* 2019;30:532-540.
- Mathiesen O, Dahl B, Thomsen BA, et al. A comprehensive multimodal pain treatment reduces opioid consumption after multilevel spine surgery. *Eur Spine J.* 2013;22:2089-2096.
- Smith J, Probst S, Calandra C, et al. Enhanced recovery after surgery (ERAS) program for lumbar spine fusion. *Periop Med (Lond).* 2019;8:1-9.
- Angus M, Jackson K, Smurthwaite G, et al. The implementation of enhanced recovery after surgery (ERAS) in complex spinal surgery. *J Spine Surg.* 2019;5:116-123.
- Ifrach J, Rohan B, Joshi DS, et al. Efficacy of an enhanced recovery after surgery (ERAS) pathway in elderly patients undergoing spine and peripheral nerve surgery. *Clin Neurol Neurosurg.* 2020;197:106115.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any

commercial or financial relationships that could be construed as a potential conflict of interest.

Received 8 December 2021; accepted 26 December 2021

Citation: *World Neurosurg. X* (2022) 14:100120.

<https://doi.org/10.1016/j.wnsx.2022.100120>

Journal homepage: www.journals.elsevier.com/world-neurosurgery-x

Available online: www.sciencedirect.com

2590-1397/© 2022 The Author(s). Published by Elsevier Inc.

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).