Low thoracic erector spinae plane block for perioperative analgesia in lumbosacral spine surgery: a case series

Bloc du plan des muscles érecteurs du rachis thoracique bas pour analgésie périopératoire dans la chirurgie du rachis lombosacré : une série de cas

Josh P. Melvin, MD · Rudolph J. Schrot, MD, MAS, FAANS · George M. Chu, MD ·
Ki Jinn Chin, MBBS (Hons), MMed, FRCPC

Received: 22 February 2018 / Revised: 21 March 2018 / Accepted: 21 March 2018 / Published online: 27 April 2018
© Canadian Anesthesiologists' Society 2018

Abstract

Purpose Severe postoperative pain following spine surgery is a significant cause of morbidity, extended length of facility stay, and marked opioid usage. The erector spinae plane (ESP) block anesthetizes the dorsal rami of spinal nerves that innervate the paraspinal muscles and bony vertebra. We describe the use of low thoracic ESP blocks as part of multimodal analgesia in lumbosacral spine surgery.

Clinical features We performed bilateral ESP blocks at the T10 or T12 level in six cases of lumbosacral spine surgery: three lumbar decompressions, two sacral laminoplasties, and one coccygectomy. Following induction of general anesthesia, single-injection ESP blocks were performed in three patients while bilateral continuous ESP block catheters were placed in the remaining three. All six patients had minimal postoperative pain and very low postoperative opioid requirements. There was no discernible motor or sensory

block in any of the cases and no interference with intraoperative somatosensory evoked potential monitoring used in two of the cases.

Conclusions The ESP block can contribute significantly to a perioperative multimodal opioid-sparing analgesic regimen and enhance recovery after lumbosacral spine surgery.

Résumé

Objectif Une douleur postopératoire sévère après la chirurgie de la colonne vertébrale est une cause importante de morbidité, de l'allongement de la durée de séjour en établissement de soins et d'une utilisation marquée du recours aux opioïdes. Le bloc du plan des érecteurs du rachis (PER) permet une anesthésie des rameaux dorsaux des nerfs rachidiens innervant les muscles paravertébraux et les vertèbres. Nous décrivons des blocs du PER thoracique bas dans le cadre d'une analgésie multimodale pour chirurgie du rachis lombosacré.

Caractéristiques cliniques Nous avons pratiqué des blocs du PER aux niveaux D10 ou D12 dans six cas de chirurgie du rachis lombosacré : trois décompressions lombaires, deux laminoplasties sacrées et une coccygectomie. Après induction de l'anesthésie générale, un bloc du PER en une seule injection a été pratiqué chez trois patients tandis que des cathéters bilatéraux pour blocs du PER ont été mis en place chez les trois autres patients. Les six patients ont présenté une douleur postopératoire minime et n'ont nécessité que très peu d'opioïdes postopératoires. Il n'y a pas eu de bloc moteur ou sensitif discernable dans aucun des cas ni aucune interférence sur le suivi des potentiels évoqués somatosensoriels peropératoires utilisés dans deux cas.

J. P. Melvin, MD · R. J. Schrot, MD, MAS, FAANS ·
G. M. Chu, MD
Sutter Medical Center, Sacramento, CA, USA

R. J. Schrot, MD, MAS, FAANS · G. M. Chu, MD
College of Osteopathic Medicine, Touro University California,
Mare Island, Vallejo, CA, USA

K. J. Chin, MBBS (Hons), MMed, FRCPC (✉)
Department of Anesthesia, Toronto Western Hospital, University
of Toronto, McL 2-405, 399 Bathurst St, Toronto, ON M5T 2S8,
Canada
e-mail: gasgenie@gmail.com

Conclusions *Le bloc des muscles érecteurs du rachis peut contribuer de manière significative à un traitement multimodal analgésique diminuant l'utilisation des opioïdes après chirurgie du rachis lombosacré.*

Lumbar spine surgery is a common procedure associated with severe postoperative pain¹ that, if poorly controlled, can increase complications and delay recovery. Opioids are the mainstay of therapy but are associated with adverse effects and a risk of long-term habituation and dependence.²

Regional analgesia techniques can play a significant role in multimodal analgesia,^{3,4} but descriptions of their use in spine surgery are sparse.⁵⁻⁷ The erector spinae plane (ESP) block technique was first described for thoracic and abdominal analgesia via its action on the ventral rami of spinal nerves.^{8,9} Nevertheless, it also anesthetizes the dorsal rami, which innervate the paraspinal muscles and vertebrae (Fig. 1). In this report, we describe our adaptation of the ESP block to provide perioperative analgesia as part of a multimodal opioid-sparing regimen in

a series of six patients undergoing lumbosacral spine surgery.

Description of the ESP block and intraoperative anesthetic care

All blocks were performed with the patient in the prone position after induction of general anesthesia. The skin was disinfected with 2% chlorhexidine in 70% alcohol. Surface anatomy or ultrasound (counting up from the 12th rib) was used to identify the appropriate thoracic level and a high-frequency linear-array ultrasound transducer (SonoSite Edge, Bothell, WA, USA) covered in a sterile sleeve was placed in a longitudinal parasagittal orientation 3 cm lateral to the midline to identify the tip of the transverse process (Fig. 2A). A 21G 100-mm block needle (Pajunk, Geisingen, Germany) was used for single-injection blocks and an 18G catheter-over-needle set for continuous blocks (E-cath Plus; Pajunk, Geisingen, Germany; this catheter extends a fixed distance of 15 mm beyond final needle tip position). The needle was inserted in plane with the ultrasound beam in a cranial-to-caudal direction to gently contact the transverse process (Fig. 2B). Correct needle tip position was signaled by linear spread of the injectate solution (20–30 mL in total) separating the erector spinae muscle from the transverse processes (Fig. 2C and 2D). This process was repeated on the other side.

General anesthesia was maintained with propofol infusion 55–100 $\mu\text{g}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ iv titrated using a Sedline® brain function monitor (Masimo, Irvine, CA, USA) to achieve a patient state index of 25–50 and bilateral spectral edge frequencies of 6–12 Hz. Rocuronium provided muscle relaxation for intubation in all cases. All patients were extubated prior to transport to the post-anesthesia care unit (PACU).

The bilateral ESP block catheters (Fig. 3) were connected in the PACU to two electronic infusion pumps (Sapphire™, Hospira, ICU Medical, San Clemente, CA, USA), which were each programmed to deliver patient-controlled boluses of 10 mL 0.2% ropivacaine at a lockout interval of 90 min with no background infusion. Patients were instructed to initiate boluses every 90 min when awake and at least every three hours during periods of sleep. Compliance was assisted by the use of the timer on patients' smartphones and reminders from nursing staff.

Fig. 1 Graphic illustration of the erector spinae plane block. Local anesthetic is injected between the erector spinae muscle and the tip of the transverse processes. This anesthetizes the dorsal rami of the spinal nerves and their branches that innervate the paraspinal muscles and bony vertebrae. (Image adapted and used with permission from Maria Fernanda Rojas Gomez)

Case descriptions

Written informed consent was obtained from all patients for this report. Clinical details are summarized in the Table.

Fig. 2 A) The ultrasound transducer is placed in a longitudinal parasagittal orientation approximately 3 cm lateral to the midline to visualize the tips of the transverse processes (TP) deep to the erector spinae muscle (ESM). B) The block needle is inserted in plane in a

cranial-to-caudal direction to contact the TP. C) Injection of local anesthetic (LA) lifts the ESM off the TPs. D) Cranial-caudal linear spread of LA is clearly seen, separating the ESM from the TPs

Patient 1

A 73-yr-old female underwent an L2-L3 lumbar spine decompression with Coflex® interlaminar stabilization (Paradigm Spine, New York, NY, USA).¹⁰ She was taking hydrocodone/acetaminophen 10/325 mg several times per day for lower back pain. She received bilateral single-injection ESP blocks at T12 with 30 mL 0.375% bupivacaine and 2 mg dexamethasone per side. Additional intraoperative analgesics included hydromorphone 1 mg *iv* at induction, acetaminophen 1 g *iv*, and ketamine 20 mg *iv* pre-incision. Wound infiltration using 10 mL 0.5% bupivacaine with 5 $\mu\text{g}\cdot\text{mL}^{-1}$ epinephrine was performed at surgical closure. The patient reported 0/10 pain on an 11-point numerical rating scale¹¹ (NRS; 0 = no pain, 10 = worst pain imaginable) in the PACU. Neurologic examination revealed full motor strength and normal sensation to pinprick in both lower extremities. The patient was continued on acetaminophen 1 g *iv* six hourly for the next 48 hr and opioids as needed. During the first 24

postoperative hours, her NRS pain scores ranged from 2-4/10 and she received one dose of morphine 4 mg *iv*, 13 hr after surgery. During the next 24 postoperative hours, her NRS pain scores ranged from 0-6/10 and she received three doses of morphine 4 mg *iv*. During postoperative hours 48-72, her NRS pain scores ranged from 0-6/10 and she received six doses of oral hydrocodone/acetaminophen 10/325 mg. She was discharged home on the third postoperative day.

Patient 2

An 81-yr-old female underwent sacral laminoplasty and microsurgical repair of two Tarlov cysts. She reported sensitivity to opioids resulting in significant nausea and vomiting. She received bilateral single-injection ESP blocks at T12 using 23 mL 0.375% bupivacaine and 2 mg dexamethasone per side. Additional intraoperative analgesics included hydromorphone 1 mg *iv* at induction and wound infiltration using 10 mL 0.25% bupivacaine

Fig. 3 A) Bilateral erector spinae plane block catheters inserted at T12 vertebral level prior to surgical incision. B) Subsequent incision for sacral laminoplasty and Tarlov cyst repair

with $5 \mu\text{g}\cdot\text{mL}^{-1}$ epinephrine at surgical closure. Her NRS pain score in the PACU was 0/10. She had normal motor strength and sensation in the lower extremities on neurologic testing. The patient was continued on acetaminophen 1 g *iv* six hourly for the next 48 hr and did not require any opioids during her hospital stay. Her NRS pain scores ranged from 0-2/10 and she was discharged home on the third postoperative day.

Patient 3

A healthy 46-yr-old male presented for coccygectomy. He received bilateral single-injection ESP blocks at T12 using 27 mL 0.375% bupivacaine and 2 mg dexamethasone per side. Additional intraoperative analgesics consisted of fentanyl $100 \mu\text{g}$ *iv* at induction and wound infiltration using 10 mL 0.25% bupivacaine with $5 \mu\text{g}\cdot\text{mL}^{-1}$ epinephrine at surgical closure. His NRS pain score in the PACU was 0/10. The patient was continued on acetaminophen 1 g *iv* six hourly for the next 24 hr. Two hours after completion of surgery, he received hydromorphone 0.5 mg *iv* for a pain score of 5/10. The patient's pain scores subsequently ranged from 2-5/10 during his overnight admission, and he received a total of three doses of hydromorphone 0.5 mg *iv*, two doses of morphine 2 mg *iv*, and two doses of hydrocodone/acetaminophen $10/325 \text{ mg}$. He was discharged from the hospital 20 hr after his arrival in the PACU.

Patient 4

A 67-yr-old female presented for sacral laminoplasty and microsurgical repair of a Tarlov cyst. She had multiple reported drug allergies, including morphine, oxycodone, duloxetine, gabapentin, and topiramate. Bilateral ESP catheters were placed at T12 and a loading injection of

25 mL 0.375% ropivacaine with $0.25 \mu\text{g}\cdot\text{kg}^{-1}$ dexmedetomidine and 2 mg dexamethasone was administered per side. Additional intraoperative analgesics included hydromorphone 2 mg *iv* at induction, acetaminophen 1 g *iv*, magnesium sulfate 2 g *iv* pre-incision, and wound infiltration using 10 mL 0.25% bupivacaine with $5 \mu\text{g}\cdot\text{mL}^{-1}$ epinephrine at surgical closure. Somatosensory evoked potentials were monitored throughout the case, with no changes noted from the baseline measurements obtained prior to the ESP block (Fig. 4).

Her NRS pain score in the PACU was 0/10 and she had full motor strength on neurologic testing of the lower extremities. Continuous ESP blockade was commenced in the PACU using the regimen described above. The patient received acetaminophen 1 g *iv* six hourly for the next 72 hr but did not require any opioids during her admission. Her NRS pain scores ranged from 1-4/10 during the first 24 hr, 1-3/10 during postoperative hours 24-48, and 1-2/10 during postoperative hours 48-72. The ESP catheters were removed just prior to her discharge home on the third postoperative day.

Patient 5

A 76-yr-old male presented for L1-L3 decompression with Coflex® interlaminar stabilization. He was taking 800 mg ibuprofen once or twice per day for low back pain. Bilateral ESP catheters were placed at T10 and a loading injection of 25 mL 0.375% ropivacaine with $0.25 \mu\text{g}\cdot\text{kg}^{-1}$ dexmedetomidine and 2 mg dexamethasone was administered per side. General anesthesia was maintained with $55\text{--}75 \mu\text{g}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ propofol without a volatile agent. Additional intraoperative analgesics included fentanyl $250 \mu\text{g}$ *iv* at induction, ketamine 20 mg *iv*, magnesium sulfate 2 g *iv* pre-incision, and wound

Table Case summaries

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Age (yr)/gender	73/female	81/female	46/male	67/female	76/male	55/male
Weight (kg)	89	49	96	77	96	73
BMI ($\text{m}\cdot\text{kg}^{-2}$)	32	17	26	28	27	23
Preoperative diagnosis	Lumbar spinal stenosis	Tarlov cysts	Coccydynia	Tarlov cysts	Lumbar spinal stenosis	Lumbar spinal stenosis
Surgery	L2-L3 decompression with interlaminar stabilization	Sacral laminoplasty and Tarlov cyst repair	Coccygectomy	Sacral laminoplasty and Tarlov cyst repair	L1-L3 decompression with interlaminar stabilization	L2-S1 decompression and excision of L3-4 intradural lesion
ESP block technique and dosing	Single-injection at T12 30 mL 0.375% bupivacaine + 2 mg dexamethasone per side	Single-injection at T12 23 mL 0.375% bupivacaine + 2 mg dexamethasone per side	Single injection at T12 27 mL 0.375% bupivacaine + 2 mg dexamethasone per side	Catheter insertion at T12 25 mL 0.375% ropivacaine + 0.25 $\mu\text{g}\cdot\text{kg}^{-1}$ dexmedetomidine + 2 mg dexamethasone per side	Catheter insertion at T10 25 mL 0.375% ropivacaine + 0.25 $\mu\text{g}\cdot\text{kg}^{-1}$ dexmedetomidine + 2 mg dexamethasone per side	Catheter insertion at T10 20 mL 0.375% ropivacaine + 0.25 $\mu\text{g}\cdot\text{kg}^{-1}$ dexmedetomidine + 2 mg dexamethasone per side
Duration of surgery (min)	175	120	80	125	137	172
Preoperative pain score at rest and with activity (0-10 NRS scale)	6/10 and 9/10	0/10 and 5/10	1/10 and 5/10	0/10 and 0/10	0/10 and 0/10	3/10 and 8/10
PACU arrival pain score and analgesic use	0/10; no opioids	0/10; no opioids	0/10; no opioids	0/10; no opioids	0/10; no opioids	0/10; no opioids
0-24 hr NRS pain scores and analgesic use	2-4/10; acetaminophen 1 g <i>iv</i> 6 hourly; gabapentin 600 mg 8 hourly; morphine 4 mg <i>iv</i> $\times$ 1 dose	0/10; acetaminophen 1 g <i>iv</i> 6 hourly	2-5/10; acetaminophen 1 g <i>iv</i> 6 hourly; hydromorphone 0.5 mg <i>iv</i> $\times$ 3 doses; morphine 2 mg <i>iv</i> $\times$ 2 doses; hydrocodone/acetaminophen 10/325 mg $\times$ 2 doses	1-4/10; acetaminophen 1 g <i>iv</i> 6 hourly	0/10; acetaminophen 1 g <i>iv</i> 6 hourly	0-3/10; acetaminophen 1 g <i>iv</i> 6 hourly; oxycodone extended-release 10 mg 12 hourly; gabapentin 300 mg 8 hourly
24-48 hr pain scores and analgesic use	0-6/10; acetaminophen 1 g <i>iv</i> 6 hourly; morphine 4 mg <i>iv</i> $\times$ 3 doses; gabapentin 600 mg 8 hourly	0-2/10; acetaminophen 1 g <i>iv</i> 6 hourly	Not applicable	1-3/10; acetaminophen 1 g <i>iv</i> 6 hourly	0/10; acetaminophen 1 g <i>iv</i> 6 hourly	0-3/10; acetaminophen 1 g <i>iv</i> 6 hourly; oxycodone extended-release 10 mg 12 hourly; gabapentin 300 mg 8 hourly

Table continued

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
48-72 hr pain scores and analgesic use	0-6/10; hydrocodone/acetaminophen 10/325 mg $\times$ 6 doses	0-2/10; oral acetaminophen 650 mg $\times$ 1 dose	Not applicable	1-2/10; oral acetaminophen 1 g 6 hourly	Not applicable	0-2/10; oral acetaminophen 1 g 6 hourly; oxycodone extended release 10 mg 12 hourly; gabapentin 300 mg 8 hourly
Hospital length of stay	3 days	3 days	24 hr	3 days	2 days	3 days

BMI = body mass index; ESP = erector spinae plane; NRS = numerical rating scale; PACU = postanesthesia care unit

infiltration using 10 mL 0.5% bupivacaine with 5 $\mu\text{g}\cdot\text{mL}^{-1}$ epinephrine at surgical closure.

The patient's NRS pain score in the PACU was 0/10. Continuous ESP blockade was maintained using the regimen described above and he received acetaminophen 1 g *iv* six hourly for the next 48 hr. Throughout his hospital admission, the patient reported NRS pain scores of 0/10 and required no opioids. He had normal motor power in both lower extremities. The ESP catheters were removed just prior to his discharge home on the second postoperative day.

Patient 6

A 55-yr-old male presented for L2-S1 decompression and excision of a L3-L4 intradural lesion. He was taking hydrocodone 30-40 mg daily and marijuana twice daily to manage chronic pain. Bilateral ESP catheters were placed at T10 and a loading injection of 20 mL 0.5% ropivacaine with 2 mg dexamethasone was administered per side. Additional intraoperative analgesics included hydromorphone 2 mg *iv* at induction, ketamine 0.5 $\text{mg}\cdot\text{kg}^{-1}$ *iv* pre-incision and 0.25 $\text{mg}\cdot\text{kg}^{-1}$ every hour, dexmedetomidine 0.4 $\mu\text{g}\cdot\text{kg}^{-1}\cdot\text{hr}^{-1}$, and wound infiltration using 10 mL 0.25% bupivacaine with 5 $\mu\text{g}\cdot\text{mL}^{-1}$ epinephrine at surgical closure. Somatosensory evoked potentials were monitored throughout the case, with no changes noted from the baseline measurements obtained prior to the ESP block.

His NRS pain score in the PACU was 0/10 and there was no change from his preoperative neurologic examination. Continuous ESP blockade was maintained using the regimen described above. He was started on oral gabapentin 300 mg every eight hours and acetaminophen 1 g six hourly. He did not receive any postoperative opioids until the morning of the first postoperative day, when he was started on oral extended-release oxycodone 10 mg twice daily to avoid symptoms of opioid withdrawal. No additional doses of opioid were required during his admission. He reported NRS pain scores of 0-3/10 during the first 48 hr and 0-2/10 during postoperative hours 48-72. The ESP catheters were removed just prior to his discharge home on the third postoperative day.

Discussion

Posterior spine surgery is amongst the most painful surgical procedures, with median pain scores (using the 0-10 NRS) on the first postoperative day ranging from 5 (spinal decompression) to 7 (spinal fusion).¹ Opioids have traditionally been the mainstay of analgesia therapy, but they may not always adequately control pain and, at high

Fig. 4 Somatosensory evoked potential waveforms recorded from the right and left lower limbs of patient #4, showing no significant changes following erector spinae plane block

doses, are associated with significant adverse effects (sedation, cognitive impairment, constipation) and the risk of long-term habituation and dependence.² Regional anesthesia is an important component of multimodal analgesic regimens^{3,4}; however, in spine surgery, this has been primarily confined to neuraxial techniques, namely epidural analgesia and intrathecal opioid.^{5,12} These have side effects and limitations and are not widely used. Local anesthetic wound infiltration is commonly performed but its benefit tends to be short-lived.¹³ Nevertheless, we employed it in all our patients as a matter of surgical routine as well as a means of delivering epinephrine to promote wound hemostasis.

The paraspinal muscles and posterior bony elements of the spine are innervated by the dorsal rami of the spinal

nerves. These originate shortly after the spinal nerves exit the vertebral foramina and travel posteriorly through the intertransverse connective tissues and the paraspinal muscles to reach the superficial tissues.¹⁴ In the ESP block, local anesthetic spreads within the musculofascial plane deep to erector spinae muscles and acts on the dorsal rami of spinal nerves at multiple levels (Fig. 1). Evidence to date indicates that spread with 20 mL of injectate extends 3–4 vertebral levels or more from the site of injection in a caudal direction.^{8,9,15} Physical spread to the lumbar paraspinal area from a thoracic site of injection has also been documented, supporting the existence of a discrete anatomical pathway.⁹ We therefore aimed in all cases to target the T11 or T12 transverse process. This capacity for extensive cranial-caudal spread is a unique

advantage of the ESP block, allowing it to be performed at a distance from the surgical field, thus minimizing the risk of microbial contamination and permitting the preoperative insertion of catheters to prolong postoperative analgesia. This is in contrast to another recently described regional analgesic technique for spine surgery, the thoracolumbar interfascial plane block, which requires injection at a vertebral level congruent with the surgical site.^{6,7}

The observed lack of impact on intraoperative electrophysiologic monitoring and the absence of a motor block¹⁶ that might hinder postoperative neurologic testing and mobilization are additional potential advantages of the ESP block that should be confirmed in a larger patient population. The lack of correlation between the degree of analgesia and motor or sensory block achieved may be explained by the limited amount of local anesthetic that actually reaches the lumbar ventral rami or nerve roots. Low concentrations of local anesthetic applied to nerve targets have been shown to preferentially inhibit pain generation and transmission compared with motor and sensory function.^{17,18} At the same time, given the need for relatively large injectate volumes to achieve spread, we employed the maximum recommended dose of bupivacaine/ropivacaine in the initial bolus to avoid excessively low local anesthetic concentrations. While the ability of dexamethasone and dexmedetomidine to augment analgesia in ESP blocks is currently unsubstantiated, we chose to add them to the local anesthetic mixture based on data from peripheral nerve blockade^{19–21} and the principle that opioid sparing is best achieved by using as many multimodal analgesic strategies as possible² rather than relying on a single “silver bullet”.

Regarding continuous ESP blockade, we chose a regimen of intermittent bolus dosing rather than continuous infusion to again ensure adequate local anesthetic spread from the catheter tip to the spinal nerves congruent with the surgical wound. At present, this choice is based on our understanding of the mechanics of the ESP block and anecdotal evidence.²² We note, however, that intermittent boluses appear superior to continuous infusion in epidural labor analgesia,²³ in contrast to peripheral nerve blockade where the current evidence is equivocal.²⁴ The former technique is more relevant to the ESP block given that both rely on local anesthetic spread within a relatively large anatomical space. A programmed intermittent bolus function was unavailable on our pumps and we instead improvised with a schedule of patient-initiated boluses. In practice, this worked well because of a high level of motivation amongst patients and nurses to maintain the degree of analgesia that was being provided.

In summary, pre-incision ESP blocks performed at the T10–T12 level contributed to effective perioperative

opioid-sparing analgesia in this preliminary series of six patients undergoing lumbosacral spine surgery. Catheter insertion in more major surgeries and patients with complex pain issues allowed prolongation of this benefit and avoidance of opioid dose escalation.

Conflicts of interest None declared.

Editorial responsibility This submission was handled by Dr. Hilary P. Grocott, Editor-in-Chief, *Canadian Journal of Anesthesia*.

Author contributions Josh P. Melvin conceived the clinical concept described and contributed to the clinical conduct of the study, data collection, and writing of the manuscript. Rudolph J. Schrot and George M. Chu contributed to the clinical conduct of the study, data collection, and writing of the manuscript. Ki Jinn Chin contributed to analysis and interpretation of the collected data, writing, preparation of accompanying figures and material, and revision of the manuscript.

Funding sources and conflict of interests This work received no specific funding from any sources.

References

1. Gerbershagen HJ, Aduckathil S, van Wijck AJ, Peelen LM, Kalkman CJ, Meissner W. Pain intensity on the first day after surgery: a prospective cohort study comparing 179 surgical procedures. *Anesthesiology* 2013; 118: 934–44.
2. Savarese JJ, Tabler NG Jr. Multimodal analgesia as an alternative to the risks of opioid monotherapy in surgical pain management. *J Healthc Risk Manag* 2017; 37: 24–30.
3. Carli F, Kehlet H, Baldini G, et al. Evidence basis for regional anesthesia in multidisciplinary fast-track surgical care pathways. *Reg Anesth Pain Med* 2011; 36: 63–72.
4. Lenart MJ, Wong K, Gupta RK, et al. The impact of peripheral nerve techniques on hospital stay following major orthopedic surgery. *Pain Med* 2012; 13: 828–34.
5. Puvanesarajah V, Liauw JA, Lo S, Lina IA, Witham TF, Gottschalk A. Analgesic therapy for major spine surgery. *Neurosurg Rev* 2015; 38: 407–18.
6. Hand WR, Taylor JM, Harvey NR, et al. Thoracolumbar interfascial plane (TLIP) block: a pilot study in volunteers. *Can J Anesth* 2015; 62: 1196–200.
7. Ueshima H, Ozawa T, Toyone T, Otake H. Efficacy of the thoracolumbar interfascial plane block for lumbar laminoplasty: a retrospective study. *Asian Spine J* 2017; 11: 722–5.
8. Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ. The erector spinae plane block: a novel analgesic technique in thoracic neuropathic pain. *Reg Anesth Pain Med* 2016; 41: 621–7.
9. Chin KJ, Adhikary S, Sarwani N, Forero M. The analgesic efficacy of pre-operative bilateral erector spinae plane (ESP) blocks in patients having ventral hernia repair. *Anaesthesia* 2017; 72: 452–60.
10. Davis RJ, Errico TJ, Bae H, Auerbach JD. Decompression and Coflex interlaminar stabilization compared with decompression and instrumented spinal fusion for spinal stenosis and low-grade degenerative spondylolisthesis: two-year results from the prospective, randomized, multicenter, Food and Drug Administration Investigational Device Exemption trial. *Spine (Phila Pa 1976)* 2013; 38: 1529–39.

11. Hjermstad MJ, Fayers PM, Haugen DF, et al. Studies comparing numerical rating scales, verbal rating scales, and visual analogue scales for assessment of pain intensity in adults: a systematic literature review. *J Pain Symptom Manage* 2011; 41: 1073-93.
12. Devin CJ, McGirt MJ. Best evidence in multimodal pain management in spine surgery and means of assessing postoperative pain and functional outcomes. *J Clin Neurosci* 2015; 22: 930-8.
13. Perera AP, Chari A, Kostusiak M, Khan AA, Luoma AM, Casey AT. Intramuscular local anesthetic infiltration at closure for postoperative analgesia in lumbar spine surgery: a systematic review and meta-analysis. *Spine (Phila Pa 1976)* 2017; 42: 1088-95.
14. Saito T, Steinke H, Miyaki T, et al. Analysis of the posterior ramus of the lumbar spinal nerve: the structure of the posterior ramus of the spinal nerve. *Anesthesiology* 2013; 118: 88-94.
15. Muñoz F, Cubillos J, Bonilla AJ, Chin KJ. Erector spinae plane block for postoperative analgesia in pediatric oncological thoracic surgery. *Can J Anesth* 2017; 64: 880-2.
16. Forero M, Rajarathinam M, Adhikary SD, Chin KJ. Erector spinae plane block for the management of chronic shoulder pain: a case report. *Can J Anesth* 2018; 65: 288-93.
17. Ford DJ, Raj PP, Singh P, Regan KM, Ohlweiler D. Differential peripheral nerve block by local anesthetics in the cat. *Anesthesiology* 1984; 60: 28-33.
18. Koplovitch P, Devor M. Dilute lidocaine suppresses ectopic neuropathic discharge in DRGs without blocking axonal propagation: a new approach to selective pain control. *Pain* 2018. DOI: <https://doi.org/10.1097/j.pain.0000000000001205>.
19. Pehora C, Pearson AM, Kaushal A, Crawford MW, Johnston B. Dexamethasone as an adjuvant to peripheral nerve block. *Cochrane Database Syst Rev* 2017; 11: CD011770.
20. El-Boghdadly K, Brull R, Sehmbi H, Abdallah FW. Perineural dexmedetomidine is more effective than clonidine when added to local anesthetic for supraclavicular brachial plexus block: a systematic review and meta-analysis. *Anesth Analg* 2017; 124: 2008-20.
21. Kaur H, Arora P, Singh G, Singh A, Aggarwal S, Kumar M. Dexmedetomidine as an adjunctive analgesic to ropivacaine in pectoral nerve block in oncological breast surgery: a randomized double-blind prospective study. *J Anaesthesiol Clin Pharmacol* 2017; 33: 457-61.
22. De La Cuadra-Fontaine JC, Altermatt FR. Continuous erector spinae plane (ESP) block: optimizing the analgesia technique. *J Cardiothorac Vasc Anesth* 2018 (in press).
23. Onuoha OC. Epidural analgesia for labor: continuous infusion versus programmed intermittent bolus. *Anesthesiol Clin* 2017; 35: 1-14.
24. Chong MA, Wang Y, Dhir S, Lin C. Programmed intermittent peripheral nerve local anesthetic bolus compared with continuous infusions for postoperative analgesia: a systematic review and meta-analysis. *J Clin Anesth* 2017; 42: 69-76.