


Pragmatic comparative effectiveness study of multimodal fascia iliaca nerve block and continuous lumbar epidural-based protocols for periacetabular osteotomy

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ABSTRACT

Perioperative pain management protocols have a significant impact on early surgical outcomes and recovery. We hypothesized that multimodal protocol including fascia iliaca compartment nerve block (MM-FICNB) would decrease the length of hospital stay (LOS) by facilitating earlier mobilization, without compromising analgesia, compared to a traditional lumbar epidural-based protocol (EP). Demographics/comorbidities, surgical/block characteristics and perioperative pain/mobilization data were collected from a prospectively recruited MM-FICNB group ($N = 16$) and a retrospective EP cohort ($N = 16$) who underwent PAO using similar surgical techniques, physical therapy/discharge criteria. Association of MM-FICNB group with LOS (primary outcome), postoperative pain, postoperative opioid requirements in morphine equivalent rates (MER) (mcg/kg/h) and time to complete physical therapy were tested using multivariable and survival regression. Patient and surgical characteristics were similar between groups. Median time for FICNB performance was significantly less than epidural (6 versus 15 min; $P < 0.001$). LOS was significantly decreased in the MM-FICNB group (2.88 ± 0.72 days) compared to the EP group (4.38 ± 1.02 days); $P < 0.001$. MM-FICNB group had significantly lower MER on POD1 ($P = 0.006$) and POD2 ($P < 0.001$), with similar pain scores on all POD. MM-FICNB group was associated with decreased LOS and earlier mobilization ($P < 0.001$) by covariate-adjusted multivariate regression. Cox proportional hazard regression model showed MM-FICNB subjects had 63 (95% CI 7–571, $P < 0.001$) times the chance of completing physical therapy goals, compared to EP. Compared to EP, MM-FICNB protocol allowed earlier mobilization and decreased post-surgical hospitalization by 1.5 days, without compromising analgesia, with important implications for value-based healthcare and cost-effectiveness.

INTRODUCTION

Periacetabular osteotomy (PAO) is commonly performed to treat symptomatic acetabular dysplasia or retroversion in skeletally mature patients. Left untreated, these conditions often lead to continued pain and the need for hip replacement at a young age [1, 2]. PAO decreases pain

associated with these conditions and delays the need for total hip replacement [3, 4]. Optimum perioperative pain control plays an important role in facilitating early function after PAO surgery. Conversely, inadequately controlled pain can hinder postoperative mobilization, increase opioid consumption, prolong hospital stays and delay recovery [5, 6].

Hence, perioperative pain management protocols have a significant impact on early surgical outcomes and recovery.

Pain after POA is multifactorial from incisions, osteotomies, muscle rearrangements and neuropathic pain. Presence of preoperative pain, comorbidities such as Ehlers–Danlos syndrome (EDS), longer surgical duration and obesity have been shown to be associated with higher postoperative pain, limiting recovery [7–9]. Opioid minimizing multimodal analgesia protocols used in enhanced recovery after surgery protocols (ERAS) have shown benefits after hip and knee arthroplasty [10–12]. Use of regional pain management procedures (peripheral nerve blocks and neuraxial analgesia) play an important role in multimodal analgesia. For PAO surgery, regional analgesia should take into account the sensory innervation of the hip joint via articular branches of the obturator nerve, femoral nerve, sciatic nerve and superior gluteal nerve branches [13]. Options for analgesia include lumbar epidural, patient-controlled analgesia pump, nerve blocks (femoral, fascia iliaca, lumbar plexus block) or local infiltration, in conjunction with muscle relaxants. Epidural analgesia is commonly used, but due to pitfalls of failure rates (27–32%) [14], the risk for rare neurologic complications, urinary retention, hypotension and motor blockade, they are currently not preferred for unilateral hip/knee major surgeries in adults [15, 16]. In our practice, perioperative pain after PAO was previously managed with continuous lumbar epidural analgesia protocol (EP). However, the above-mentioned concerns with epidural analgesia limiting mobilization on postoperative day 1 prompted the initiation of a multimodal pain management protocol comprising fascia iliaca compartment nerve block (MM-FICNB) in lieu of EP.

FICNB is a simple and effective compartment block that has been used for postoperative analgesia after hip surgery [17–21]. The compartment is a potential space bounded anteriorly by the fascia lata and posteriorly by the iliacus and psoas muscles. Under ultrasound guidance, injection of a large volume of local anesthetic beneath fascia iliaca travels cephalad to block the femoral, lateral cutaneous and obturator nerves. Since the PAO incision lies largely in the interval between the sartorius and the tensor fascia lata, and this anterolateral portion of the hip capsule is mostly innervated by the femoral nerve, FICNB is expected to block incisional pain. However, some studies show no difference in pain intensity after FICNB compared to sham blocks for hip surgery [22], and there are no studies evaluating the effectiveness of multimodal protocols including FICNB for mobilization and recovery after PAO in adolescents and young adults. We hypothesized that our new, MM-FICNB based analgesia protocol will

allow earlier mobilization and decrease the length of hospital stay without compromising analgesia when compared to the previous EP.

MATERIALS AND METHODS

A pragmatic study was conducted to compare the effectiveness of a newer multimodal protocol including FICNB (MM-FICNB) with a previously employed epidural pain protocol (EP) for pain control after periacetabular osteotomy (PAO). The study was approved by our Institutional Review Board. Data collection for patients receiving EP was done using retrospective chart review, for which consent waiver was obtained; subjects receiving MM-FICNB protocol were recruited prospectively, and written consent obtained as appropriate.

Study participants

Participants of any age, sex or race who had a diagnosis of symptomatic hip dysplasia or retroversion who underwent PAO from May 2015 to January 2017 were included. During this timeframe, we transitioned clinically from using an EP (05/2015–06/2016) to a MM-FICNB protocol (07/2016–01/2017). Preoperative coagulopathy, infection at the site of injection, preexisting neurological symptoms or sensation/motor deficits, history of chemotherapy or allergy to local anesthetics would exclude patients from either procedure.

Protocol description

Intraoperative anesthetic management (common)

All surgeries were performed by two experienced surgeons at similar points on the learning curve. All patients received similar preoperative evaluation and underwent standard general endotracheal anesthesia for the procedure with standard monitoring recommended by American Society of Anesthesiologists. Patients received intravenous midazolam, propofol, fentanyl and muscle relaxants for induction/tracheal intubation and inhalation-based maintenance of anesthesia. Muscle relaxants were reversed at the end of surgery before tracheal extubation. Hydromorphone/morphine was used intraoperatively at the discretion of the anesthesia team and diazepam 0.05 mg/kg (maximum 4 mg) was administered intravenously after trachea was extubated. All patients received anti-emetics (dexamethasone and ondansetron) and appropriate antibiotics for prophylaxis. Patients in both groups received intraoperative dose of intravenous acetaminophen and ketorolac (see Table I). They also received 1000 mg tranexamic acid before incision and 1000 mg before skin closure to decrease the potential for blood loss.

Table 1: Details of the perioperative protocols for the two groups—multimodal fascia iliaca compartment nerve block group/MM-FICNB (new) and epidural based protocol (old)

	<i>MM-FICNB protocol</i>	<i>EP</i>
Preoperative		
Preparation	Similar education and preoperative optimization	
Premedication	Pregabalin 50–75 mg orally about an hour before surgery Celebrex 200 mg orally about an hour before surgery Midazolam intravenous as needed	Nothing specific
Intraoperative		
Anesthesia	General endotracheal anesthesia (GETA): Intravenous induction with fentanyl, lidocaine propofol and muscle relaxant per discretion of anesthesia team Maintenance with inhalational anesthesia and muscle relaxants and opioids as needed Diazepam 0.05 mg/kg IV after tracheal extubation; Intravenous acetaminophen (15 mg/kg) max 1000 mg; Ketorolac 0.5 mg/kg (maximum 15 mg)	
Procedure and protocol specific analgesics	Methadone 0.1 mg/kg (max 5 mg) Ultrasound guided, infrainguinal, fascia iliaca nerve block single injection (under GETA, before incision) with 0.2% ropivacaine 1 ml/kg (max 40 ml)	Lumbar epidural catheter placement (L2–3 or L3–4) before induction of anesthesia, with midazolam/fentanyl Loading dose 10 ml of ropivacaine 0.2% Maintenance 8–10 ml/h with ropivacaine 0.125–0.2% (maximum dose 0.4 mg/kg/h)
POD 0-1	Pain service follows patient	
Activity	Early mobilization and involvement of physical/occupational therapy;	Spirometer 10×/h while awake
Diet	Clears and advance to regular diet as tolerated Start bowel regimen (stool softeners)	
Drains/catheters	Discontinue foley catheter	Continue foley catheter
Protocol-specific analgesia	Methadone 0.1 mg/kg (max 5 mg) 12 h from previous intraoperative dose	Protocol specific analgesia

(continued)

Table 1: (continued)

MM-FICNB protocol		EP
Analgesia common to both groups	+ Oxycodone orally 0.1 mg/kg (5–7.5 mg) every 4 h when tolerating diet	
	+ Acetaminophen 15 mg/kg IV (max 1000 mg) × 3 doses followed PO 15 mg/kg (max 650 mg) q6h Max dose 3 g/day	
Opioid side effect management	+ Ketorolac 0.5 mg/kg (max 10–15 mg) IV q6h (unless patient is on aspirin or enoxaparin)	
	+ Diazepam 0.05 mg/kg (max 5 mg) IV q4h PRN muscle spasms	
	+ Methocarbamol 15 mg/kg (max 1000 mg) q8h IV	
	+ Hydromorphone 0.1 mcg/kg every 4 h IV PRN severe pain	
	PRN nausea/vomiting: Ondansetron 4 mg IV q6h; PRN pruritis: Nalbuphine 0.05 mg/kg; PRN respiratory depression/oversedation: Naloxone 1–2 mcg/kg (for over-sedation); 10–20 mcg/kg (for life threatening respiratory depression);	
POD 2		
Protocol-specific analgesia	Nothing specific	Discontinue epidural catheter and analgesia
Discharge planning	Switch IV to acetaminophen PO 650 mg q6h (max 75 mg/kg/day or 3 g/day)	
	Switch IV to PO diazepam 0.05–0.075 mg/kg (max 5 mg) q4h PRN muscle spasm	
	Switch methocarbamol IV to PO 15 mg/kg (500–1000 mg) q8h	
	Continue oxycodone PO every 4 h	
	Hydromorphone 0.1 mcg/kg every 4 h IV PRN severe pain	
	Regular; Bowel regimen (stool softener/Senna)	
	Physical/occupational therapy; Spirometer 10×/h while awake	
	None	Discontinue foley catheter
	Discharge home once physical therapy goals completed	
	POD 3 and beyond	
All	Continue activity; Continue incentive spirometry; Continue bowel regimen and diet; Home if excellent mobilization and pain control with PO oxycodone, acetaminophen and diazepam.	

RN, *pro re nata*, or when necessary; IV, intravenous; PO, per os/oral; POD, postoperative day.

The regional procedures described below were performed by experienced members of the perioperative pain service.

Epidural protocol

In the epidural group, a lumbar (L2–3, L3–4) epidural catheter (20 G) was placed before induction of anesthesia, with the patient in sitting position, using a loss of resistance with saline technique (18 G epidural Tuohy needle). The epidural infusion with 0.2% ropivacaine was started intraoperatively and continued until postoperative day 2 at 10–12 ml/h. On a postoperative day (POD) 2, the epidural catheter was removed, followed by removal of the foley catheter 6 h later.

MM-FICNB protocol

The MM-FICNB group received preoperative pregabalin 50–75 mg and celecoxib 200 mg orally. Single-injection FICNB was performed under ultrasound guidance using an in-plane technique prior to incision, under GETA. After identifying the iliacus muscle lateral to the femoral artery, the needle (22 G × 2" (50 mm) with facet tip ©Pajunk medical systems, L.P., Georgia, USA) was visualized entering the fascia lata and the fascia iliaca and 0.2% ropivacaine—1 ml/kg up to 40 ml was injected after aspiration, beneath the fascia lata (Figure 1). Methadone (0.1 mg/kg max 5 mg) was administered intraoperatively before incision, and another dose 12 h after. Pregabalin was continued every 12 h after surgery for a total of four doses.

Postoperative pain regimen (common to both groups)

Postoperatively, both groups were followed by the perioperative pain team with standardized order sets as described in Table I.

Physical therapy and discharge

Postoperatively, physical therapists provided patient/caregiver education regarding mobility, transfers and discharge planning. Physical therapy goals to be satisfied for discharge included ability to perform supine to sit to stand at edge of bed (EOB) with supervision with assistive device toe-touch weight bearing on affected lower extremity (TTWB), ambulate functional distances with supervision with TTWB and negotiate stairs TTWB with crutches with minimum assist. Physical therapist documented completion of staged goals in patient's electronic medical record. Occupational therapy worked with patients for activities of daily life training and caregiver education. Discharge goals remained the same over the entire study period.

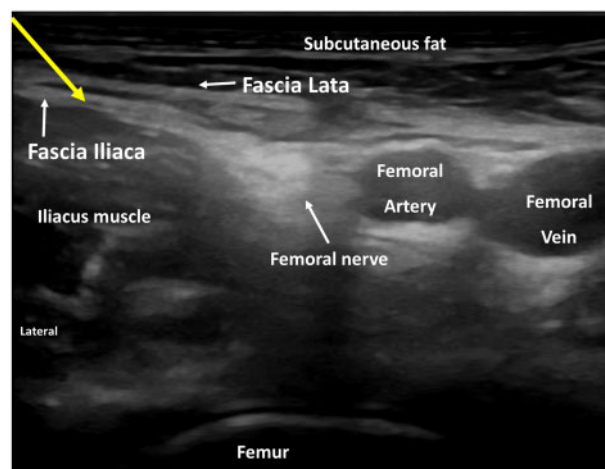


Fig. 1. Ultrasound image of landmarks in infrainguinal fascia iliaca compartment nerve block (FICNB). Using the in-plane ultrasound technique, a high volume of local anesthetic is injected underneath the fascia iliaca to provide analgesia targeting the femoral, lateral femoral cutaneous and obturator nerves that innervate the anterolateral and anteromedial aspect of the hip and thigh. The yellow arrow represents trajectory of needle entry and tip of arrow indicates the location of local anesthetic deposition.

Data collection

The following preoperative data were collected: demographics, comorbidities, anxiety scores, pain scores, home medications; intraoperatively, time taken for the performance of the procedure (epidural, FICNB), duration of surgery, blood loss, fluids administered, opioid doses administered. Postoperative pain scores [Numeric Rating Scale (0–10)] and rescue intravenous opioids administered on POD0 (day of surgery), POD1 and POD2 were collected. All rescue doses of intravenous opioids were converted to morphine equivalent rates (MER—units mcg/kg/h) for ease of comparison, using a conversion of 1 mg morphine = 0.2 mg hydromorphone = 1 mg methadone. We collected data on POD when physical therapy goals were achieved [stand EOB with supervision, ambulate functional distances (few steps and at least 15 steps) and negotiate stairs] as well as the date of discharge. Any untoward effects in either group was also recorded.

Outcomes

The primary outcome was the length of hospital stay (LOS), calculated by subtracting the procedure date from the discharge date. Secondary outcomes were analgesia (pain scores and intravenous rescue opioid doses) and mobilization (completion of physical therapy goals).

Statistical analysis

Descriptive statistics (mean and standard deviation, or median and interquartile range for continuous variables, and frequencies and percentages for categorical variables) were generated for demographics and other data characteristics by group. Groups were compared for continuous baseline variables using two-sample *t*-tests (if normally distributed) or Wilcoxon rank-sum test (if not normally distributed). For categorical baseline variables, Fisher's exact or Chi-square tests were used. We calculated standardized mean difference (SMD) to quantify differences between the groups. Conventionally, SMD of 0.2, 0.5 and 0.8 or higher are considered small, median and large, respectively. Test for partially overlapping data was used for subjects who had repeat surgery as this accounts for the dependency between repeated measures. For secondary mobilization outcome (time to final physical therapy), LOS was used as censored time to event when final physical therapy goal was not achieved before discharge, and Log-rank test was used to compare between groups. We developed four multivariable regression models with MM-FICNB group as independent variable for; (i) LOS adjusted for duration of surgery, comorbidity (EDS), total MER and intraoperative fluids; (ii) average pain scores over postoperative days, (iii) total postoperative MER [adjusted for preoperative pain, comorbidity (EDS), duration of surgery] and (iv) time to final physical therapy goal [adjusted for postoperative pain scores, comorbidity (EDS) and preoperative pain score] using Cox proportional hazard model for time to event data. All tests were two-sided with a significant level $\alpha = 0.05$. Additionally, we used *P*-values cut-off of 0.0125 for statistical significance to account for multiple testing on one primary outcome and three secondary outcomes listed above. All statistical analyses were run in SAS v9.4 (SAS Institute, Cary, NC, USA).

Power analysis

The study was powered to detect a significant difference in the primary outcome LOS. With $n = 32$ (16 each group), a two-sample *t*-test has more than 85% power to detect a one day difference in LOS (assuming a common std of 0.9) with a significance level of 0.05.

RESULTS

Over the study timeframe, 16 consecutive subjects who received EP (until June 2016) and 16 consecutive patients under the MM-FICNB protocol (initiated in July 2016) satisfied inclusion criteria. Three patients underwent hip surgery on each side at least a year apart—one of them received the epidural protocol both the times, while the

other two received EP for the first hip and MM-FICNB protocol with the second hip surgery.

Group characteristics

EP and MM-FICNB groups were similar in demographics (Table II), preoperative pain and comorbidities. About half the patients in both groups were using analgesic medications preoperatively, mostly non-steroidal anti-inflammatory drugs. Surgical characteristics (surgical duration, reported blood loss) were not different among the groups. Time for performing ultrasound-guided FICNB was about 10 min less than an epidural block ($P < 0.001$). A higher proportion of subjects in EP group had postoperative adverse outcomes (5/16; headache-1, lethargy-1, nausea-2, unrelated sacroiliac joint issues-1) compared to MM-FICNB group (1/16; numbness lateral thigh-1, which resolved over 3–4 months) ($P = 0.172$).

Primary outcome (LOS)

The average LOS for the entire cohort was 3.63 ± 1.16 days. We found LOS to be significantly longer in the EP group (4.38 ± 1.02 days) compared to the MM-FICNB group (2.88 ± 0.72 days) ($P < 0.001$, two-sample *t*-test, tests on partially overlapped data gave similar results) (Table III). Using multivariable regression adjusted for covariates, we found that the only factor that influenced LOS was the group (MM-FICNB) [Beta: -1.557 (SE 0.368); $P < 0.001$]. Multivariable regression results are provided in Table IV.

Secondary outcomes

Pain and opioid outcomes

Intraoperative MER were not significantly different between the two groups. Postoperative MER and pain scores for the groups are presented in Table III. MM-FICNB group used significantly more MER on POD0 but significantly less opioid MER on POD1 and POD2. Pain scores were not significantly different on any postoperative day, although there was a trend for lower mean pain scores in the MM-FICNB group after POD0 while remaining stable in the EP. Multivariable regression with total MER and average pain over the entire stay, adjusted for covariates showed that the group (MM-FICNB) did not play a statistically significant role in determining pain outcomes (Table IV).

Time to mobilization

Time after surgery when subjects met physical therapy goals are provided in Table III. Subjects in both the EP and MM-FICNB groups met goals for EOB supine-sit-

Table II. Patient, surgical and block characteristics of subjects in the epidural and multimodal fascia iliaca block protocol (MM-FICNB) groups

Variables	Epidural (n = 16)	MM-FICNB (n = 16)	SMD	P-value
Age (years) Median (Q1, Q3)	17 (14.5, 18)	17 (15, 18)	0.155	0.970*
Sex (M/F)	1/15	1/15	0	1.00
Weight (kg) mean \pm SD	60.61 \pm 10.35	67.16 \pm 14.75	0.514	0.156
Preoperative pain score (NRS) Median (Q1, Q3)	2 (0, 4)	0 (0, 3.5)	0.278	0.401*
Laterality left/right	3/13	8/8	0.697	0.0627**
Comorbidities <i>n</i> (%)				
Ehlers–Danlos syndrome	3 (18.75)	4 (25)	0.152	1
Scoliosis	3 (18.75)	0 (0.00)	0.679	0.226
Psych (ADHD, depression)	2 (12.5)	1 (6.25)	0.216	1
Home pain meds <i>n</i> (%)				
NSAID (ibuprofen, naproxen)	4 (25)	5 (31.25)	0.139	1
Gabapentin	3 (18.75)	2 (12.5)	0.173	1
Pregabalin	0 (0.00)	1 (6.25)	0.365	1
Time for block (min) Median (Q1, Q3)	15 (13, 18)	6 (4, 7)	1.773	<0.001*
Duration of surgery (h) Mean \pm SD	5.09 \pm 0.97	4.79 \pm 0.91	0.317	0.377
Blood loss (ml/kg) Median (Q1, Q3)	8.99 (6.90, 10.26)	8.12 (4.40, 13.33)	0.317	0.757*
Intraoperative fluids (ml/kg) Median (Q1, Q3)	67.93 (61.54, 85.3)	60.26 (45.37, 67.32)	0.552	0.080*
Intraoperative blood administration (ml/kg) Median (Q1, Q3)	4.03 (1.48, 5.77)	2.92 (1.66, 6.43)	0.186	0.720*

ADHD, attention deficit hyperactivity disorder; NSAID, non-steroidal anti-inflammatory drugs; NRS, numerical rating scale; SMD, standardized mean difference. Continuous variables were compared using *t*-tests or Wilcoxon tests. Categorical variables were compared using Fishers exact test or Chi-square test. P-values with * sign: used Wilcoxon test. P-values with ** sign: used Chi-square test.

stand with assistance on POD 1. In EP, nausea (4 subjects), dizziness (2 subjects) and ‘inability to feel legs’ (1 patient) were documented as reasons for lack of mobilization on POD1; one subject in FICNB group complained of numbness in the lateral thigh on POD1. Subjects in MM-FICNB group could ambulate using TTWB precautions ($P < 0.001$) and navigate stairs ($P < 0.001$) earlier than the EP group (Table II). About half the EP group did not achieve the final goal at the time of hospital discharge, and LOS was substituted for these patients. However, all of them followed up with physical therapy after discharge.

Cox proportional hazard model adjusted for covariates showed that MM-FICNB group was associated with earlier completion of final physical therapy goals. ($P < 0.001$) (Table IV). Proportional hazard assumption was tested and satisfied. The median time to negotiate steps reduced from 4 days in the EP group to 2.5 days in the MM-FICNB group, or 37.5% ($P = 0.006$ Wilcoxon rank-sum test, $P < 0.001$ log-rank test). Cox proportional hazard regression model with adjustment for covariates showed that a patient in the MM-FICNB group who has not yet negotiated steps at a certain time has 63 (95% CI 7–571,

Table III. Comparison of primary and secondary outcomes between the epidural and multimodal fascia iliaca block protocol (MM-FICNB) groups

Outcomes	Epidural	MM-FICNB	P-value
Primary outcome			
Length of hospital stay (days); Mean (SD)	4.38 (1.02)	2.88 (0.72)	<0.001
Secondary outcomes			
MER intraoperative; Mean (SD)	48.70 (17.91)	58.90 (26.30)	0.210
MER POD 0; Median (Q1, Q3)	0 (0, 4.29)	8.74 (6.59, 12.16)	<0.001*
MER POD 1; Median (Q1, Q3)	1.45 (1.08, 3.23)	0 (0, 0.9)	0.006*
MER POD2; Median (Q1, Q3)	1.64 (1.06, 3.17)	0 (0, 0)	<0.001*
POD 0 pain scores; Mean (SD)	4.11 (1.73)	4.47 (1.58)	0.544
POD 1 pain scores; Mean (SD)	4.67 (1.45)	3.91 (1.64)	0.175
POD 2 pain scores; Mean (SD)	4.47 (1.94)	3.54 (1.28)	0.122
Time to achieve supine to sit to stand EOB (POD); Median (Q1, Q3)	1.5 (1, 2)	1 (1, 1)	0.211*
Time to achieve ambulation—few steps in room using TTWB (POD); Median (Q1, Q3)	2 (2, 2)	1 (1, 1)	<0.001*
Time to be able to ambulate minimum 15 steps with supervision and TTWB (POD); Median (Q1, Q3)	4 (3, 4)	2 (1, 2)	<0.001*
Time to negotiate stairs (at least 4 stairs) (POD); Median (Q1, Q3)	4 (3.5, 5.5)	2.5 (1.5, 3)	0.006*

P-values with * sign: used Wilcoxon test; others used two-sample *t* test.

MER, morphine equivalent rate in mcg/kg/h; POD, postoperative day; EOB, edge of bed; TTWB, touch weight bearing precautions on surgical side.

$P < 0.001$) times the chance of negotiating steps at the next point in time compared to patient in the EP group (Figure 2).

DISCUSSION

Our study shows that the use of MM-FICNB protocol facilitated earlier mobilization and decreased length of hospital stay by 1.5 days, compared to the EP protocol. In addition, subjects receiving the MM-FICNB protocol required less intravenous rescue opioid doses on postoperative days 1 and 2 when compared to patients receiving EP, achieving comparable analgesia. There were fewer side effects in the MM-FICNB group and the FICNB took significantly less time to perform than the epidural.

To our knowledge, no prior study has evaluated LOS or mobilization goals as outcomes with the use of FICNB as part of a MM regimen. LOS is important to study as an outcome given recent trends indicating a transition from traditional 'fee-for-service' models to 'bundled payments' whereby health care providers are encouraged to deliver care more efficiently while improving quality, cost and

outcomes [23]. LOS after PAO was shown in prior studies to be 4–5 days [24], similar to what we found in the EP protocol (4.38 ± 1.02 days). In our previous studies investigating the cost-effectiveness of analgesic regimens after spine fusion, we found that average daily in-patient costs in an orthopedic ward \approx \$2654 (direct costs \approx \$1639; indirect costs \approx \$1015) [25]. Thus, MM-FICNB protocol, associated with significantly decreased length of stay (2.88 ± 0.72 days) has the potential to significantly improve value-based care, decreasing cost without affecting analgesia. LOS after orthopedic surgeries could be affected by preoperative comorbidity, prior pain/disability, surgical complexity, intraoperative fluid administration and perioperative complications [15]. These have been accounted for in the multivariate regression model. A previous study evaluated a modified surgical technique for PAO and found that rectus-sparing approach without routine arthrotomy could decrease postoperative pain as well as LOS to 3–4 days [24].

Multimodal approaches use pharmacologic interventions targeting different pathways, and as part of ERAS

Table IV. Multivariable regression models for outcomes as dependent variables and group (multimodal Fascia iliaca compartment nerve block (MM-FICNB)) as dependent variable, adjusted for relevant covariates.

<i>Parameter estimates</i>		
<i>Variable</i>	<i>Parameter estimate (SD)</i>	<i>P-value</i>
Primary outcome: Length of stay		
MM-FICNB group	−1.557 (0.368)	<0.001*
Duration of surgery (h)	0.053 (0.190)	0.785
Total postoperative MER	0.032 (0.038)	0.398
Intraoperative fluids (ml/kg)	0.006 (0.007)	0.398
EDS	0.431 (0.390)	0.279
Secondary outcome: average postoperative pain score		
Preoperative pain score	0.034 (0.096)	0.725
EDS	0.266 (0.563)	0.641
Duration of surgery (h)	−0.649 (0.254)	0.017
MM-FICNB group	−0.630 (0.466)	0.188
Secondary outcome: total postoperative MER		
Preoperative pain score	−0.004 (0.349)	0.992
EDS	−0.270 (2.037)	0.895
Duration of surgery (h)	−1.865 (0.920)	0.053
MM-FICNB group	3.337 (1.685)	0.058
Secondary outcome: final physical therapy goal		
	HR (95% CI)	P-value
EDS	0.484 (0.128, 1.829)	0.285
Preoperative pain score	1.02 (0.831, 1.252)	0.851
Mean pain score POD0	1.008 (0.638, 1.593)	0.972
Mean pain score POD1	1.38 (0.766, 2.485)	0.283
Mean pain score POD2	0.673 (0.419, 1.08)	0.1
MM-FICNB group	62.977 (6.946, 570.996)	<0.001*

EDS, Ehlers–Danlos syndrome; POD, postoperative day; MER, morphine equivalence rate in mcg/kg/h; HR, hazard ratio in survival analysis.

*P-values significant at $P < 0.0125$.

pathways [15], aim to minimize opioids as opioid adverse effects increase morbidity and delay discharge after orthopedic surgery [26]. Our MM-FICNB protocol included celecoxib, pregabalin and methadone, in addition to acetaminophen and ketorolac (common to both protocols). Systematic reviews have found that preoperative oral

celecoxib (a selective cyclooxygenase 2 inhibitor), compared with placebo, resulted in reduced morphine consumption, improved mobilization and decreased time to discharge up to 24–48 h after hip surgery [27]. Pregabalin has demonstrated anti-hyperalgesic properties; a recent Cochrane review and trial found that pregabalin improved

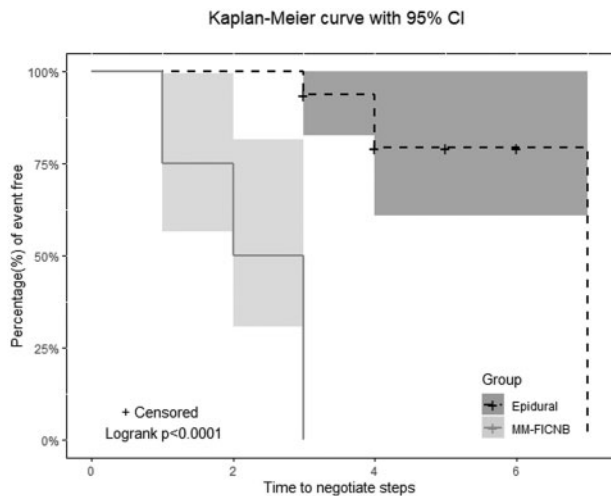


Fig. 2. Plots of the Kaplan–Meier product limit estimates of time to complete physical therapy goals (negotiate stairs) in epidural (dashed lines) and multimodal fascia iliaca nerve block (MM-FICNB) (grey line) groups with corresponding 95% Hall–Welner bands shown (shaded areas) shows significantly ($P < 0.001$) earlier completion by MM-FICNB group.

pain control up to 24 and 48 h (upto a week), reduced morphine consumption and improve mobilization after knee and hip arthroplasty [28, 29], However, the regimen included dosing of celecoxib for 3 days and pregabalin for 7 days. Of note, recent meta-analyses and ERAS recommendations for hip surgeries (adults) do not show benefits from preoperative gabapentinoids for postoperative analgesia [15, 30]. A review showed intraoperative methadone use associated with significant reductions in postoperative analgesic requirements, compared to patients administered shorter-acting intraoperative opioids [31]. This is attributed to its unique pharmacokinetic profile and additional effects on the *N*-methyl-d-aspartate and serotonergic receptors. While the optimal dose is yet unknown, pre-precision use has been found to be beneficial in hip surgery patients [32]. Our study design did not allow us to determine if these medications independently influenced outcomes. Importantly, ERAS pathways stress on preoperative patient education, optimization including physiotherapy and interdisciplinary collaboration [15, 33].

Although epidural analgesia is opioid sparing [34], lumbar epidural infusions of even relatively low-concentrations (bupivacaine 0.1%) result in temporary lower extremity motor weakness in 36% of patients [35]. This might explain why mobilization outcomes were superior for the MM-FICNB group in our study. Even if some degree of unilateral motor weakness could be expected after FICNB [36], this would still preserve the other extremity for ambulation. After hip arthroplasty, FICNB was found to not

impede postoperative ambulation; the primary factor influencing ambulation distance was body mass index [37]. On a precautionary note, negative impact of early mobilization was presented by a retrospective review of a standard (weight bearing at 2 months) versus accelerated mobilization protocol (exercise training and weight bearing starting on the day of surgery as tolerated) after PAO. They found a higher incidence of pelvic fracture in the earlier mobilization group upon follow-up over 2 years [38]. Similar to our findings that EDS did not affect mobilization after PAO, another recent study showed comparable patient-reported outcomes in females with or without joint hypermobility after hip arthroscopy and capsular plication [39].

In children, suprainguinal FICNB was shown to be effective (lower opioid consumption and shorter PACU times) following hip arthroscopy, compared to no block [40]. Suprainguinal FICNB may be superior to infrainguinal FICNB (used in our study) for hip surgery [41], the rationale being that more cranial deposition of local anesthetic leads to better spread under the fascia iliaca with better blockade of the obturator nerve medial to the psoas muscle [42]. There are no prior studies comparing FICNB with epidural analgesia for hip surgery. Other regional techniques (intrathecal morphine, local anesthetic infiltration and lumbar plexus block) were shown to be superior to FICNB for analgesia after hip arthroscopy; however, only short-term outcomes (1–2 h upto 24 after surgery) were evaluated in these studies [43–45].

Limitations of the study include a small sample size, inability to randomize interventions due to the pragmatic nature of the study, non-contemporary comparison groups and possible Hawthorne effect (alteration of behavior among subjects due to their awareness of being observed as part of the study) in the prospectively recruited group. The study strengths include standardization of all other variables (two surgeons at similar points in their learning curve, similar techniques and discharge criteria), consecutive patient sampling which excludes bias, inclusion of efficiency (performance times) and cost-efficacy relevant outcomes like length of hospital stay. Other psychological factors including preoperative depression, anxiety and pain catastrophizing also play a role in pain and recovery after hip surgery and need attention in future studies [9]. The cost-effectiveness of such MM regimens needs to be investigated prospectively in larger cohorts.

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Data Availability

The data underlying this article will be shared on reasonable request to the corresponding author.

CONFLICT OF INTEREST STATEMENT

None of the authors have any conflicts to disclose.

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