ANESTHESIOLOGY

Posterior Quadratus Lumborum Block in Total Hip Arthroplasty

A Randomized Controlled Trial

Sophia Margareta Brixel, M.D., Philippe Biboulet, M.D., Fabien Swisser, M.D., Olivier Choquet, M.D., Yassir Aarab, M.D., Helen Nguyen, M.D., Sophie Bringuier, Pharm.D., Ph.D., Xavier Capdevila, M.D., Ph.D.

Anesthesiology 2021; 134:722–33

EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Early mobilization after joint replacement surgery requires effective analgesia
- Interfacial plane injections including quadratus lumborum block have been advocated for pain relief after hip joint replacement, but evidence for this approach is sparse

What This Article Tells Us That Is New

- In the context of a multimodal postoperative analgesic strategy, providing a quadratus lumborum block using ropivacaine resulted in no less morphine consumption or pain in the first 24 postoperative hours compared to saline injection
- Quadratus lumborum block also provided no advantages in terms of time to first standing, ambulation, or hospital stay

ABSTRACT

Background: Pain management is important for ensuring early mobilization after hip arthroplasty; however, the optimal components remain controversial. Recently, the quadratus lumborum block has been proposed as an analgesic option. The current study tested the hypothesis that the posterior quadratus lumborum block combined with multimodal analgesia decreases morphine consumption after hip arthroplasty.

Methods: This study was a prospective, randomized, double-blind, placebo-controlled trial. Before general anesthesia, 100 participating patients scheduled for elective total hip arthroplasty were randomly allocated to receive a 30-ml injection posterior to the quadratus lumborum muscle with either 0.33% ropivacaine (n = 50) or normal saline (n = 50). For all patients, multimodal analgesia included systematic administration of acetaminophen, ketoprofen, and a morphine intravenous patient-controlled analgesia. The primary outcome was total intravenous morphine consumption in the first 24 h. Secondary outcomes recorded intraoperative sufentanil consumption; morphine consumption in the postanesthesia care unit; pain scores at extubation and at 2, 6, 12, and 24 h; motor blockade; time to first standing and ambulation; hospital length of stay; and adverse events.

Results: There was no significant difference in the 24-h total morphine consumption (ropivacaine group, median [interquartile range], 13 [7 to 21] *versus* saline group, 16 [9 to 21] mg; median difference, −1.5; 95% CI, −5 to 2; $P = 0.337$). Pain scores were not different between the groups ($\beta = -0.4$; 95% CI, −0.9 to 0.2; $P = 0.199$). There was no statistical difference between the two groups in intraoperative sufentanil consumption, morphine consumption in the postanesthesia care unit, motor blockade, times to first standing (median difference, 0.83 h; 95% CI, −1.7 to 3.4; $P = 0.690$) and ambulation (median difference, −1.85 h; 95% CI, −4.5 to 0.8; $P = 0.173$), hospital length of stay, and adverse events.

Conclusions: After elective hip arthroplasty, neither morphine consumption nor pain scores were reduced by the addition of a posterior quadratus lumborum block to a multimodal analgesia regimen.

(Anesthesiology 2021; 134:722–33)

Early mobilization after total hip arthroplasty features as a strong recommendation in the enhanced recovery after surgery program.[1] However, early physiotherapy is only possible with effective analgesia with few side effects. The optimal regimen with which to manage early postoperative pain after total hip arthroplasty remains controversial.[2] Opioids, widely used for pain management, are responsible for adverse effects such as nausea, vomiting, dizziness, and urinary retention. Numerous techniques have been assessed to reduce morphine consumption after hip arthroplasty. Multimodal analgesia regimens, which include nonsteroidal anti-inflammatory drugs and acetaminophen, result in lower pain scores at rest and during mobilization, with a resultant reduced opioid consumption.[1,3,4] Conversely, local anesthetic infiltration neither reduces morphine consumption nor improves postoperative rehabilitation.[1,5] Although regional anesthesia techniques, such as the lumbar plexus block[4,6] or the femoral nerve block,[7] have opioid-sparing effects, they can result

This article is featured in "This Month in Anesthesiology," page 1A. Part of this work was presented as the Study of the QUadratus lumborum block in total hip ARthroplasty, Efficacy (SQUARE), winner of the Scientific Committee Award at the Residents' Contest for Clinical Research at the annual Congress for the French Society of Anesthesiology and Critical Care Medicine Society (Société Française d'Anesthésie et de Réanimation), in Paris, France, September 20, 2019. This article has a visual abstract available in the online version.

Submitted for publication October 20, 2020. Accepted for publication February 11, 2021. Published online first on March 19, 2021. From the Department of Anesthesiology and Critical Care Medicine, Lapeyronie University Hospital (S.M.B., P.B., F.S., O.C., H.N, S.B., X.C.), the Department of Anesthesiology and Critical Care Medicine, Saint Eloi University Hospital (Y.A.), the Department of Medical Statistics (S.B.), Centre Hospitalier Universitaire Montpellier, and French National Institute of Health and Medical Research (INSERM) Unit 1051, Montpellier NeuroSciences Institute (X.C.), University of Montpellier, Montpellier, France.

 Anesthesiology 2021; 134:722–33. DOI: 10.1097/ALN.0000000000003745

in significant muscle weakness and subsequent falls. Thus, other analgesic techniques, with few side effects, are needed for reducing morphine consumption. In recent years, several case reports have described the efficacy of the quadratus lumborum block in hip surgery.[8–11] Ultrasound-guided quadratus lumborum block is an interfascial plane block of the posterior abdominal wall, first described as a posterior variant of the transversus abdominis plane block. There are three different approaches currently described, referring to the needle tip position with respect to the quadratus lumborum muscle: lateral to the muscle (termed quadratus lumborum block 1); posterior to the muscle (termed quadratus lumborum block 2); and anterior to the muscle (termed transmuscular block or quadratus lumborum block 3; fig. 1).[12] The anterior quadratus lumborum block was recently shown to be effective for pain relief after total hip arthroplasty.[13] This deep approach, however, can result in quadriceps muscle weakness due to spread of the local anesthetic to the lumbar plexus.[14] In contrast, the posterior quadratus lumborum block approach is more superficial with less motor blockade than the anterior approach.[14] In a magnetic resonance study, the dye spread is wider in the posterior approach compared to the lateral.[15] Although this posterior approach has been reported as effective for analgesia after total hip arthroplasty in a retrospective cohort,[16] randomized controlled studies are lacking. The extent of sensory blockade has moreover been minimally studied in clinical settings.

In the current study, we hypothesized that the posterior quadratus lumborum block (quadratus lumborum block 2), in combination with multimodal analgesia, decreases morphine consumption after elective total hip arthroplasty. Furthermore, we aimed to assess the spread of the solution in the interfascial space, the extent of the sensory blockade, the motor blockade, and the benefit in terms of early rehabilitation.

Materials and Methods

Study Design and Study Population

The Study of the QUadratus lumborum block in total hip ARthroplasty, Efficacy (SQUARE) was designed as a prospective, randomized, double-blind, placebo-controlled, single-center, superiority clinical trial using two parallel groups. The study was conducted at Lapeyronie University Hospital

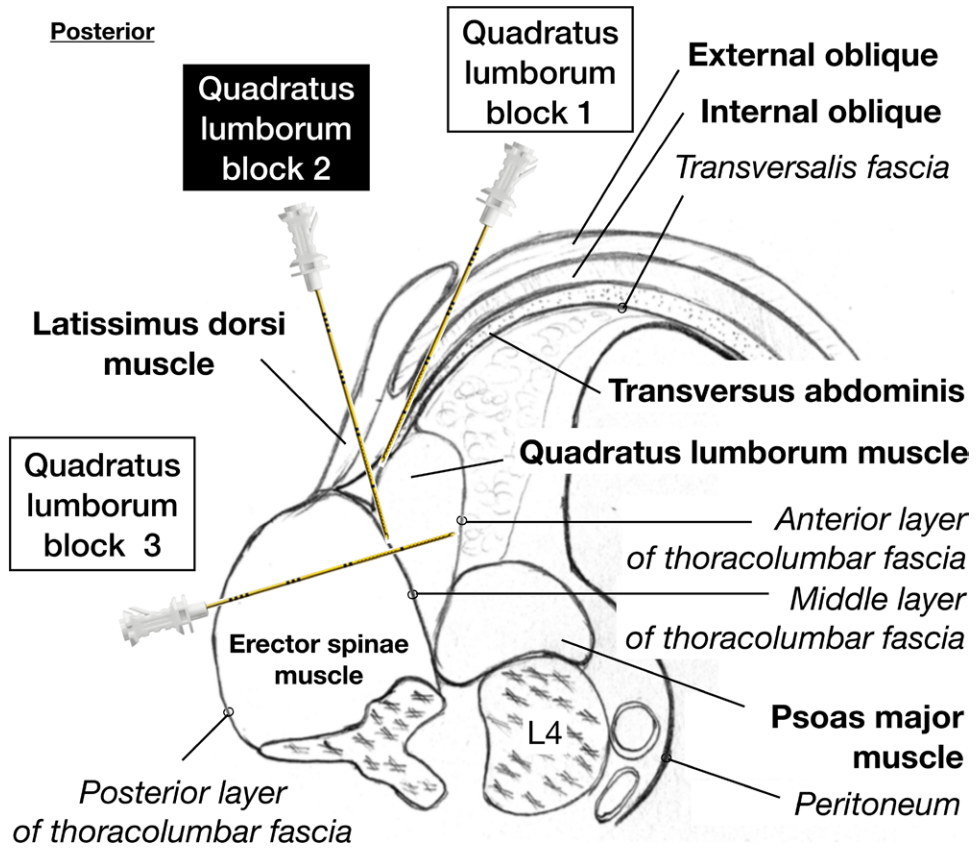

Fig. 1. Diagrammatic representation of the lateral and posterior abdominal wall muscles with the facial layers. The needles represent the direction and the target for each quadratus lumborum block approach. Quadratus lumborum blocks 1, 2, and 3 represent needle tip positions lateral, posterior, and anterior, respectively, to the quadratus lumborum muscle.

(Montpellier, France). In accordance with the Declaration of Helsinki, the trial was approved by the ethics committee (Comité de Protection des Personnes, Sud Méditerranée III, Montpellier-Nîmes, France, No. 2017.05.05 bis) and was prospectively registrated in ClinicalTrials.gov on June 16, 2017, with identifier NCT03189290, and principal investigator Philippe Biboulet. All patients provided written informed consent before inclusion.

Eligible patients for participation in the study were those scheduled for elective, unilateral primary total hip arthroplasty under general anesthesia, following an enhanced recovery after surgery pathway, aged 18 yr or older, affiliated with a medical insurance system, and with an American Society of Anesthesiologists (Schaumburg, Illinois) Physical Status I to III. Exclusion criteria included pregnancy, breastfeeding, cognitive impairment with difficulties in pain evaluation, allergy or intolerance to drugs relevant to the study, severe coagulopathy, and chronic kidney disease (estimated glomerular filtration rate inferior to 50 ml · min^{-1} · 1.73 m^{-2}). Study exclusion also applied to patients with peripheral neuropathy or those receiving treatment for chronic non-hip pain.

Randomization and Blinding

The day before surgery, the participants were recruited by the study staff, and written informed consent was obtained. On the day of surgery, included patients were assigned randomly in a 1:1 ratio to either the ropivacaine or the saline group, using a computer-generated block randomization technique, with a block size of 10 patients. Randomization was performed by the Department of Medical Statistics, and the allocated sequence was concealed in sequentially numbered, opaque, sealed envelopes prepared by an investigator without clinical involvement in the trial. Before the patient's arrival to the operating room, an independent registered nurse anesthetist opened the envelope in the pharmacy of the operating room and prepared the allocated study drugs, ropivacaine or saline, in syringes labeled "SQUARE." After filling the syringes, the empty vials were returned to the central pharmacy. Then the study drugs, visually identical, were deposited in the patients' operating rooms. Blinding to group allocation applied for enrolled patients, anesthesiologists, physiotherapists, and the investigators performing follow-up visits. Enrollment ceased when the target sample size was obtained.

Intraoperative Management

Immediately before general anesthesia induction, the quadratus lumborum block was performed with the patient in the lateral decubitus position, with the block side and operative side nondependent. A curvilinear low-frequency ultrasound probe was placed transversely, transitioning laterally from the umbilicus to the posterior axillary line. The muscles of the lateral abdominal wall (external oblique, internal oblique, and transversus abdominis), of the posterior abdominal wall (latissimus dorsi, quadratus lumborum, and erector spinae), and anterior to the quadratus lumborum (psoas muscle) were visualized (fig. 1). The transducer was placed between the iliac crest and the twelfth rib and adjusted to visualize the shamrock sign (fig. 2).[17] A 21-gauge 100-mm nerve block needle was inserted in-plane in a lateroposterior direction. The needle tip was advanced and positioned posterior to the quadratus lumborum muscle (fig. 1). Careful hydrolocalization technique, with the allocated blinded solution, was used to localize the needle tip and the correct point of injection. After negative aspiration, 30 ml of the solution, either 3.3 mg/ml (0.33%) ropivacaine (ropivacaine group) or normal saline (saline group), was injected in the interfascial plane posterior to the quadratus lumborum muscle, between the quadratus lumborum and the erector spinae muscles. The anesthesiologist recorded the final solution spread on an anatomical diagram, consistent with spread (1) posterior (quadratus lumborum block 2) to the quadratus lumborum muscle, (2) anterior (quadratus lumborum block 3) to the quadratus lumborum muscle, (3) back flowing toward the transversus abdominis (quadratus lumborum block 1), or (4) combination spread. The procedural duration, from sonography localization to the completion of injection, was recorded.

On completion of the quadratus lumborum block procedure, general anesthesia induction, with the patient in a supine position, was performed using a standard protocol with target-controlled infusion of sufentanil (Geps model; plasma concentration, 0.3 to 0.4 ng/ml) and of propofol (Schnider model; plasma concentration, 4 to 6 μg/ml). In addition, 0.3 mg/kg ketamine and 0.15 mg/kg dexamethasone were infused. After endotracheal intubation, the sufentanil infusion was decreased to a target plasma concentration of 0.1 ng/ml, with intraoperative titration as required, at the discretion of the anesthesiologist. Total hip arthroplasty, with a posterior approach, was performed by the same surgical team. There was no local anesthetic infiltration in the surgical area. At 30 min before surgery completion, 1,000 mg of acetaminophen and 100 mg of ketoprofen were infused.

The patients were extubated in the postanesthesia care unit. Pain was assessed at rest and at 30-min intervals for 2 h, with a numeric rating scale from 0 to 10, with 0 signifying no pain and 10 signifying the worst possible pain. If the numeric rating scale was more than 3, a morphine titration of 2 mg every 5 min was administered. If the morphine dose exceeded 0.3 mg/kg, additional rescue medication, including 20 mg of nefopam, 1 μg/kg clonidine, and 10 mg of ketamine, was administered at the discretion of the anesthesiologist. Postoperative nausea and vomiting was treated with 4 mg of IV ondansetron. The extent of sensory blockade was assessed with a cold glass vial. The skin area where patients described a loss of cold sensation was graphically mapped on a representation of the hip divided into nine skin areas. At 2 h after extubation, the numeric

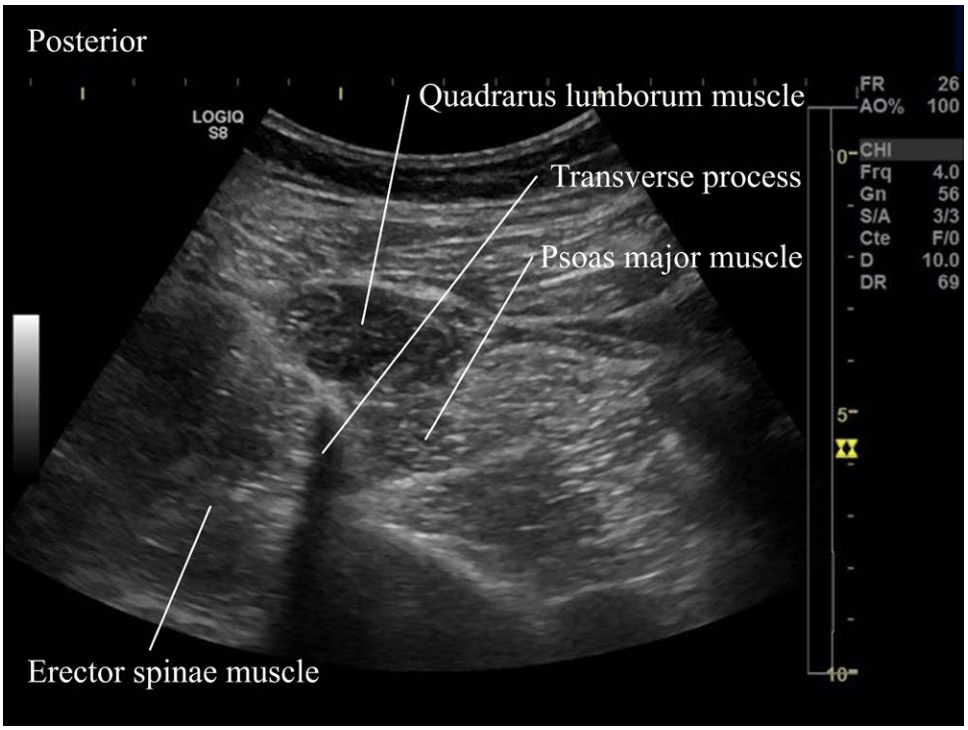

Fig. 2. Ultrasound location of the quadratus lumborum muscle with the Shamrock sign. The three leaves of the sign are composed of the quadratus lumborum muscle and the psoas major and erector spinae muscles, whereas the transverse process constitutes the stem. The quadratus lumborum muscle is seen as a darker muscle at the apex of the transverse process.

rating scale at rest and during passive 90° hip flexion was evaluated in all patients. Motor weakness was assessed using the Bromage score,[18] where 3 indicates unable to move feet, knee, or hip; 2 indicates able to move feet only; 1 indicates able to move feet and knee; and 0 indicates full flexion of feet, knee, and hip. A score of 2 or 3 is defined as significant motor weakness. Before discharge from the postanesthesia care unit, the maximal numeric rating scale experienced by the patients during their postanesthesia care unit stay was evaluated.

Postoperative Management

On the surgical ward, the patients systematically received 1,000 mg of acetaminophen IV at 6-h intervals and 100 mg of ketoprofen IV at 12-h intervals. A lightweight mobile infusion pump (Rythmic Evolution, Micrel Medical Devices, Greece) for IV patient-controlled analgesia was programmed with a bolus dose of 1 ml of morphine (1 mg/ml, with 100 μg/ml droperidol to reduce postoperative nausea and vomiting) and a lockout time of 7 min, without background infusion. The numeric rating scale was assessed at rest at 6, 12, and 24 h after extubation and on movement (passive 90° hip flexion) at 6 and 24 h after extubation. Motor blockade was assessed at 6 h after extubation using the Bromage score. At 24 h after extubation, the maximal numeric rating scale experienced by the patients during their surgical ward hospitalization was evaluated. Adverse events, including postoperative nausea and vomiting and urinary retention, were recorded during the first 24 h. These evaluations were performed by the anesthesiology team blinded to the study group. Early rehabilitation was facilitated by physiotherapists, with patients encouraged to first stand postoperatively on the day of surgery and to ambulate either on the day of surgery or the day after (depending on surgical ward admission time). Time to first standing, time to first ambulation, and the hospital length of stay were recorded.

Sample Size Estimation and Statistical Analysis

The primary outcome measure was the total cumulative IV morphine consumption at 24 h after extubation, inclusive of morphine administrated in the postanesthesia care unit and IV patient-controlled analgesia–administered morphine. Morphine consumption was chosen as the primary outcome, consistent with other studies on pain relief in total hip arthroplasty.[4–6,13,16] Secondary outcomes included intraoperative sufentanil consumption; morphine consumption in the postanesthesia care unit; area of cutaneous sensory loss sensation; pain scores at rest at extubation time and 2, 6, 12, and 24 h after extubation; pain scores during passive 90° hip flexion at 2, 6, and 24 h after extubation; maximal pain score

during the intervals between extubation time and 2 h after extubation and between 2 and 24 h after extubation; motor blockade at 2 and 6 h after extubation; time to first standing and ambulation; hospital length of stay; and adverse events including block-related side effects. The sample size has been estimated *a priori* with calculation based on the anticipated opioid consumption difference between study groups. We used the study of Minville *et al.*,[19] which found that patients required 43 ± 16 mg (mean ± SD) of morphine in the first 24 h after a primary total hip replacement. Power calculation for a 25% difference in morphine consumption (10.7 mg), with an α probability level of 0.05 and a power of 0.90 ($1 - \beta$), yielded a sample size of 47 patients/group. The statistical analysis was carried out with intention to treat for a sample size of 100 patients. Categorical variables were expressed as a number and a percentage. Quantitative variables were expressed as the median and the interquartile range. The normality of the distribution of quantitative variables was determined using the Shapiro–Wilk test. The primary outcome was compared using Mann–Whitney test. For secondary outcomes, comparisons of quantitative variables between the two study groups were made using an unpaired two-tailed *t* test or a Mann–Whitney test. Comparisons of categorical variables were realized using a chi-square test or Fisher exact test, as appropriate. Pain scores at rest and on movement over the first 24 h after surgery were analyzed using a mixed model accounting for repeated measurements in the same patient. The numeric rating scale was the dependent variable. The randomization group, the mobilization, and the different measurement times were analyzed as fixed effects, with random intercept for the patient. The slope, the group, and the time interaction were tested. A model selection procedure (Bayesian Information Criterion, Bayesian Information Criterion minimization) was used to determine a final model. The group–time interaction was finally excluded in the final model. Estimates were reported using a 95% CI. To illustrate time to standing and time to ambulation, Kaplan–Meier curves and log-rank tests were used to explore the probability of patients being bedbound within each group. The data were right-censored 72 h postoperatively. A two-sided *P* value of less than 0.05 was considered statistically significant. Statistical analyses were performed with SAS Enterprise Guide version 7.1 (SAS Institute, USA).

Results

From July 2017 to September 2018, 289 patients scheduled for elective total hip replacement were assessed for eligibility. After assessment, 100 patients were randomly assigned to one of the two groups, with 50 patients/group (fig. 3). All 100 patients were included in the analysis. Patient characteristics are described in table 1. There were no missing data.

Quadratus Lumborum Block

Details of the interfascial solution spread in the two groups during the quadratus lumborum block procedure are documented in table 2. Graphical mapping of cutaneous sensory loss in the ropivacaine group, for quadratus lumborum block 2 (n = 18), quadratus lumborum blocks 2 + 1 (n = 18), and quadratus lumborum blocks 2 + 1 + 3 (n = 10) is reported in figure 4. Detailed mapping of loss of cold sensation in all the patients of the ropivacaine group is available in the appendix. No patient had loss of cold sensation cephalad to the twelfth rib. Of 50 patients, 12 (24%) did not have loss of cold sensation in the hip area. Of those, four patients had only anesthetic spread posterior to the quadratus lumborum muscle (quadratus lumborum block 2), whereas eight had anesthetic spread both posterior and lateral to the quadratus lumborum muscle (quadratus lumborum block 2 + 1).

Morphine Consumption

During the first 24 h after surgery, the cumulative IV morphine consumption was 13 (7 to 21) mg in the ropivacaine group and 16 (9 to 21) mg in the saline group (median difference, −1.5; 95% CI, −5 to 2; $P = 0.337$). Intraoperative sufentanil consumption was 27 (20 to 35) μg in the ropivacaine group and 26 (18 to 34) μg in the saline group (median difference, 0; 95% CI, −5 to 5; $P = 0.910$). Morphine consumption in the postanesthesia care unit was 10 (4 to 13) mg in the ropivacaine group *versus* 10 (5 to 15) mg in the saline group (median difference, −1; 95% CI, −3 to 1; $P = 0.448$). Cumulative morphine consumption in the 12 patients without cutaneous sensory loss in the ropivacaine group was 9 (4 to 16) mg.

Pain Scores

Numeric rating scale results at extubation time and 2, 6, 12, and 24 h postoperatively are shown in figure 5. Comparisons, by analysis of repeated measures, revealed that pain scores during the first postoperative 24 h were not different between the two groups ($\beta = -0.4$; 95% CI, −0.9 to 0.2; $P = 0.199$). Numeric rating scale score decreased over time ($\beta = -0.9$ to -1.9) with respect to extubation time ($P < 0.0001$). Pain was higher during mobilization ($\beta = 1.3$; 95% CI, 1.1 to 1.5; $P < 0.0001$). In the postanesthesia care unit, between extubation time and 2 h after extubation, the maximal numeric rating scale was 7 (5 to 8) in the ropivacaine group and 7 (5 to 8) in the saline group (median difference, 0; 95% CI, −1 to 1; $P = 0.696$). In the postanesthesia care unit, 25 patients had insufficient analgesia despite morphine titration (13 patients in the ropivacaine group and 12 in the saline group; $P = 0.771$) and required additional rescue analgesia. On the surgical ward, between 2 and 24 h after extubation, the maximal numeric rating scale was 4 (3 to 5) in the ropivacaine group and 4.5 (2 to 7) in the saline group (median difference, −0.5; 95% CI, −2 to 1; $P = 0.624$).

Rehabilitation Outcomes

There was no significant difference between the ropivacaine and the saline groups for both (1) time to first standing, at 19.7

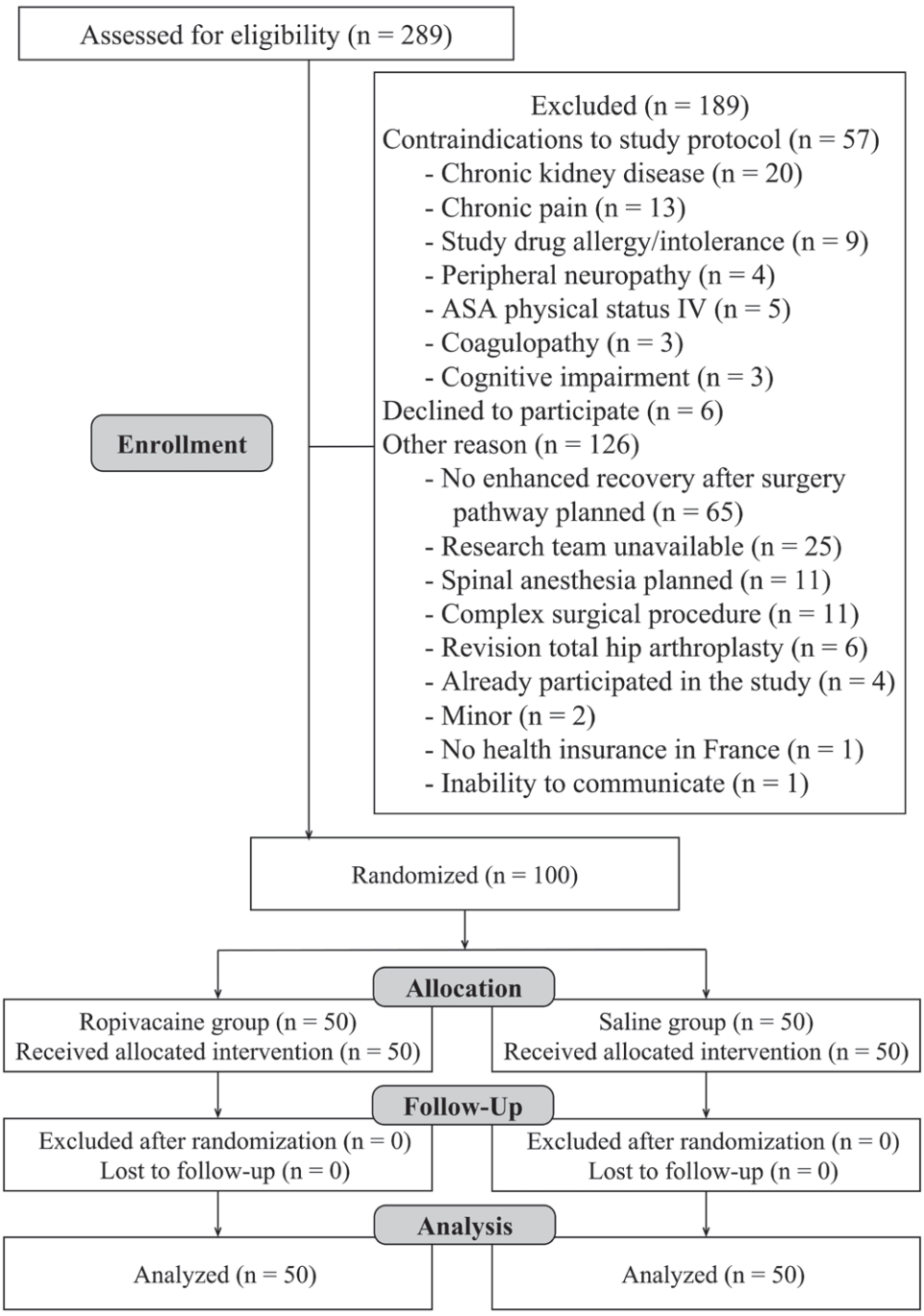

Fig. 3. Consolidated Standards of Reporting Trials diagram showing flow of study participants. ASA, American Society of Anesthesiologists.

(5.1 to 24.4) *versus* 18.7 (5.6 to 23.2) h (median difference, 0.8; 95% CI, −1.7 to 3.4; $P = 0.690$) and (2) time to first ambulation, at 23.9 (20.5 to 28.1) *versus* 22.5 (19 to 25) h (median difference, −1.8; 95% CI, −4.5 to 0.8; $P = 0.173$). The Kaplan–Meier curves for time to first standing ($P = 0.247$) and time to first ambulation ($P = 0.286$) are presented in figure 6. Hospital length of stay was not different between the ropivacaine and the saline group: 4 (3 to 5) *versus* 4 (3 to 5) days, respectively (median difference, −0.5; 95% CI, −1 to 0; $P = 0.227$).

Adverse Events and Safety

There were no complications or adverse events during the quadratus lumborum block procedure. At 2 h after extubation, significant motor weakness with a Bromage score of 2 or

Table 1. Patient Characteristics

Variables	Ropivacaine Group (n = 50)	Saline Group (n = 50)
Age, yr	68 (59 to 72)	65 (59 to 72)
Male	30 (60)	20 (40)
Height, cm	171 (166 to 176)	165 (160 to 172)
Weight, kg	76 (67 to 85)	76 (65 to 86)
Body mass index, kg/m^2	26 (23 to 30)	27 (23 to 29)
American Society of Anesthesiologists Physical Status score		
I	16 (32)	14 (28)
II	33 (66)	36 (72)
III	1 (2)	0
Surgical indication		
Degenerative joint disease	47 (94)	46 (92)
Inflammatory arthritis	3 (6)	4 (8)
Duration of block procedure, min	5 (3 to 7)	5 (4 to 8)
Duration of surgery, min	70 (63 to 77)	68 (61 to 81)

The results are expressed as median (25th percentile to 75th percentile) or number (%).

Table 2. Interfascial Solution Spread

Solution Spread	All Patients (n = 100)	Ropivacaine Group (n = 50)	Saline Group (n = 50)
Quadratus lumborum block 1	2	1	1
Quadratus lumborum block 2	37	18	19
Quadratus lumborum block 3	1	1	0
Quadratus lumborum blocks 2+1	35	18	17
Quadratus lumborum blocks 2+3	2	2	0
Quadratus lumborum blocks 1+3	1	0	1
Quadratus lumborum blocks 2+1+3	22	10	12

The solution spread was defined according to its location in relation to the quadratus lumborum muscle. Quadratus lumborum blocks 1, 2, and 3 indicate lateral, posterior, and anterior locations, respectively.

higher was observed in one patient in each group, which had regressed completely at 6 h after extubation in both patients. At 6 h after extubation, significant motor weakness was recorded only in one patient in the saline group ($P = 0.489$).

Postoperative nausea and vomiting occurred in 7 patients in the ropivacaine group and 12 patients in the saline group ($P = 0.202$). Urinary retention occurred in 2 patients in the ropivacaine group and in 4 patients in the saline group ($P = 0.678$).

Discussion

In this study, the posterior quadratus lumborum block (quadratus lumborum block 2) did not reduce opioid consumption during the first 24 postoperative hours in patients undergoing elective total hip replacement treated systematically with a multimodal analgesia regimen. Neither did this block have an effect on pain scores, time to first standing, time to first ambulation, or hospital length of stay.

In the pathway of enhanced recovery after surgery, early mobilization is highly recommended. Although an approach using epidural and/or nerve blocks provides good analgesia, it can result in delayed ambulation.[1] The search for optimal analgesia with less invasive techniques has made interfascial plane blocks increasingly popular.[20,21] However, in addition to the numerous case reports published, there remains a strong need for rigorous assessment of these new interfascial plane approaches, including both their clinical effect and the underlying mechanism of action.

First, regarding the analgesic effect of the quadratus lumborum block in hip surgery, randomized controlled trials are scarce, and our results contrast with those of others studies. One randomized trial, comparing a lateral quadratus lumborum block (quadratus lumborum block 1) with a femoral nerve block, revealed the role of the quadratus lumborum block 1 in lowering pain scores and opioid consumption in patients undergoing hemiarthroplasty for femoral neck fracture.[22] In this hip fracture context, where multimodal analgesia was not systematically utilized, the postoperative pain mechanisms may vary compared with the elective total hip arthroplasty context. In a retrospective comparative study, patients with a posterior quadratus lumborum block (quadratus lumborum block 2) also had lower pain scores and lower opioid requirements after elective total hip arthroplasty.[16] However, in this study, total opioid consumption was expressed in oral morphine equivalents, and multimodal analgesia with nonsteroidal anti-inflammatory drugs and acetaminophen was not used. In a prospective randomized trial, after elective total hip arthroplasty, the anterior quadratus lumborum block (quadratus lumborum block 3) similarly led to lower pain scores and lower oral morphine equivalent consumption.[13] The effect of the anterior quadratus lumborum block (quadratus lumborum block 3) has also been studied in a retrospective propensity-matched cohort study in which the anterior quadratus lumborum block was compared with the lumbar plexus block for total hip replacement.[23] There was no difference between the two groups both in the IV morphine equivalent consumption and in pain scores. Because the lumbar plexus block is known to reduce pain after total hip replacement,[2,4] this study demonstrates an impressively similar analgesic efficacy associated with the anterior quadratus lumborum block.

Second, there are few available data elucidating the underlying mechanism of action of these interfascial plane blocks. None of the studies referenced above have provided an assessment of the local anesthetic spread or of the sensory and motor blockade to explain the mechanism of action.[13,16,22,23] The analgesic mechanism for the different quadratus lumborum block approaches thus remains poorly understood.[24] Limited publications suggest that the effect of the anterior quadratus lumborum block (quadratus lumborum block 3) in hip surgery[13,23] could be explained by

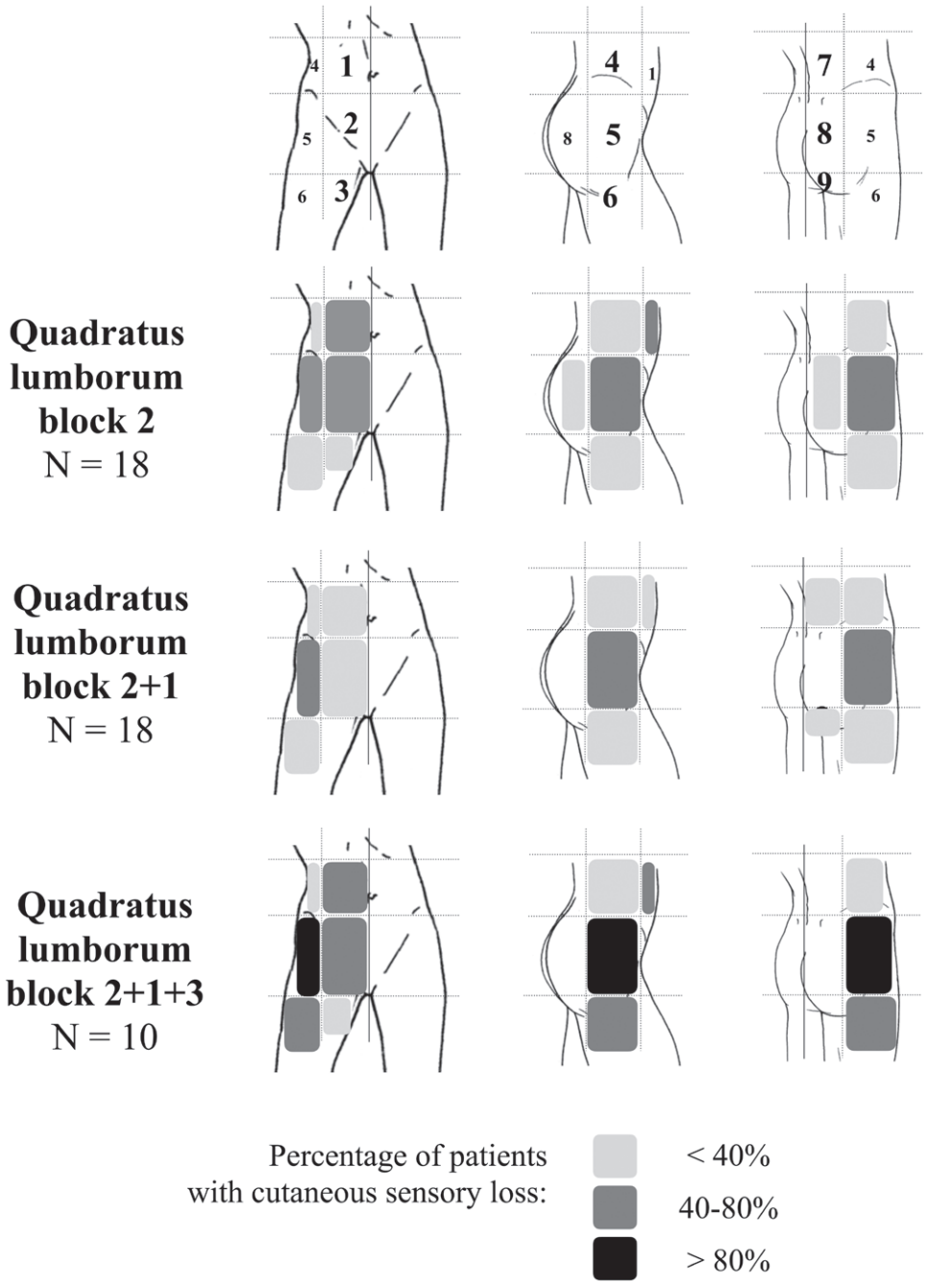

Fig. 4. Distribution of cutaneous sensory loss in the nine hip areas in the ropivacaine group. Quadratus lumborum blocks 1, 2, and 3 indicate the spread of ropivacaine lateral, posterior, or anterior, respectively, to the quadratus lumborum muscle.

local anesthetic spread to the lumbar plexus. In favor of this postulated mechanism, two cadaveric studies observed injectate spread to the upper lumbar plexus branches after an anterior quadratus lumborum block.[25,26] Additionally, in one retrospective study, the incidence of quadriceps muscle weakness after an anterior quadratus lumborum block was 90%, suggesting a block of the lumbar plexus.[14] With respect to the possible mechanism of action of the posterior quadratus lumborum block (quadratus lumborum block 2), this is even more debatable, but the results of our study provide the beginnings for further understanding. In our study, first, despite a rigorous control of the needle tip position, the solution injected between the quadratus lumborum and the erector spinae muscles had unpredictable spread, with

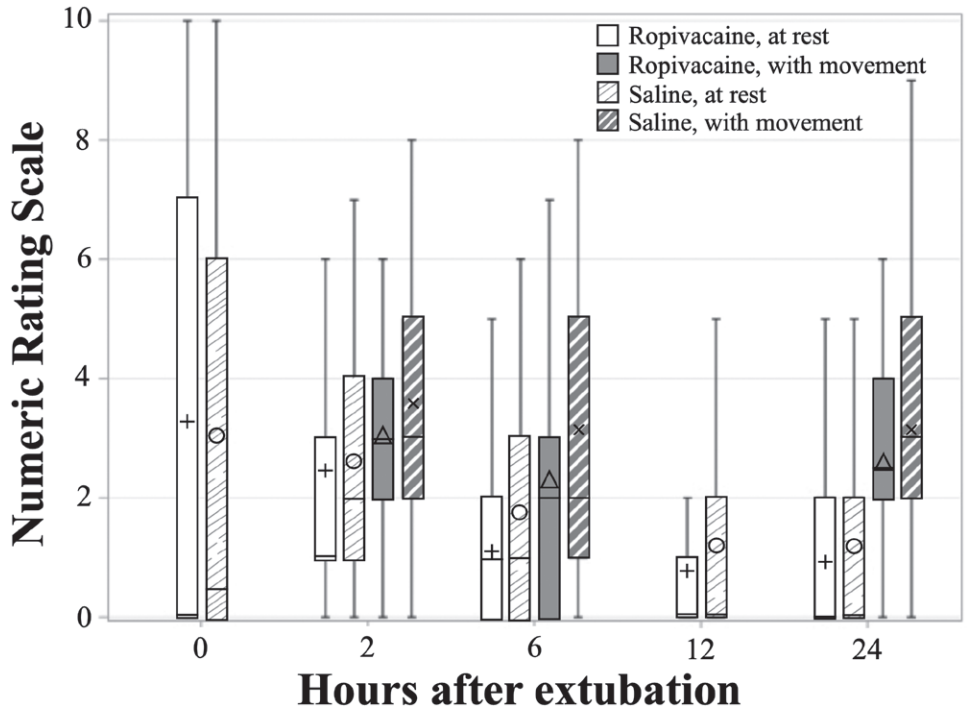

Fig. 5. Pain expressed with a numeric rating scale at rest and during movement in the ropivacaine and saline groups. Zero represents no pain, and 10 represents the worst possible pain. For the box and whisker plots, the *horizontal bars* indicate the medians, the *upper and lower limits* of the boxes indicate the interquartile range, and the *ends of the whiskers* are the minimal and maximal values. +, ○, Δ, and × indicate the mean values.

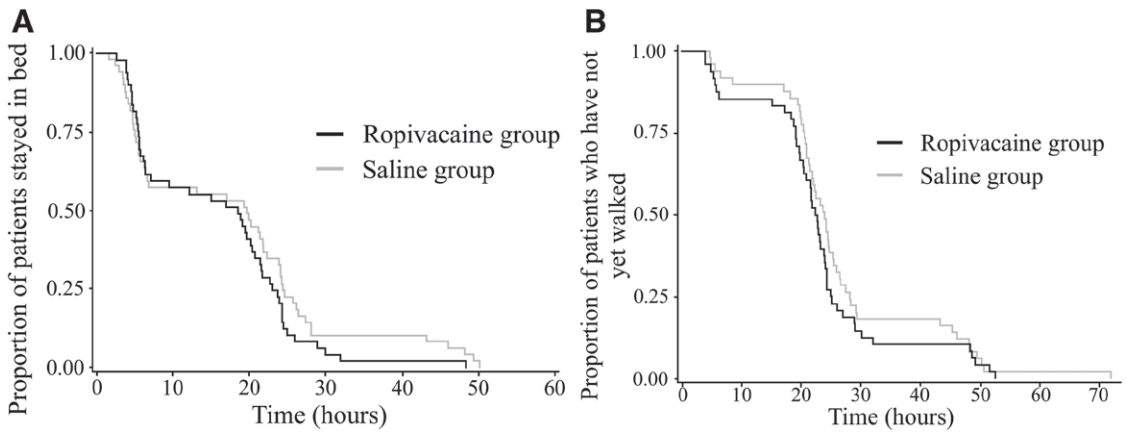

Fig. 6. Probability of bedbound patients over time according to the groups. (*A*) Time to first standing. (*B*) Time to first ambulation.

local anesthetic visible at multiple varying locations around the quadratus lumborum muscle. It is possible that local anesthetic spread in these interfascial plane blocks primarily depends on tissue compliance rather than on the precise needle tip position within the thoracolumbar interfascial planes. Second, the cutaneous loss of cold sensation noted in our study was similar in all patients, irrespective of the individual local anesthetic spread pattern. This cutaneous anesthesia noted may be secondary to blockade of the subcostal, iliohypogastric, genitofemoral, and lateral femoral cutaneous nerves. This sensory block was demarcated at the inferior rib cage margin, with no spread in the cephalad direction

beyond this margin. Similar observations with a limited sensory blockade have been published in several case reports.[8–11] Finally, no motor blockade was reported after this posterior quadratus lumborum block. Innervation of the hip joint is complex and provided by branches of the lumbar and sacral plexus.[27] Because nociceptors are mainly distributed on the anterior side of the joint capsule, the role of the obturator and femoral nerves in hip nociception is crucial.[28] In our study, theses nerves were not blocked after the posterior quadratus lumborum block, possibly explaining the lack of analgesic effect of this block for total hip arthroplasty noted in our trial. Another commonly postulated mechanism of action is that local anesthetic spreads into the thoracic paravertebral space.[29,30] However, as noted in our study and others, sensory blockade associated with this block is often patchy, not corresponding to a classic dermatomal distribution.[8–11,29]

This study has some limitations. First, this was a single-center trial, and external validity may be attenuated. However, total hip arthroplasty is a standardized procedure with similar patient care in most developed countries. Conversely, in this single-center study, all procedures were performed by the same surgical team, with the same surgical approach, and the administration of systematic multimodal analgesia is standardized across the nurse anesthetist team. Second, despite the *a priori* sample size calculation, the study was underpowered to detect a significant morphine consumption difference between the two groups, with a smaller difference obtained in our results compared to the study used for our sample size calculation.[19] To detect a statistical difference between the two groups, 2,029 patients would have had to be included in each group, after *a posteriori* sample size calculation. However, would a 3-mg difference between the two groups, noted in this study, be clinically relevant? The low cumulative postoperative morphine consumption at 24 h after surgery suggests an effective IV multimodal analgesia regimen systematically used in all our patients.[1–4] Notably, nonsteroidal anti-inflammatory agents have a significant intrinsic opioid-sparing effect in orthopedic surgery.[1,2] In the same way, intraoperative use of ketamine and dexamethasone may have contributed to postoperative analgesia and therefore may have reduced the measured contribution of the quadratus lumborum block. Third, the optimal anesthesia choice, of general anesthesia *versus* spinal anesthesia, in total hip replacement can be debatable. In our institution, hip surgery is mainly performed under general anesthesia to optimize patient comfort. Within an enhanced recovery after surgery program, general anesthesia additionally seems to result in a more favorable recovery profile compared with spinal anesthesia.[31] Fourth, because physiotherapist availability in our center was until 4 PM daily, the difference between groups in achieving early rehabilitation could have been underestimated. In some cases, we imagine that physiotherapist-accompanied rehabilitation would have been delayed until the following day for patients admitted late to the orthopedic ward after 4 PM. Finally, 12 patients in the ropivacaine group had low morphine consumption despite surprisingly no loss of cold sensation in the postanesthesia care unit. It is possible that there is a lack of correspondence between analgesia and loss of cold sensation or that there was inaccurate sensory blockade evaluation, for example because of patient drowsiness. In conclusion, we found the posterior quadratus lumborum block to have no clinically significant effect on morphine consumption and pain scores after total hip arthroplasty in the presence of a multimodal analgesia regimen.

Acknowledgments

The authors thank Guillaume Charon (International Product Manager at MICREL Medical Devices, Nice, France), for the allocation of three Rythmic Evolution infusion pumps; Laure Dega, C.R.N.A., and Martine Deschaises, C.R.N.A. (Department of Anesthesiology and Critical Care Medicine, Lapeyronie University Hospital, Montpellier, France), for their assistance; Aurelien Canon, M.D., Nathalie Bernard, M.D., Caroline Thuile, M.D., Thibault Loupec, M.D., Jules Gallais, M.D., Fanny Bauchy, M.D., Jibril Nouri, M.D., Maxime Varobieff, M.D., Sonia Tazerout, M.D., and Geoffrey Dagod, M.D. (Department of Anesthesiology and Critical Care Medicine, Lapeyronie University Hospital, Montpellier, France), for their enrollment of patients; and Bruno Souche, M.D. (Department of Anesthesiology and Critical Care Medicine, Saint Eloi University Hospital, Montpellier, France), for software adaptations to prescription protocols.

Research Support

Support was provided solely from institutional and/or departmental sources.

Competing Interests

The authors declare no competing interests.

Reproducible Science

Full protocol available at: p-biboulet@chu-montpellier.fr. Raw data available at: p-biboulet@chu-montpellier.fr.

Correspondence

Address correspondence to Dr. Biboulet, Lapeyronie University Hospital, 34295 Montpellier cedex 5, France. p-biboulet@chu-montpellier.fr. This article may be accessed for personal use at no charge through the Journal Web site, www.anesthesiology.org.

References

1. Wainwright TW, Gill M, McDonald DA, Middleton RG, Reed M, Sahota O, Yates P, Ljungqvist O:

Consensus statement for perioperative care in total hip replacement and total knee replacement surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations. Acta Orthop 2020; 91:3–19
2. Højer Karlsen AP, Geisler A, Petersen PL, Mathiesen O, Dahl JB: Postoperative pain treatment after total hip arthroplasty: A systematic review. Pain 2015; 156:8–30
3. Sinatra RS, Jahr JS, Reynolds LW, Viscusi ER, Groudine SB, Payen-Champenois C: Efficacy and safety of single and repeated administration of 1 gram intravenous acetaminophen injection (paracetamol) for pain management after major orthopedic surgery. Anesthesiology 2005; 102:822–31
4. Biboulet P, Morau D, Aubas P, Bringuier-Branchereau S, Capdevila X: Postoperative analgesia after total-hip arthroplasty: Comparison of intravenous patient-controlled analgesia with morphine and single injection of femoral nerve or psoas compartment block: A prospective, randomized, double-blind study. Reg Anesth Pain Med 2004; 29:102–9
5. Zoric L, Cuvillon P, Alonso S, Demattei C, Vialles N, Asencio G, Ripart J, Nouvellon E: Single-shot intraoperative local anaesthetic infiltration does not reduce morphine consumption after total hip arthroplasty: A double-blinded placebo-controlled randomized study. Br J Anaesth 2014; 112:722–8
6. Stevens RD, Van Gessel E, Flory N, Fournier R, Gamulin Z: Lumbar plexus block reduces pain and blood loss associated with total hip arthroplasty. Anesthesiology 2000; 93:115–21
7. Fournier R, Van Gessel E, Gaggero G, Boccovi S, Forster A, Gamulin Z: Postoperative analgesia with "3-in-1" femoral nerve block after prosthetic hip surgery. Can J Anaesth 1998; 45:34–8
8. Hockett MM, Hembrador S, Lee A: Continuous quadratus lumborum block for postoperative pain in total hip arthroplasty: A case report. A A Case Rep 2016; 7:129–31
9. Johnston DF, Sondekoppam RV: Continuous quadratus lumborum block analgesia for total hip arthroplasty revision. J Clin Anesth 2016; 35:235–7
10. Ueshima H, Yoshiyama S, Otake H: The ultrasound-guided continuous transmuscular quadratus lumborum block is an effective analgesia for total hip arthroplasty. J Clin Anesth 2016; 31:35
11. La Colla L, Uskova A, Ben-David B: Single-shot quadratus lumborum block for postoperative analgesia after minimally invasive hip arthroplasty: A new alternative to continuous lumbar plexus block? Reg Anesth Pain Med 2017; 42:125–6
12. El-Boghdadly K, Elsharkawy H, Short A, Chin KJ: Quadratus lumborum block nomenclature and anatomical considerations. Reg Anesth Pain Med 2016; 41:548–9
13. Kukreja P, MacBeth L, Sturdivant A, Morgan CJ, Ghanem E, Kalagara H, Chan VWS: Anterior quadratus lumborum block analgesia for total hip arthroplasty: A randomized, controlled study. Reg Anesth Pain Med 2019; 44:1075–9
14. Ueshima H, Hiroshi O: Incidence of lower-extremity muscle weakness after quadratus lumborum block. J Clin Anesth 2018; 44:104
15. Blanco R, Ansari T, Girgis E: Quadratus lumborum block for postoperative pain after caesarean section: A randomised controlled trial. Eur J Anaesthesiol 2015; 32:812–8
16. Kukreja P, MacBeth L, Potter W, Buddemeyer K, DeBell H, Elsharkawy H, Kalagara H, Wajnsztejn A, Pires EA, Godoy-Santos AL, Shah A: Posterior quadratus lumborum block for primary total hip arthroplasty analgesia: A comparative study. Einstein (Sao Paulo) 2019; 17:eAO4905
17. Sauter AR, Ullensvang K, Niemi G, Lorentzen HT, Bendtsen TF, Børglum J, Pripp AH, Romundstad L: The Shamrock lumbar plexus block: A dose-finding study. Eur J Anaesthesiol 2015; 32:764–70
18. Bromage PR, Burfoot MF, Crowell DE, Pettigrew RT: Quality of epidural blockade: I. Influence of physical factors. Br J Anaesth 1964; 36:342–52
19. Minville V, Lubrano V, Bounes V, Pianezza A, Rabinowitz A, Gris C, Samii K, Fourcade O: Postoperative analgesia after total hip arthroplasty: Patient-controlled analgesia *versus* transdermal fentanyl patch. J Clin Anesth 2008; 20:280–3
20. Chin KJ, McDonnell JG, Carvalho B, Sharkey A, Pawa A, Gadsden J: Essentials of our current understanding: Abdominal wall blocks. Reg Anesth Pain Med 2017; 42:133–83
21. Elsharkawy H, Pawa A, Mariano ER: Interfascial plane blocks: Back to basics. Reg Anesth Pain Med 2018; 43:341–6
22. Parras T, Blanco R: Randomised trial comparing the trans*versus* abdominis plane block posterior approach or quadratus lumborum block type I with femoral block for postoperative analgesia in femoral neck fracture, both ultrasound-guided. Rev Esp Anestesiol Reanim 2016; 63:141–8
23. Adhikary SD, Short AJ, El-Boghdadly K, Abdelmalak MJ, Chin KJ: Transmuscular quadratus lumborum *versus* lumbar plexus block for total hip arthroplasty: A retrospective propensity score matched cohort study. J Anaesthesiol Clin Pharmacol 2018; 34:372–8
24. Elsharkawy H, El-Boghdadly K, Barrington M: Quadratus lumborum block: anatomical concepts, mechanisms, and techniques. Anesthesiology 2019; 130:322–35
25. Adhikary SD, El-Boghdadly K, Nasralah Z, Sarwani N, Nixon AM, Chin KJ: A radiologic and anatomic assessment of injectate spread following transmuscular quadratus lumborum block in cadavers. Anaesthesia 2016: 72:73–9
26. Carline L, McLeod GA, Lamb C: A cadaver study comparing spread of dye and nerve involvement after three

different quadratus lumborum blocks. Br J Anaesth 2016; 117:387–94
27. Birnbaum K, Prescher A, Hessler S, Heller KD: The sensory innervation of the hip joint: An anatomical study. Surg Radiol Anat 1997; 19: 371–5
28. Gerhardt M, Johnson K, Atkinson R, Snow B, Shaw C, Brown A, Vangsness CT Jr: Characterisation and classification of the neural anatomy in the human hip joint. Hip Int 2012; 22:75–81
29. Carney J, Finnerty O, Rauf J, Bergin D, Laffey JG, Mc Donnell JG: Studies on the spread of local anaesthetic solution in transversus abdominis plane blocks. Anaesthesia 2011; 66:1023–30
30. Børglum J, Moriggl B, Jensen K, Lønnqvist P-A, Christensen AF, Sauter A, Bendtsen TF: Ultrasound-guided transmuscular quadratus lumborum blockade. Br J Anaesth 2013; 111(issue eLetters Supplement). Available at: https://doi.org/10.1093/bja/el_9919. Accessed December 22, 2020.
31. Harsten A, Kehlet H, Ljung P, Toksvig-Larsen S: Total intravenous general anaesthesia vs. spinal anaesthesia for total hip arthroplasty: A randomised, controlled trial. Acta Anaesthesiol Scand 2015; 59:298–309

Appendix: Distribution of Cutaneous Sensory Loss in the Nine Hip Areas in the Ropivacaine Group

	Hip Areas								
Solution Spread	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Quadratus lumborum block 1 (n = 1)	0	1	1	0	1	1	0	0	0
Quadratus lumborum block 2 (n = 18)	9	8	2	6	10	6	0	2	0
Quadratus lumborum block 3 (n = 1)	0	0	0	0	1	1	0	0	0
Quadratus lumborum blocks 2 + 1 (n = 18)	6	7	0	7	10	5	1	0	1
Quadratus lumborum blocks 2 + 3 (n = 2)	1	1	0	0	2	0	0	0	0
Quadratus lumborum blocks 2 + 1 + 3 (n = 10)	5	6	3	3	10	4	0	0	0

The solution spread was defined according to its location in relation to the quadratus lumborum muscle. Quadratus lumborum blocks 1, 2, and 3 indicate lateral, posterior, and anterior locations, respectively.