EJA

Eur J Anaesthesiol 2023; **40:**660–671

ORIGINAL ARTICLE

Comparison between supra-inguinal fascia iliaca and pericapsular nerve group blocks on postoperative pain and functional recovery after total hip arthroplasty

A noninferiority randomised clinical trial

Michele Carella, Florian Beck, Nicolas Piette, Sébastien Denys, Jean-Pierre Lecoq and Vincent L. Bonhomme

BACKGROUND Pain after a posterolateral approach for total hip arthroplasty (THA) may affect early functional recovery. Supra-inguinal fascia iliaca (SFIB) and pericapsular nerve group (PENG) blocks have been proposed as promising analgesia techniques.

OBJECTIVES This trial was conducted to compare a PENG with a SFIB for controlling postoperative pain and for providing functional recovery.

DESIGN Noninferiority monocentric randomised controlled study.

SETTING One hundred and two patients scheduled for a total hip arthroplasty via the posterolateral approach under spinal anaesthesia were prospectively allocated to two groups. Data acquisition occurred between October 2021 and July 2022 at the University Hospital of Liege.

PATIENTS One hundred and two patients completed the trial.

INTERVENTIONS Group SFIB received supra-inguinal fascia iliaca block (SFIB) (40 ml ropivacaine 0.375%), whereas group PENG received a PENG block (20 ml ropivacaine 0.75%).

MAIN OUTCOME MEASURES Rest and mobilisation pain on a 0 to 10 numeric rating scale at fixed time points: 1 and 6 h after surgery, on day-1 and day-2 at 8 a.m.,1 p.m. and 6 p.m. On day-1 and day-2, evolution of quality-of-recovery-15 score was assessed, and timed-up-and-go, 2 and 6 min-walking tests. The noninferiority margin was set as 1 numeric rating scale point 6 h after surgery.

RESULTS Six hours after surgery, pain scores in group PENG were noninferior to those of group SFIB, with a difference between medians at 0 (95% CI −0.93 to 0.93). There were no significant differences between the groups regarding rest and dynamic pain trajectories during the first 48 postoperative hours, with no significant effects of group (rest $P = 0.800$; dynamic $P = 0.708$) or interaction between group and time (rest $P = 0.803$; dynamic $P = 0.187$). Similarly, no significant differences were observed regarding motor and functional recovery as assessed by timed-up-and-go ($P = 0.197$), 2 min ($P = 0.364$), and 6 min walking ($P = 0.347$) tests and quality-of-recovery-15 ($P = 0.417$) score.

CONCLUSION Following a total hip arthroplasty via the posterolateral approach, a PENG block is noninferior to SFIB regarding postoperative pain control 6 h after surgery, and functional recovery.

TRIAL REGISTRATION European Clinical Trial Register under EudraCT-number 2020-005126-28 (https://www.clinicaltrialsregister.eu/ctr-search/trial/2020-005126-28/BE).

Published online 30 June 2023

From the Department of Anaesthesia and Intensive Care Medicine, Liege University Hospital (MC, FB, NP, J-PL, VLB), Inflammation and Enhanced Rehabilitation Laboratory (Regional Anaesthesia and Analgesia), GIGA-I3 Thematic Unit, GIGA-Research (MC, NP, J-PL), Anaesthesia and Perioperative Neuroscience Laboratory, GIGA-Consciousness Thematic Unit, GIGA-Research (FB, VLB) and Department of Physical Medicine, Rehabilitation and Sports Traumatology, Liege University Hospital, Liege, Belgium (SD)

Correspondence to Michele Carella, MD, Department of Anaesthesia and Intensive Care Medicine, Liège University Hospital - Sart Tilman site, Avenue de l'Hôpital 1, Domaine Universitaire du Sart Tilman, Bâtiment B35, 4000 Liège, Belgium.
E-mail: mcarella@chuliege.be

DOI:10.1097/EJA.0000000000001875

KEY POINTS

- Supra-inguinal fascia iliaca block is recommended for analgesia after total hip replacement.
- PENG block is also effective and, in theory, should have better functional recovery.
- Both blocks provide similar pain trajectories.
- No differences between the blocks exist in terms of postoperative functional recovery and walking performance.
- Either techniques can be used successfully for pain relief after a posterolateral approach for total hip arthroplasty.

Introduction

Described as 'the surgery of the century', total hip arthroplasty (THA) is characterised by moderate-to-severe early postoperative pain.[1,2] This is one of the main factors limiting postoperative functional recovery, with the peak pain intensity being typically at around 6 h after surgery with spinal anaesthesia.[3]

THA by the posterolateral approach (PLTHA) remains one of the most popular surgical techniques, due in part to fewer postoperative complications.[4,5]

Several multimodal analgesia techniques and peripheral nerve blocks (PNB) have been proposed to flatten the pain peak that occurs during the first hours after surgery. PNBs, as well as spinal anaesthesia, are also effective at reducing postoperative complications after THA.[6,7] The balance between optimal analgesia and sparing the quadriceps strength considerably limits the choice among usable PNBs. Some PNBs result in a motor block with quadriceps femoris weakness, causing delayed functional recovery and increasing the risk of postoperative falls.[8]

A longitudinal supra-inguinal approach to the fascia iliaca compartment has been shown to be efficient at relieving pain after both the anterior and posterolateral approach for THA.[9,10] The supra-inguinal fascia iliaca block (SFIB) performed in patients having received spinal anaesthesia for surgery reduces postoperative opioid consumption, improves postoperative pain management and functional performance during the first 48 h after surgery.[10] Similarly, the pericapsular nerve group (PENG) block has been demonstrated to be effective in PLTHAs, not only regarding postoperative pain management but also because of preservation of quadriceps femoris strength.[11–13] Although the PENG block is presumed to be more quadriceps strength sparing, at present, no study has focused on the differences between it and SFIB in terms of postoperative functional recovery and walking performance.

In this trial, our primary aim was to investigate whether the PENG block was noninferior to the SFIB in patients receiving spinal anaesthesia for PLTHA in terms of pain control at postoperative hour 6, the time of the pain intensity peak. Secondarily, we compared the PENG block and SFIB regarding the first postoperative 48 h pain trajectory, opioid consumption, global functional recovery and performance-based motor assessment.

Methods

This prospective, randomised, clinical trial was approved by our Institutional Review Board (Comité d'Ethique Hospitalo-Facultaire Universitaire de Liège; President: Professor V. Seutin; IRB number: 707) under the study number 2020/381 on 18 January 2021. Before patient enrolment, the trial protocol was registered in the European Clinical Trial Register under the EudraCT-number 2020-005126-28 (https://www.clinicaltrialsregister.eu/ctr-search/trial/2020–005126–28/BE) on 16 June 2021 (principal investigator: Michele Carella). After a detailed explanation about the study rationale by the principal investigator, written informed consent was obtained before inclusion of eligible patients into the trial. This study follows the applicable CONSORT guidelines and was performed in accordance with the most recent version of the Helsinki Declaration. Data acquisition occurred between 11 October 2021 and 6 July 2022 at the University Hospital of Liege, Belgium.

Patients scheduled to undergo elective PLTHA under spinal anaesthesia were consecutively and prospectively considered as eligible for inclusion. Exclusion criteria were refusal of the patient to participate, and general contra-indications to PNBs. Other exclusion criteria included obesity with BMI greater than 35 kg m^{-2} (since functional recovery in obese patients is impaired); emergency hip arthroplasty; previous hip surgery; drug addiction, including ongoing opioid treatment; severe kidney or liver diseases; inability to understand the study protocol or the correct use of a patient-controlled intravenous analgesia (PCIA) device. A computer-generated list was used for randomisation. Patient and surgeon were blinded to group assignment. The anaesthetist who collected intraoperative and postoperative data was also blinded regarding the group assignment. PENG or SFIB was performed by an unblinded experienced anaesthetist. Groups differed according to the performance of SFIB with 40 ml of ropivacaine 0.375% or PENG with 20 ml of ropivacaine 0.75%.

All patients received oral premedication with oral etoricoxib 60 mg at least 90 min before spinal anaesthesia. Spinal anaesthesia involved the intrathecal injection of 2 ml isobaric bupivacaine 0.5% combined with 0.2 ml of sufentanil 5 μg ml^{-1}.

Before data analysis, the research team verified that patients had not experienced severe intraoperative hypotension or oximetry desaturation less than 88% as such patients may have a different trajectory of care with middle or intensive care needed.

For antiemetic and anti-inflammatory purposes, a single intravenous dose of dexamethasone was administered after spinal anaesthesia (0.15 mg kg^{-1}, maximum 10 mg). Where necessary, patients received an intravenous dose of ondansetron 4 mg every 8 h to treat postoperative nausea and vomiting (PONV). Each patient received 1 g of intravenous paracetamol at the end of surgery. After surgery, patients received oral paracetamol, 1 g every 6 h, and etoricoxib 60 mg every 24 h.

A PCIA device was provided to all patients (Rythmic Evolution, Micrel Medical Devices SA, Koropi, Greece), containing a 0.2% morphine solution and connected in parallel to the intravenous line. The PCIA was programmed with a nonmodifiable algorithm that included 1 mg boluses and 5 min lockout time, with a maximum administered dose over 4 h that could not exceed a total of 20 mg intravenous morphine.

Supra-inguinal fascia iliaca and pericapsular nerve group blocks

Both PNB techniques were performed after SA. Despite the intention-to-treat approach of our trial, when a failure of SA with conversion to general anaesthesia was necessary, we decided before enrolment to exclude data from these patients. Indeed, the use of general anaesthesia projects a different pain trajectory from SA, and this could have interfered with the primary endpoint of the study (Supplementary Appendix 1, http://links.lww.com/EJA/A849, Figs. 1 and 2).

The SFIB was performed using the technique described by Desmet *et al.* [9] The PENG block was performed according to the technique described by Giron-Arango *et al.*[14]

Recorded parameters and time points of interest

A blinded observer noted the intensity of pain on a 0 to 10 numeric rating scale at fixed time points: one hour and six hours after surgery; and at day-1 and day-2 at 8am, 1pm and 6pm at rest and on mobilisation, i.e., passive thigh flexion (rest NRS and dynamic NRS). The blinded observer noted postoperative morphine-related side effects such as nausea and vomiting, itching, acute urinary retention, delay in the recovery of gastrointestinal transit, dizziness, drowsiness, and discomfort (Fig. 3).

The blinded physical therapist collected data regarding functional outcomes and postoperative motor performance

Fig. 1 Sono-anatomical image with injection and spread of local anaesthetic during supra-inguinal fascia iliaca block.

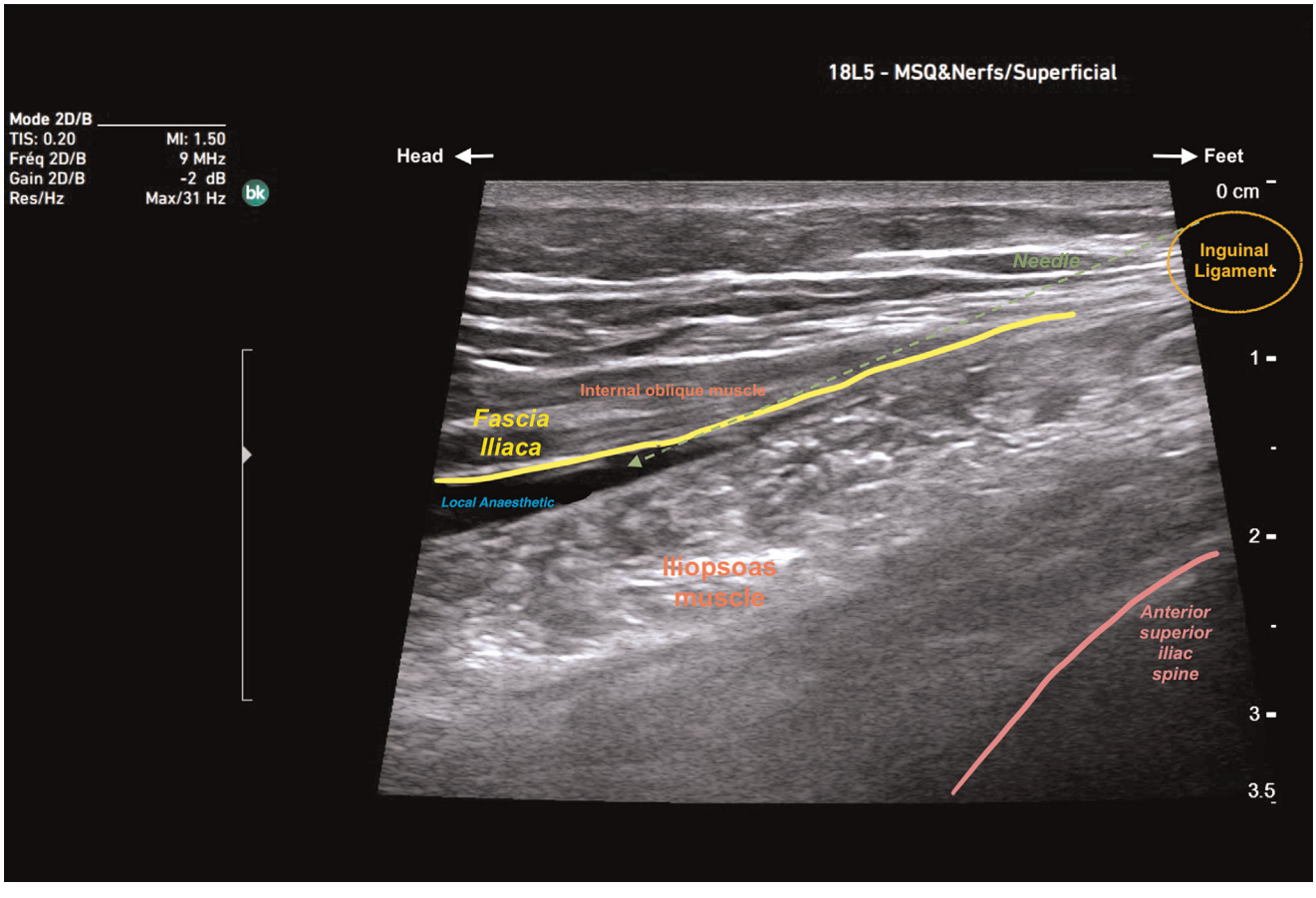
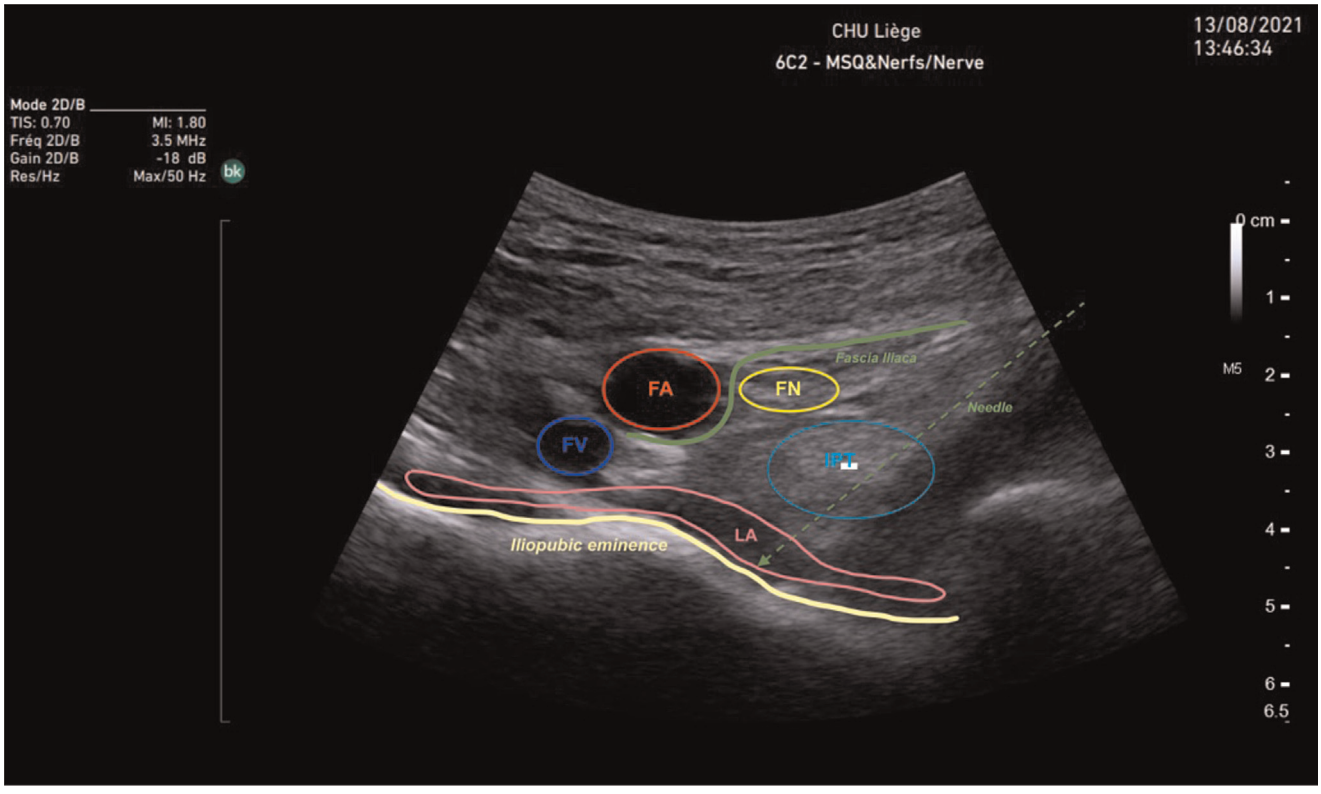
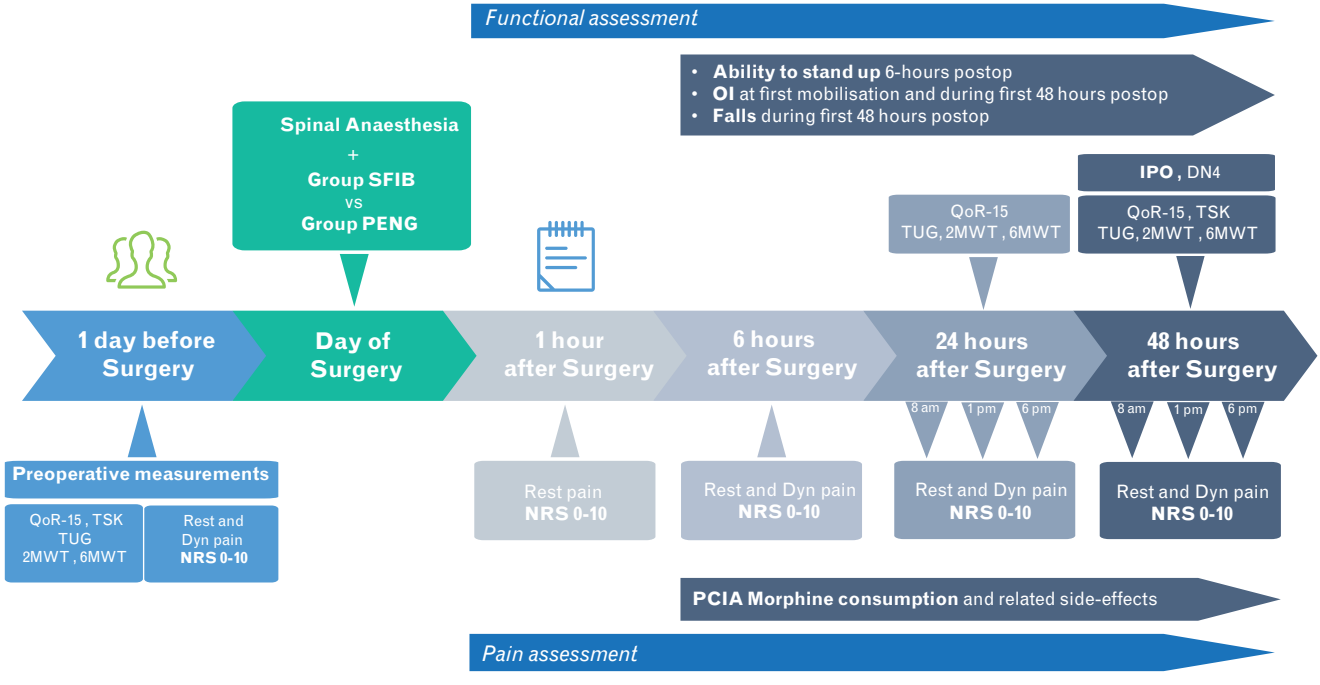


Fig. 2 Sono-anatomical image with injection and spread of local anaesthetic during pericapsular nerve group block.



FA, femoral artery; FN, femoral nerve; FV, femoral vein; IPT, iliopsoas tendon; LA, local anaesthetic.

Fig. 3 Timeline of data acquisition.



2MWT, 2-min walking distance test; 6MWT, 6-min walking distance test; DN4, DN4 questionnaire; Dyn, dynamic pain (i.e. on movement); IPO, International Pain Outcomes questionnaire; NRS, numeric rating scale for pain; OI, orthostatic intolerance; PCIA, patient controlled intravenous analgesia; PENG, Pericapsular Nerve Group Block; Postop, postoperatively; QoR-15, quality-of-recovery 15-items score; SFIB, supra-inguinal fascia iliaca block; TSK, Tampa Scale of Kinesiophobia; TUG, timed up-and-go test.

24 and 48 h after surgery through the timed up-and-go test (TUG), the 2 min walking distance test (2MWT) and the 6 min walking distance test (6MWT). The quality of postoperative functional recovery and the variations and differences between groups were assessed using the validated French version of the quality-of-recovery 15-items score (QoR-15) at 24 and 48 h after surgery.[15] For all these outcomes, a comparative baseline assessment the day before surgery was conducted for each patient for TUG, 2MWT, 6MWT and QoR-15. To investigate a possible correlation between preoperative and postoperative kinesiophobia and functional performance, a preoperative and 48 h postoperative assessment was performed using the Tampa Scale of Kinesiophobia (TSK).[16]

The risk of early acute postsurgical neuropathic pain was assessed using the DN4 questionnaire 48 h after surgery.[17] All episodes of falls during the first 48 postoperative hours were recorded and a blinded physical therapist noted the occurrence of orthostatic intolerance defined by the sudden onset of at least one of the following sensations: dizziness, nausea, vomiting, feeling of heat, blurred vision and vagal syncope. In addition, we wanted to observe the difference between the two groups regarding the incidence of orthostatic intolerance at first mobilisation, and the number of patients who felt able to stand up and walk around the bed 6 h after surgery.

Global pain management and patient satisfaction were assessed by the International Pain Outcomes (IPO) questionnaire.[18] The duration of total hospitalisation (LOS) as well as the need to refer to a specialised postoperative rehabilitation centre were also noted.

Statistical analyses

The primary endpoint of the study was the noninferiority of the PENG pain score at rest 6 h after surgery when compared with the SFIB group. Secondary endpoints were the between-group differences in the evolution of pain trajectories during the first 48 h, as well as total morphine consumption, the quality of functional recovery and performance during the first 48 h as assessed by the TUG, 2MWT, 6MWT and QoR-15, the incidence of falls, orthostatic intolerance during the first 48 postoperative hours and morphine-related side effects at day-1 and day-2. Other secondary endpoints included total length of stay, TSK, DN4 score and pain management assessment by the French-validated IPO questionnaire.

All statistical analyses and a priori sample size calculation were performed using the R package (version 4.2.2, R Foundation for Statistical Computing, Vienna, Austria). We performed a sample size calculation where the noninferiority margins were set at the minimum detectable and clinically relevant value of pain intensity at the zenith of postoperative pain 6 h after THA with spinal anaesthesia,[3] namely 1 NRS point. Based on previous data from our institution (mean NRS ± SD) of 2.26 ± 1.47 at rest 6 h after surgery, 46 patients per group were needed to reach 90% power with an alpha threshold of 0.025, using a one-sided two-sample *t* test. Assuming a 10% postrandomisation dropout, 102 patients were finally randomised at a 1 : 1 ratio.

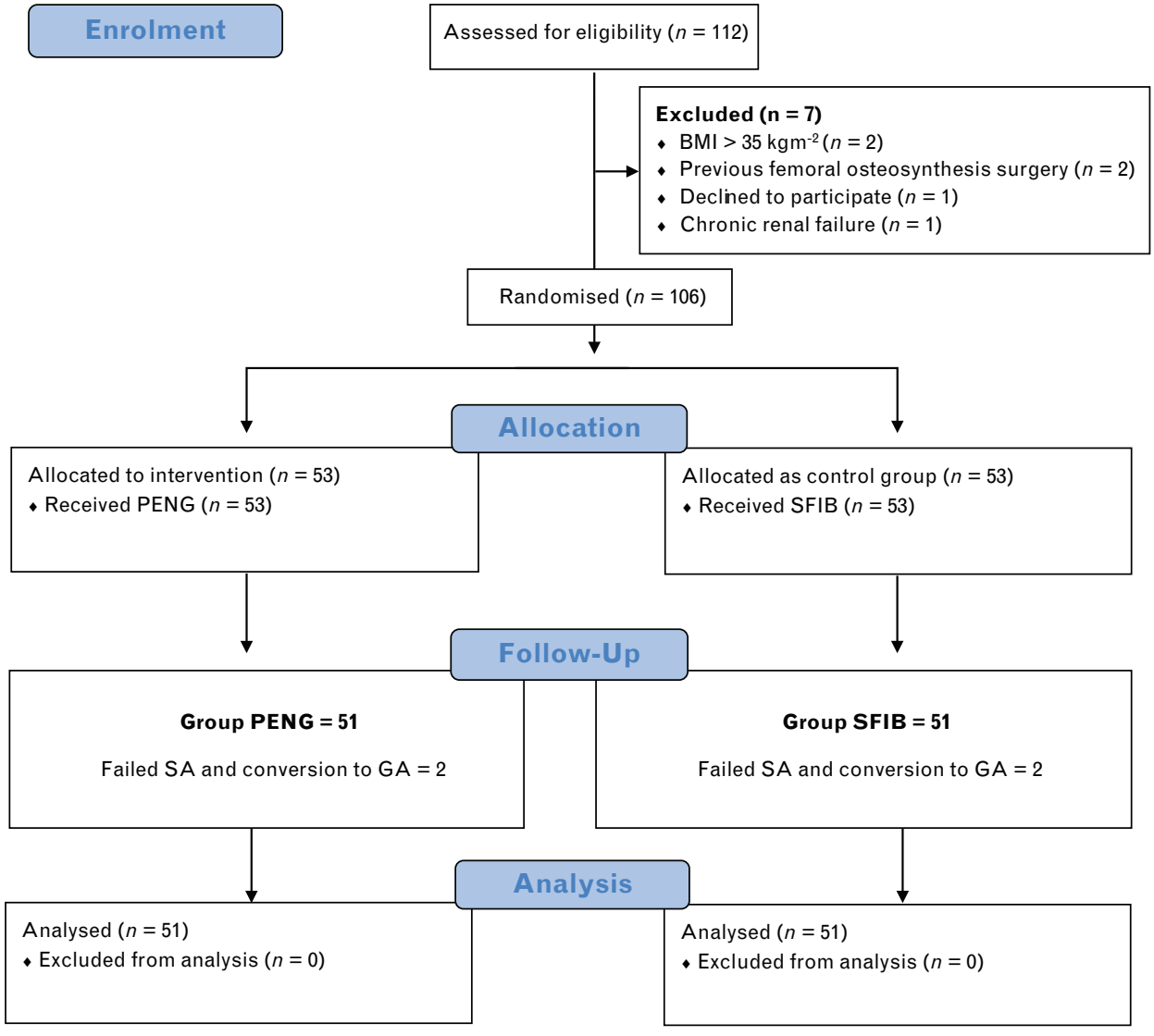
Normality of distributions were tested whenever required by calculating the skewness of distributions and using the Shapiro–Wilk test. Patient charactersitics and nonrepeated measures data were compared between groups using Fisher's exact tests, χ^2 tests, Wilcoxon–Mann–Whitney or two-tailed Student unpaired *t* tests as appropriate. The 95% confidence interval (95% CI) of the median was calculated using the Huber sandwich estimator method. We used generalised linear mixed model (GLMM) tests to analyse postoperative pain intensity at rest and on mobilisation, TUG, 2MWT, 6MWT, QoR-15 and compared their evolution over time between groups of patients. For the mixed model, time, group and their interaction were defined as fixed effects, with time as a repeated-measure factor. The chosen covariance type was the variance components. The degrees of freedom were calculated using the residual method. A sequential Bonferroni correction was applied to adjust for multiple comparisons. To assess the robustness of our results regarding secondary outcomes, a sensitivity analysis was performed for the time–group interaction on the evolution of pain at rest and on mobilization, as well as on TUG, 2MWT, 6MWT and QoR-15. An effect size was considered to be minimal where Cohen's *F* was less than 0.2. We performed a receiver-operating characteristic (ROC) curve analysis to assess the relationship between the incidence of orthostatic intolerance and postoperative haemoglobin blood level at day-1, as a binary outcome and predictor, respectively. A one-tailed *P* value less than 0.025 for the noninferiority analysis or a two-tailed *P* value less than 0.05 for analyses of secondary endpoints were considered statistically significant as appropriate.

Results

The study was conducted from October 2021 to July 2022 at the Liege University Hospital, Belgium. A total of 112 patients scheduled for elective PLTHA were screened for eligibility. After exclusion of six screened patients because of the patient's refusal (2 patients), or not meeting all inclusion criteria (4 patients), 106 patients were enrolled into the study and randomly assigned to one of the two study groups, with a 1 : 1 ratio. Four additional patients were secondarily excluded from further analysis because of the necessity to convert spinal anaesthesia to general anaesthesia. Data were analysed for the remaining 102 patients. Allocation process according to CONSORT is presented in Fig. 4.

Patient characteristics, preoperative pain, length of surgical procedure and surgical characteristics were not different between groups (Table 1).

Fig. 4 CONSORT flow chart of patient enrolment, group allocation, follow-up, and data analysis. CONSORT, CONsolidated Standards Of Reporting Trials; group SFIB, control group; group PENG, intervention group.



The between-group median (95% CI) difference in NRS pain intensity at rest 6 h after surgery was 0 (−0.93 to 0.93) ($P = 0.001$), with an acceptance of the noninferiority hypothesis (Fig. 5). According to the GLMM analysis (Supplementary Appendix 2, http://links.lww.com/EJA/A850), NRS for pain at rest and on mobilisation (Fig. 6) were not significantly different between the groups at all time points of interest, with no main effect of either group or interaction between time and group. The 48 h cumulative morphine consumption (mg; median [IQR]) was not significantly different between groups (group SFIB, 10 [7 to 16] vs. group PENG, 9 [5 to 14]; $P = 0.480$) (Table 2).

According to GLMM analyses on postoperative functional assessment, no significant differences were observed between the groups as regards performance from the preoperative day to the first 24 and 48 h after surgery. No statistically significant main effect of group ($P = 0.656$) or interaction between time and group ($P = 0.197$) were observed for TUG (Fig. 7a), 2MWT ($P = 0.249$ and $P = 0.364$, respectively; Fig. 7b), 6MWT ($P = 0.419$ and $P = 0.347$, respectively; Fig. 7c), and QoR-15 ($P = 0.235$ and $P = 0.417$, respectively; Fig. 7d).

Sensitivity analysis confirmed a minimal effect size for the evolution of pain at rest (Cohen's $f = 0.066$) and on mobilisation (Cohen's $f = 0.126$), as well as for the functional outcomes (Cohen's f: TUG = 0.129; 2MWT = 0.098; 6MWT = 0.099; QoR-15 = 0.094; Appendix 2, http://links.lww.com/EJA/A850).

Table 1 Patient and surgical procedure characteristics.

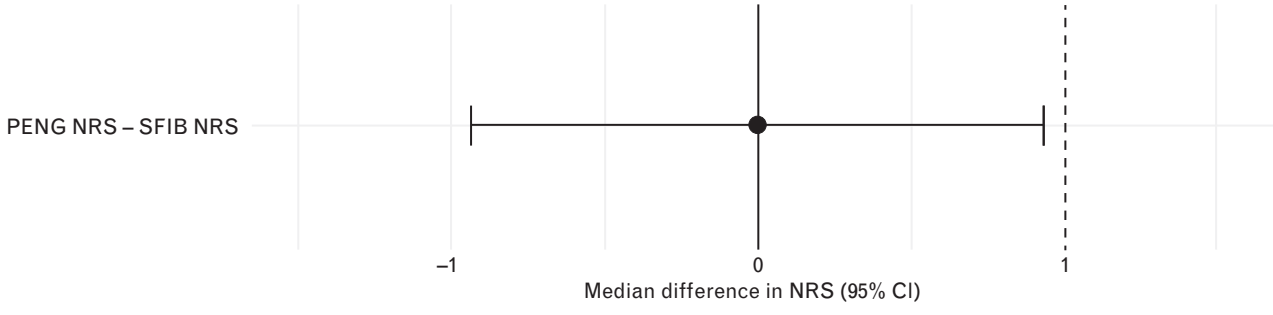
	SFIB ($n = 51$)	PENG ($n = 51$)
Patient characteristics		
Age (years)	64.8 ± 12.7	68.2 ± 10.5
Sex (women)	30 (58.8)	27 (52.9)
ASA classification		
I	2 (3.9)	4 (7.8)
II	49 (96.1)	47 (92.2)
Weight (kg)	76.6 ± 15.7	77.6 ± 16.2
Height (m)	1.65 [1.6 to 1.75]	1.68 [1.6 to 1.79]
BMI (kg m^{-2})	27.47 [23.15 to 31.12]	26.04 [24.18 to 29.72]
Medical preoperative conditions		
Apfel score		
1	5 (9.8)	2 (3.9)
2	18 (35.3)	26 (51)
3	27 (52.9)	23 (45.1)
4	1 (2)	0 (0)
Lee's score		
0	43 (84.3)	40 (78.4)
1	6 (11.8)	11 (21.6)
2	2 (3.9)	0 (0)
Diabetes	1 (2)	1 (2)
History of chronic alcohol abuse	7 (13.7)	12 (23.5)
Smoking tobacco	9 (17.6)	5 (9.8)
Preoperative Pain, NRS	4 [1 to 6.0]	4 [2 to 5]
Preoperative Hb (g dl^{-1})	14.0 ± 1.5	13.8 ± 1.8
Surgical characteristics		
Duration of surgery (min)	65 [60 to 69.5]	63 [60 to 72.5]
Side (right)	31 (60.8)	26 (51)

Data are mean ± SD, median [IQR], *n* (%). Hb, haemoglobin; NRS, numeric rating scale; PENG, pericapsular nerve group block; SFIB, supra-inguinal fascia iliaca block.

No between-group difference was observed in the number of patients who felt able to stand up and walk around the bed 6 h after surgery: group SFIB 23 (45.1%) vs. group PENG 20 (39.2%), $P = 0.689$. Nor was there a difference in the incidence of orthostatic intolerance on first mobilisation 6 h after surgery: group SFIB 1 (5%) vs. group PENG 2 (5%), $P = 1$ (Table 2).

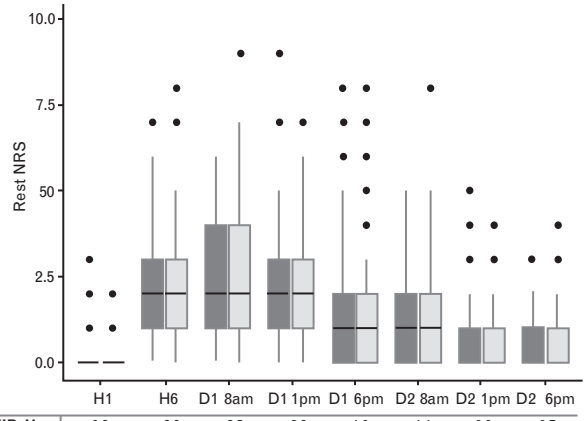
Postoperative haemoglobin evolution over time was similar between the groups and no significant differences were observed between the groups regarding the preoperative and postoperative evolution of kinesiophobia ($P = 0.555$ for group and $P = 0.463$ for time–group interaction; Appendix 2, http://links.lww.com/EJA/A850). ROC analysis assessing the predictive ability of postoperative haemoglobin level with regard to the incidence of orthostatic intolerance revealed an area under the curve (95% CI) of 0.671 (0.465 to 0.718), indicating no significant relationship on postoperative day-1 (Appendix 2, http://links.lww.com/EJA/A850).

Fig. 5 Noninferiority tested 6 h after surgery with the minimum clinically relevant difference between medians set at 1 NRS point (vertical dotted line). The 95% confidence interval (95% CI) for the median is calculated with Huber sandwich estimator method.

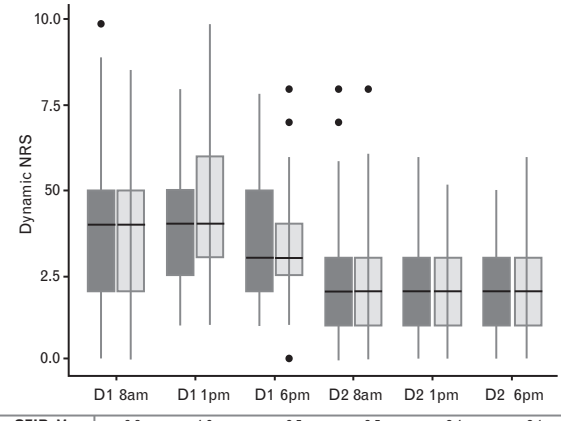


	Difference (95% CI)	*P*	Test
PENG NRS – SFIB NRS median	0 (–0.933 to 0.933)	0.001	Non Inferiority Mann Whitney U

Fig. 6 Evolution of numeric rating scale for pain at rest (Rest) and on mobilisation (Dynamic) over the time points of interest: H1, 1 h after surgery; H6, 6 h after surgery; D1 or D2 8 a.m., 1 p.m., 6 p.m., day 1 or day 2 after surgery at 8 a.m., 1 p.m. or 6 p.m. in group SFIB (light grey) and in group PENG (dark grey). Box plots of the medians of the values: lower error bar = lowest value excluding outliers; lower limit of box = 25th centile (Q1); bold bar = median; upper limit of box = 75th centile (Q3); upper error bar = highest value excluding outliers; outliers are values that are more than 1.5 × interquartile range below Q1 or above Q3. Within-group means and between-group mean difference are provided in the tables below each figure, according to the generalised linear mixed model analysis. Numbers have been rounded up to the first decimal, with the 95% confidence interval (95% CI) of the means and of the mean difference.



	H1	H6	D1 8am	D1 1pm	D1 6pm	D2 8am	D2 1pm	D2 6pm
Group SFIB: Mean	0.3	2.3	2.5	2.3	1.9	1.1	0.9	0.7
95% CI	0.1 to 0.5	1.8 to 2.8	2 to 3	1.8 to 2.8	1.4 to 2.4	0.7 to 1.5	0.6 to 1.2	0.4 to 0.9
Group PENG: Mean	0.4	2.1	2.4	2.1	1.6	1.2	1.1	0.7
95% CI	0.2 to 0.6	1.6 to 2.6	1.9 to 2.9	1.6 to 2.6	1.1 to 2.2	0.8 to 1.6	0.7 to 1.4	0.4 to 0.9
Mean difference	−0.1	0.2	0.1	0.2	0.2	−0.1	−0.2	0
95% CI	−0.3 to 0.2	−0.6 to 0.9	−0.6 to 0.9	−0.5 to 1	−0.5 to 1	−0.7 to 0.4	−0.7 to 0.3	−0.4 to 0.4



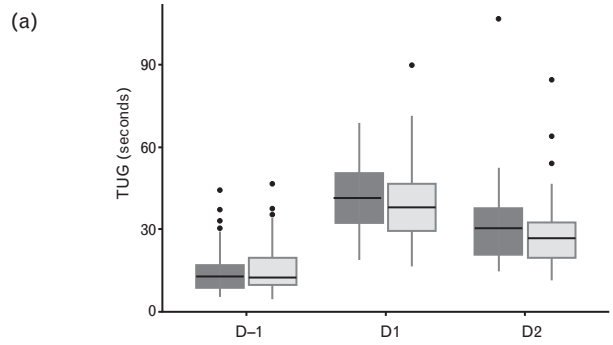
	D1 8am	D1 1pm	D1 6pm	D2 8am	D2 1pm	D2 6pm
Group SFIB: Mean	3.8	4.6	3.5	2.5	2.4	2.1
95% CI	3.2 to 4.5	4 to 5.1	3 to4	2 to 3	2 to 2.8	1.7 to 2.4
Group PENG: Mean	4.1	3.9	3.4	2.6	2.3	2
95% CI	3.5 to 4.7	3.4 to 4.5	2.9 to3.9	2.1 to 3.1	1.9 to 2.7	1.7 to 2.4
Mean difference	-0.3	0.7	0.2	-0.1	0.1	0.1
95% CI	-1.1 to 0.6	-0.2 to 1.5	-0.6 to 0.9	-08 to 0.6	-04 to 0.7	-0.5 to 0.6

Table 2 **Postoperative evolution of secondary outcomes.**

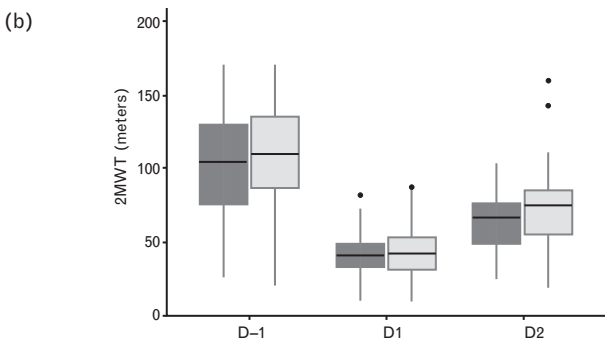
	SFIB ($n = 51$)	PENG ($n = 51$)	*P* value
Morphine consumption over 48 h (mg)	10 [7 to 16]	9 [5 to 14]	0.48
DN4	1 [0 to 2]	1 [0 to 2]	0.181
Posthospital institutional rehabilitation	13 (25.5)	20 (39.2)	0.204
Length of stay, days)	3 [3 to 4]	3 [3 to 4]	0.375
Postop D1 Hb (g dl^{-1})	12 [11 to 13]	12 [11 to 13.5]	0.965
Ability to stand up 6 h after surgery	23 (45.1)	20 (39.2)	0.689
OI at first mobilization	1 (5)	1 (5)	1
OI during the first 48 h postsurgery	8 (15.7)	7 (13.7)	1
Falls during the first 48 h postsurgery	1 (2)	1 (2)	1
Patients with TSK > 40 postsurgery	22 (43.1)	25 (49)	0.691
Postoperative nausea or vomiting			
Day-1	6 (11.8)	6 (11.8)	1
Day-2	0 (0)	3 (5.9)	0.243
Dizziness			
Day-1	9 (17.6)	10 (19.6)	1
Day-2	2 (3.9)	3 (5.9)	1
Itching			
Day-1	3 (5.9)	2 (3.9)	1
Day-2	1 (2)	1 (2)	1
Drowsiness			
Day-1	9 (17.6)	11 (21.6)	0.804
Day-2	1 (2)	5 (9.8)	0.205
Acute urinary retention			
Day-1	0 (0)	1 (2)	1
Day-2	0 (0)	2 (3.9)	0.495
Recovery of gastrointestinal transit			
Day-1	46 (90.2)	47 (92.2)	1
Day-2	50 (98)	47 (92.2)	0.362

Data are median [IQR] and *n* (%). DN4, DN4 questionnaire on postoperative day-2; Hb, haemoglobin; OI, orthostatic intolerance; PENG, pericapsular nerve group block; SFICB, supra-inguinal fascia iliaca block. TSK > 40, patients with significant postoperative kinesiophobia, that is, Tampa Scale of Kinesiophobia score greater than 40/68.

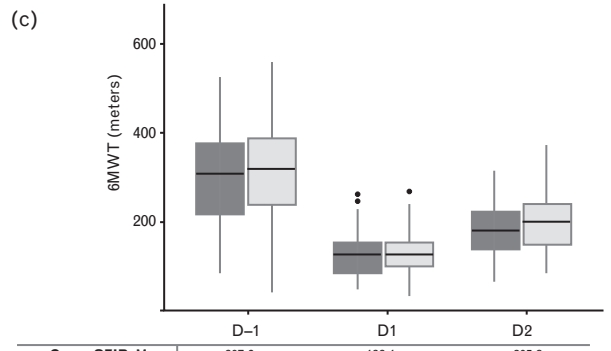
Fig. 7 Time taken (seconds) to perform the Timed Up and Go test (a), distance walked (m) at the 2 min walk test (2-MWT) (b) and 6 min walking test (6-MWT) (c) and evolution of French validated Quality of Recovery-15 items (d), over the time points of interest (D−1 = 1 day before surgery; D1 = 1 day after surgery; D2 = 2 days after surgery) in group SFIB (light grey) and in group PENG (dark grey). Box plots of the medians of the values: lower error bar = lowest value excluding outliers; lower limit of box = 25th centile (Q1); bold bar = median; upper limit of box = 75th centile (Q3); upper error bar = highest value excluding outliers; outliers are values that are more than 1.5× interquartile range below Q1 or above Q3. Within-group means and between-group mean difference are provided in the tables below each figure, according to the generalised linear mixed model analysis. Numbers have been rounded up to the first decimal, with the 95% confidence interval (95% CI) of the means and of the mean difference.



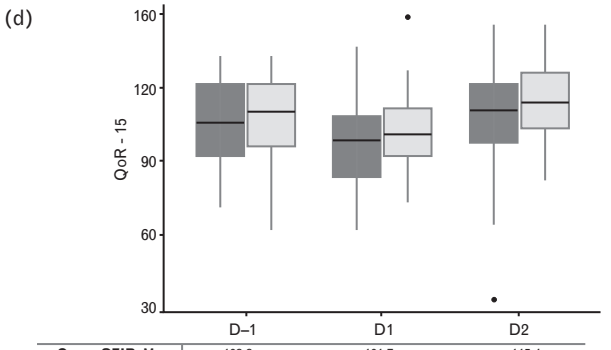
	D–1	D1	D2
Group SFIB: Mean	15.8	40.4	29.1
95% CI	13.3 to 18.3	36.6 to 44.2	25.1 to 33
Group PENG: Mean	14.7	41.3	32.1
95% CI	12.2 to 17.2	37.5 to 45.1	28.2 to 36.2
Mean difference	1.2	−0.9	−3.1
95% CI	−2.4 to 4.7	−6.3 to 4.5	−8.2 to 2.5



	D–1	D1	D2
Group SFIB: Mean	106.8	42.9	71.9
95% CI	95.7 to 117.9	38.5 to 47.4	65.1 to 78.3
Group PENG: Mean	104.2	40.9	61.8
95% CI	92.9 to 115.4	36.4 to 45.5	54.9 to 68.7
Mean difference	2.7	2	10.1
95% CI	−13.1 to 18.4	−4.4 to 8.4	0.4 to 19.8



	D–1	D1	D2
Group SFIB: Mean	307.6	133.1	205.8
95% CI	272.6 to 342.5	118.7 to 146.4	187.9 to 223.7
Group PENG: Mean	306	128.2	180
95% CI	270.7 to 341.3	113.7 to 142.7	161.9 to 197.9
Mean difference	1.6	4.9	26
95% CI	−48.11.1 to 51.3	−15.5 to 25.3	0.6 to 51.5



	D–1	D1	D2
Group SFIB: Mean	108.8	101.7	115.4
95% CI	103.8 to 113.8	97.2 to 106.1	110.5 to 120.3
Group PENG: Mean	107.8	98.3	109.8
95% CI	102.8 to 112.4	93.9 to 102.8	104.8 to 114.7
Mean difference	−2.4	−4.6	−2.2
95% CI	−11.1 to 6.4	−13.4 to 4.2	−10.1 to 5.6

The need for postoperative rehabilitation in a specific care centre after discharge was comparable between groups, as well as total length of stay (Table 2). No statistically significant difference was observed regarding the risk of developing persistent postoperative neuropathic pain, as assessed by the DN4 score (Table 2).

No difference was observed between the groups regarding the incidence of orthostatic intolerance or falls during the first postoperative 48 h: group SFIB 8 (15.7%) vs. group PENG 7 (13.7%) $P = 1$, and group SFIB 1 (2%) vs. group PENG 1 (2%) $P = 1$, respectively (Table 2). Similarly, no difference was observed regarding morphine side effects during the first postoperative 48 h such as PONV, itching, dizziness, drowsiness, acute urinary retention and delayed recovery of gastrointestinal transit (Table 2).

According to the IPO questionnaire, no differences were found between groups regarding the impact that pain had during the first 48 postoperative hours on daily activities and emotions, its severity, opioid side effects and perceptions of care, with comparable patient satisfaction (Table 3). No episodes of paraesthesia related to possible femoral cutaneous lateral nerve injury were recorded, as well as no signs of local anaesthetic systemic toxicity or intravascular puncture.

Table 3 IPO questionnaire on postoperative day-2.

	SFIB ($n = 51$)	PENG ($n = 51$)	*P* value
Pain severity and interference subscale			
Worst pain in 24 h	7 [5 to 8]	7 [4 to 8]	0.723
Least pain in 24 h	0 [0 to 1]	0 [0 to 2]	0.674
Percentage of time in severe pain	0.1 [0.1 to 0.2]	0.1 [0.1 to 0.2]	0.695
Pain interference with activities in bed	4 [1.5 to 6]	3 [1 to 5]	0.502
Pain interference with activities out of bed	0 [0 to 0]	0 [0 to 0]	0.388
Pain interference with breathing/coughing	1 [0 to 4]	0 [0 to 2]	0.341
Pain interference with sleep	2 [0.5 to 4]	3 [2 to 5]	0.27
Affection subscale			
Emotional impairment due to pain: anxious	0 [0 to 0]	0 [0 to 0]	0.730
Emotional impairment due to pain: helpless	0 [0 to 0]	0 [0 to 0]	0.258
Adverse drug reactions subscale			
Adverse effects: nausea	0 [0 to 0]	0 [0 to 0]	0.798
Adverse effects: drowsiness	0 [0 to 2]	0 [0 to 1]	0.853
Adverse effects: itching	0 [0 to 0]	0 [0 to 0]	0.08
Adverse effects: dizziness	0 [0 to 0]	0 [0 to 0]	0.436
Perception of care subscale			
Percentage of pain relief from all treatments	0.8 [0.7 to 1]	0.8 [0.8 to 1]	0.82
Wish for more pain treatment (yes = 1)	3 (5.9)	5 (9.8)	0.715
Information about pain treatment options (yes = 1)	47 (92.2)	45 (88.2)	0.741
Participation in decision making	9 [8 to 10]	9 [7 to 9]	0.303
Satisfaction with pain treatment	9 [8 to 10]	9 [8 to 10]	0.125
Use of nonmedicine methods for pain relief	47 (92.2)	45 (88.2)	0.741
Persistent painful condition before surgery	3 (5.9)	7 (13.7)	0.318
Intensity of persistent pain before surgery	4 [1 to 6]	4 [2 to 5]	0.515

Data are median [IQR] and *n* (%). PENG, pericapsular nerve group block; SFIB, supra-inguinal fascia iliaca compartment block.

Discussion

The main finding of our study is the noninferiority of the PENG block as compared with SFIB with regard to postoperative pain relief at the peak of pain intensity, 6 h after surgery. Our sensitivity analyses also allow us to state with confidence that the two studied PNBs provide the same pain trajectories and functional recovery during the first 48 h after PLTHA.

The groups were similar in terms of patient characteristics, and our population represents a consistent sample of patients with arthritic hip disorder, in which joint anatomy rather than BMI seems to play a preponderant role, notably regarding the indication for prosthetic surgery.[19]

No differences between groups were found regarding opioid consumption, incidence of morphine-related side effects, orthostatic intolerance, the ability of patients to stand up 6 h after surgery or global pain perception and satisfaction.

The originality of our study resides in demonstrating that the PENG block, a recently proposed and attractive distal PNB technique, is at least as effective as the recommended SFIB, whose efficacy has recently been reaffirmed.[8,10] Before this study, the noninferiority of PENG to SFIB was far from being obvious. Although PENG has demonstrated efficacy in PLTHA, it has no blocking effect on the lateral femoral cutaneous nerve, an exclusively sensory nerve particularly involved in the sensory innervation of the territory covering the surgical incision and soft tissue dissection during a posterolateral approach to the hip.[11,13] Conceptually, PENG might have been less effective than SFIB on postoperative pain but, instead, we have shown it provides better postoperative functional recovery.[20] Indeed, PENG acts on the distal sensory branches of the anterior portion of the joint capsule, thus sparing the motor innervation to the quadriceps femoris, theoretically impacted by the SFIB femoral nerve block. According to our results, there is no difference between the two blocks in either respect. This is probably because of the small contribution of pain related to skin incision in PLTHA compared with deep tissue dissection and, therefore, blockade of the lateral femoral cutaneous nerve is of less importance.[21,22]

The only study that compared the effectiveness of these two techniques did not include a clinical assessment of postoperative functional recovery, but only an isometric measure of quadriceps femoris muscle strength.[12] Although SFIB may be the cause of quadriceps femoris weakness, in our trial, this does not seem to have any impact on overall postoperative functional performance. Specifically, no difference was observed between SFIB and PENG with regard to walking ability and performance. This emphasises the importance of clinical walking tests in the study of the functional impact of PNBs and redefines the impact of SFIB on quadriceps femoris impairment.

We also determined a patient's global functional recovery through the French-validated QoR-15. A recent update suggests that a difference of 6 points is the minimum

clinically detectable value of QoR-15, and in our trial, no clinically significant difference was observed between groups.[23]

Our results are obviously applicable only to patients receiving spinal anaesthesia. Indeed, the trajectory of postoperative pain substantially differs between patients who have received general anaesthesia or spinal anaesthesia, and any assumptions of similar pain relief may not be warranted. However, our trial reflects current clinical practice insofar as spinal anaesthesia remains the gold standard analgesia technique.[24,25] Assessments of pain were undertaken 6 h after surgery (thus approximately 8 h after spinal anaesthesia) because this represents when the residual effect of intrathecal bupivacaine wear off. On postoperative day-1 and day-2, a patient-centred approach was preferred with assessments adapted to the daily rhythm of patients rather than to fixed intervals.

The choice of ropivacaine was dictated by its lower cardiotoxicity compared with levobupivacaine, which could have been a potential alternative.[26] Although no plasma concentration measurements were done in our study, the total dose of ropivacaine administered always remained lower than the maximum recommended dose.[27] When conceiving our trial, we intentionally kept the administered dose of ropivacaine (150 mg) consistent between the two groups. Although a minimum volume of 40 ml is recommended for SFIB, in order to have clinically detectable efficacy on the femoral, lateral femoral cutaneous and obturator nerves, for PENG, there are currently no studies recommending a minimum local anaesthetic volume to ensure efficacy.[28,29] Future studies involving healthy volunteers and imaging techniques or involving dissected cadavers should focus on establishing the minimum effective volume for PENG.

The risk of developing persistent postsurgical neuropathic pain was also assessed in our study, using the DN4 questionnaire 48 h after surgery.[17] This risk seems low, and equivalent for both regional techniques, but direct proof of this would require longer follow-up.

Our study has several limitations. First, the anaesthetist who performed the blocks was not blinded to the patient's group. We could have used both techniques on each patient, randomly using a corresponding volume of a placebo solution to perform one of the blocks. However, considering the potential infection risk in the context of prosthetic surgery, we preferred to forego this opportunity by accepting the possible bias to the study. Noteworthy, the anaesthetist who performed the techniques was not further involved in the trial, neither in data collection nor analysis, and thus their nonblindness has little or no influence on our results. SFIB and PENG have already proven their efficacy compared with placebo in PLTHA.[10,11] For this reason, we considered a sham technique to be invasive and noncontributory. Second, in this study, no functional assessment or quantitative walking analysis was performed during the first 12 postoperative hours. This does not allow transferring our results to outpatient THA performed using an anterior surgical approach. Specifically dedicated studies should be conducted, particularly assessing the functional equivalence between SFIB and PENG regarding walk performance during the immediate postoperative period. Within a usual surgical timeframe, reliable functional assessment would, therefore, occur during the evening or night hours, with likely confounding factors related to fatigue and sleepiness. The 24- and 48 h postoperative determination seemed to us more interesting, consistent and comprehensive for the common clinical practice of PLTHA. In addition, in order to make our observations more consistent with respect to the patients' circadian rhythm, we selected time points of interest at fixed times on the first two postoperative days: morning (8 a.m.), midday (1 p.m.) and evening (6 p.m.). Although this element may be innovative compared with other studies, we felt it was a more patient-centred design in terms of the patients' daily routine. Third, with longitudinal data, such as postoperative pain intensity, the GLMM is the most appropriate choice, despite the nonnormal distribution of our data.[30] Unfortunately, no nonparametric alternative exists for a two-factor mixed model. Finally, no determination of isometric muscle strength was assessed after the peripheral blocks. Indeed, early mobilisation is a complex recovery process, in which multiple psychological and physiological factors are involved. We considered performance-based and patient-centred outcomes most useful in determining the functional recovery.[31]

Conclusion

We conclude that, in PLTHA under SA, SFIB with ropivacaine 0.375% or PENG with ropivacaine 0.75% provide similar analgesia, allows similar opioid-sparing with no differences in global postoperative functional recovery. Hence, in inpatient PLTHA, clinicians can use either technique according to their skills, preferences and practices. Although recent PROSPECT guidelines do not mention PENG as an option, our study has shown robust evidence of efficacy in analgesia for THA,[8] adding additional data to update the multimodal analgesia options for this procedure.

Acknowledgements relating to this article

Assistance with the study: none.

Financial support and sponsorship: this work was supported by the Department of Anaesthesiology and Intensive Care, Liège University Hospital, Liège, Belgium.

Conflicts of interest: VLB has received funds and research support from Orion Pharma as well as honoraria from Medtronic. He is Deputy Editor-in-Chief of the *Acta Anaesthesiologica Belgica*, and has a consultancy contract with Edwards Medical. Other authors declare no conflicts of interest.

Presentation: preliminary results of this study have been presented at the Graduation Day of the Belgian Society of Anaesthesiology, Resuscitation, Perioperative medicine and Pain management held in Brussels on 18 June 2022. An abstract of the preliminary results has also been presented at the annual congress of the European Society of Regional Anaesthesia (ESRA) on 21 25 June 2021, in Thessaloniki (Greece).

This manuscript was handled by Esther M. Pogatzki-Zahn.

References

1 Ferguson RJ, Palmer AJ, Taylor A, *et al.* Hip replacement. *Lancet* 2018; **392**:1662–1671.
2 Karlsen APH, Geisler A, Petersen PL, *et al.* Postoperative pain treatment after total hip arthroplasty: a systematic review. *Pain* 2015; **156**:8–30.
3 Panzenbeck P, von Keudell A, Joshi GP, *et al.* Procedure-specific acute pain trajectory after elective total hip arthroplasty: systematic review and data synthesis. *Br J Anaesth* 2021; **127**:110–132.
4 Pincus D, Jenkinson R, Paterson M, *et al.* Association between surgical approach and major surgical complications in patients undergoing total hip arthroplasty. *JAMA* 2020; **323**:1070–1076.
5 Wang Z, Hou JZ, Wu CH, *et al.* A systematic review and meta-analysis of direct anterior approach versus posterior approach in total hip arthroplasty. *J Orthop Surg Res* 2018; **13**:229.
6 Memtsoudis SG, Cozowicz C, Bekeris J, *et al.* Peripheral nerve block anesthesia/analgesia for patients undergoing primary hip and knee arthroplasty: recommendations from the International Consensus on Anesthesia-Related Outcomes after Surgery (ICAROS) group based on a systematic review and meta-analysis of current literature. *Reg Anesth Pain Med* 2021; **46**:971–985.
7 Memtsoudis SG, Cozowicz C, Bekeris J, *et al.* Anaesthetic care of patients undergoing primary hip and knee arthroplasty: consensus recommendations from the International Consensus on Anaesthesia-Related Outcomes after Surgery group (ICAROS) based on a systematic review and meta-analysis. *Br J Anaesth* 2019; **123**:269–287.
8 Anger M, Valovska T, Beloeil H, *et al.*, PROSPECT Working Group* and the European Society of Regional Anaesthesia and Pain Therapy. PROSPECT guideline for total hip arthroplasty: a systematic review and procedure-specific postoperative pain management recommendations. *Anaesthesia* 2021; **76**:1082–1097.
9 Desmet M, Vermeylen K, Van Herreweghe I, *et al.* A Longitudinal supra-inguinal fascia iliaca compartment block reduces morphine consumption after total hip arthroplasty. *Reg Anesth Pain Med* 2017; **42**:327–333.
10 Carella M, Beck F, Piette N, *et al.* Effect of suprainguinal fascia iliaca compartment block on postoperative opioid consumption and functional recovery in posterolateral-approached total hip arthroplasty: a single-blind randomized controlled trial. *Reg Anesth Pain Med* 2022; **47**:547–553.
11 Pascarella G, Costa F, Del Buono R, *et al.*, collaborators. Impact of the pericapsular nerve group (PENG) block on postoperative analgesia and functional recovery following total hip arthroplasty: a randomised, observer-masked, controlled trial. *Anaesthesia* 2021; **76**:1492–1498.
12 Aliste J, Layera S, Bravo D, *et al.* Randomized comparison between pericapsular nerve group (PENG) block and suprainguinal fascia iliaca block for total hip arthroplasty. *Reg Anesth Pain Med* 2021; **46**:874–878.
13 Zheng J, Pan D, Zheng B, *et al.* Preoperative pericapsular nerve group (PENG) block for total hip arthroplasty: a randomized, placebo-controlled trial. *Reg Anesth Pain Med* 2022; **47**:155–160.
14 Giron-Arango L, Peng PWH, Chin KJ, *et al.* Pericapsular Nerve Group (PENG) block for hip fracture. *Reg Anesth Pain Med* 2018; **43**:859–863.
15 Demumieux F, Ludes PO, Diemunsch P, *et al.* Validation of the translated Quality of Recovery-15 questionnaire in a French-speaking population. *Br J Anaesth* 2020; **124**:761–767.
16 Miller RP, Kori SH, Todd DD. The Tampa Scale: a measure of Kinisophobia. *Clin J Pain* 1991; **7**:51–52.
17 Beloeil H, Sion B, Rousseau C, *et al.*, SFAR research network. SFAR research network: early postoperative neuropathic pain assessed by the DN4 score predicts an increased risk of persistent postsurgical neuropathic pain. *Eur J Anaesthesiol* 2017; **34**:652–657.
18 Rothaug J, Zaslansky R, Schwenkglenks M, *et al.* Patients' perception of postoperative pain management: validation of the International Pain Outcomes (IPO) questionnaire. *J Pain* 2013; **14**:1361–1370.
19 Teirlinck CH, Dorleijn DMJ, Bos PK, *et al.* Prognostic factors for progression of osteoarthritis of the hip: a systematic review. *Arthritis Res Ther* 2019; **21**:192.
20 Yamak Altinpulluk E, Galluccio F, Salazar C, *et al.* PENG block in prosthetic hip replacement: a cadaveric radiological evaluation. *J Clin Anesth* 2020; **65**:109888.
21 Nielsen TD, Moriggl B, Barckman J, *et al.* Cutaneous anaesthesia of hip surgery incisions with iliohypogastric and subcostal nerve blockade: a randomised trial. *Acta Anaesthesiol Scand* 2019; **63**:101–110.
22 Brennan TJ. Pathophysiology of postoperative pain. *Pain* 2011; **152 (3 Suppl)**:S33–S40.
23 Myles PS, Myles DB. An updated minimal clinically important difference for the QoR-15 scale. *Anesthesiology* 2021; **135**:934–935.
24 Johnson RL, Frank RD, Habermann EB, *et al.* Neuraxial anesthesia is associated with improved survival after total joint arthroplasty depending on frailty: a cohort study. *Reg Anesth Pain Med* 2020; **45**:405–411.
25 Weinstein SM, Baaklini LR, Liu J, *et al.* Neuraxial anaesthesia techniques and postoperative outcomes among joint arthroplasty patients: is spinal anaesthesia the best option? *Br J Anaesth* 2018; **121**:842–849.
26 Casati A, Santorsola R, Cerchierini E, *et al.* Ropivacaine. *Minerva Anestesiol* 2001; **67**:15–19.
27 Eng HC, Ghosh SM, Chin KJ. Practical use of local anesthetics in regional anesthesia. *Curr Opin Anaesthesiol* 2014; **27**:382–387.
28 Vermeylen K, Desmet M, Leunen I, *et al.* Supra-inguinal injection for fascia iliaca compartment block results in more consistent spread towards the lumbar plexus than an infra-inguinal injection: a volunteer study. *Reg Anesth Pain Med* 2019; **44**:483–491.
29 Morrison C, Brown B, Lin DY, *et al.* Analgesia and anesthesia using the pericapsular nerve group block in hip surgery and hip fracture: a scoping review. *Reg Anesth Pain Med* 2021; **46**:169–175.
30 Schober P, Vetter TR. Linear mixed-effects models in medical research. *Anesth Analg* 2021; **132**:1592–1593.
31 Roberts GP, Levy N, Lobo DN. Patient-centric goal-oriented perioperative care. *Br J Anaesth* 2021; **126**:559–564.