

## ORIGINAL RESEARCH

## REGIONAL ANESTHESIA

# A comparative study between ultrasound-guided four-in-one block vs. femoral nerve block vs. adductor canal block to enhance recovery after knee replacement surgery

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## Abstract

**Background & Objective:** Ultrasound-guided 4-in-1 block has been suggested as a good alternative to various other nerve blocks to control pain after total knee replacement (TKR) surgery. We compared the three regional techniques; 4-in-1 block, femoral nerve block (FNB) and adductor canal block (ACB) following TKR regarding pain scores, opioid consumption, quadriceps muscle strength and early ambulation.

**Methodology:** We enrolled 93 patients and divided them into three equal groups of 31 each. Patients received either 4-in-1 block (Group A), FNB (Group B) or ACB (Group C) under ultrasound guidance. Outcome measures included assessment of VAS scores at 2, 4, 8, 12, 16, and 24 h. Nalbuphine consumption was calculated in the first 24 h. We also evaluated quadriceps muscle strength and early ambulation using straight leg raising (SLR) test at 12 and 24 h, and timed up-and-go (TUG) test at 24 h postoperatively.

**Results:** Patients received 4-in-1 block showed lower pain scores and lower nalbuphine consumption compared to FNB or ACB. Also, the SLR test values at 12h were higher ( $p$ -value<0.001), and TUG test values were lower ( $p$ -value0.005) in 4-in-1 block and ACB groups compared to FNB group.

**Conclusion:** The results of our study conclude that 4-in-1 block was found to be superior in pain control after TKR surgeries compared to FNB or ACB alone. It also facilitates early ambulation as it preserves quadriceps muscle strength.

**Trial Registration:** PACTR202110830502351.

**Abbreviations:** ACB - Adductor canal block; TKR - Total knee replacement; SLR - Straight leg raising test; FNB - Femoral nerve block; TUG test - Timed up-and-go test

**Key words:** Total knee replacement; Nerve block; Nerve Block / methods; Pain Management / methods; Pain, Postoperative / complications; Pain, Postoperative / drug therapy; Four in one block; Femoral nerve block; Adductor canal block

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## 1. Introduction

Enhanced recoveries after TKR are gaining popularity in orthopedic surgeries. Preservation of the motor power along with good analgesia has become the favorable postoperative goal allowing earlier physical therapy, rapid recovery, and early hospital discharge.<sup>1</sup>

Peripheral nerve blocks have been used increasingly to achieve effective analgesia following total knee replacement (TKR). Femoral nerve block (FNB) is known to be very effective as regard to pain relief in knee replacement surgeries; however, it affects the strength of the quadriceps muscle, thus impairing postoperative mobilization and increasing the risk of falls. Adductor canal block (ACB) has been considered as a new alternative technique to achieve pure sensory blockade with minimal effect on quadriceps muscle and an analgesic effect equivalent to FNB. The main aim of pain management after TKR is achieving a balance between analgesia and muscle strength.<sup>2</sup>

FNB or ACB alone, cannot achieve total analgesia around the whole knee after TKR because the knee is innervated by both the lumbar plexus (femoral and obturator nerves) and the sacral plexus (sciatic nerve). As a result patients who underwent TKR and received FNB or ACB, frequently suffered from postoperative posterior knee pain requiring supplemental opioid medications.<sup>2,3,4</sup> FNB alone has been countered by many studies and considered it to be inadequate, as the sciatic nerve supplies the posterior regions of the knee. Thus, performing of both SNB and FNB would improve analgesia after TKR.<sup>5</sup>

The addition of the sciatic nerve block to the femoral nerve block has ensured adequate analgesia with lower perioperative opioids consumption for knee and below knee surgeries. The 4-in-1 block which targets saphenous nerve, obturator nerve, sciatic nerve and the nerve to vastus medialis, was suggested to achieve this combination and to provide better outcomes.<sup>6</sup>

This study aimed to compare the three regional techniques, ultrasound-guided 4-in-1 block, FNB, or ACB following TKR, regarding pain scores, opioid

consumption, quadriceps muscle strength, and the early ambulation.

## 2. Methodology

The study was a randomized prospective comparative study conducted from February 2020 to August 2021 at Ain Shams University Hospitals. It was approved by the research ethics committee at the faculty of medicine, Ain Shams University (FMASU MD 63a / 2020 / 2021) and registered with Pan African Clinical Trial Registry, identifier: PACTR202110830502351. Written informed consent was obtained from all patients. 93 patients aged between 21 - 70 y, American Society of Anesthesiologists (ASA) physical status I and II scheduled for elective total knee replacement surgery. Non-ambulatory/bed-ridden patients, patients with coagulopathy, infection at the site of injection, incorrect injection site, sensitivity to local anesthetics or nalbuphine, polytrauma patients having lower limb fractures, patients with pre-existing myopathy or neuropathy on the operating limb, patients with significant cognitive dysfunction, chronic analgesic abusers, encountered cardiac arrest during or after injection, presence of surgical complications were excluded.

Selected patients were divided into three equal groups of 31 each and received one of the following blocks:

- Group A: Patients received 4-in-1 block with 30 ml of bupivacaine 0.2%.
- Group B: Patients received femoral nerve block with 15 ml of bupivacaine 0.2%
- Group C: Patients received adductor canal block with 15 ml of bupivacaine 0.2%.

The primary outcome was the assessment of postoperative pain using the visual analog scale (VAS) score in the first 24 h at 2, 4, 8, 12, 16 and 24 h postoperatively. The secondary outcomes were calculation of the cumulative postoperative opioid (nalbuphine) consumption and comparing the quadriceps muscle strength, early ambulation between the groups using straight leg raise (SLR) test at 12 h and 24 h and Timed Up-and-Go (TUG) test at 24 h postoperatively.

## 2.1. Study Interventions:

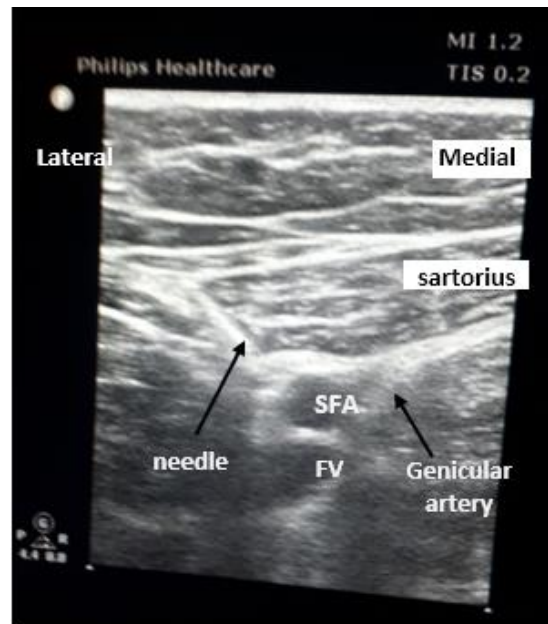
Preoperative preparation for all patients included history, examinations and investigations according to the patient's condition. All patients received general anesthesia (GA). Inj. midazolam 0.05 mg/kg IV was given as premedication. Standard ASA monitors; electrocardiogram (ECG), pulse oximetry (SpO<sub>2</sub>), non-invasive blood pressure (NIBP), and capnography were attached. Intravenous induction was done using fentanyl 1-2 µg/kg, propofol 1-2 mg/kg and atracurium 0.5 mg/kg, followed by insertion of the endotracheal tube. GA was maintained using inhaled 2% sevoflurane in a O<sub>2</sub> and air (50:50%), atracurium 0.1 mg/kg every 20-25 minutes. After the end of the surgical operation (before extubation), patients received either 4-in-1 block, FNB, or ACB according to which group they were allocated. Blocks were performed using Philips CX50 general imaging ultrasound system with linear transducer, using a 21-gauge 100-mm PAJUNK® SonoPlex® needle. After performing the blocks, the patients were extubated fully awake after giving a reversal agent. All patients were then transferred to post anesthesia care unit (PACU), monitored for vital data and the efficacy of the blockade. After one hour the patients were transferred to the in-patient unit.

### 2.1.1. 4-in-1 block (Group A):

Patients made to lie supine with the ipsilateral limb in frog leg position. Under complete aseptic conditions, the linear high-frequency ultrasound transducer placed over the medial condyle of the femur, the vastus medialis muscle, and the intersection of the vastus and sartorius (anteromedial inter-muscular septum) was identified. Sliding the transducer proximally until the superficial femoral artery (SFA) visualized in the adductor hiatus and the descending genicular artery seen branching from it. This point was the point of injection (8-10 cm above the medial condyle of the femur). The needle was inserted in-plane in a lateral-to-medial orientation under ultrasound guidance till it reached the perivascular region. After negative aspiration, the pre-decided 30 ml of bupivacaine 0.2% was injected and the spread of drug solution was visualized pushing the superficial femoral artery posteriorly (Figure 1).

### 2.1.2. Femoral nerve block (Group B):

Patients in supine position, with the ipsilateral limb abducted and externally rotated. Under complete aseptic conditions, the linear high-frequency ultrasound transducer was placed over the femoral crease, once the femoral nerve and artery have been visualized. The needle was inserted in-plane in a lateral-to-medial orientation under ultrasound guidance till it reached the femoral nerve. After negative aspiration, the pre-decided 15 ml of bupivacaine 0.2% was injected around the



**Figure 1: Ultrasound image showing point of injection in 4-in-1 block technique**

**SFA: superficial femoral artery, FV: femoral vein**

femoral nerve and the spread of drug solution was observed under ultrasound imaging.

### 2.1.3. Adductor canal block (Group C):

The same position of the patient as FNB was used. Under complete aseptic conditions, the linear high-frequency ultrasound transducer was placed on the medial aspect of the thigh, (approximately midway between anterior superior iliac spine and patella). Once the saphenous nerve, femoral artery, and vein were identified. The needle was inserted in-plane in a lateral-to-medial orientation under ultrasound guidance till it reached saphenous nerve deep to the sartorius muscle. After negative aspiration, the pre-decided 15 ml of bupivacaine 0.2% was injected around the saphenous nerve and the spread of drug solution was observed under ultrasound imaging.

### 2.1.4. Outcome assessments

Pain in the postoperative period was assessed at 2, 4, 8, 12, 16 and 24 h, during the first 24 h using VAS score. When VAS score was  $\geq 4.5$  cm, nalbuphine 0.1 mg/kg was given slow IV over 10 min as a rescue analgesia. Total nalbuphine consumption was calculated.

Quadriceps muscle strength was evaluated at (12 h and 24 h) postoperatively using straight leg raise (SLR) test, by the ability of the patient to raise his leg straight. The motor power of the quadriceps muscle was graded as: Grade 0: normal muscle power, Grade I: motor weakness, Grade II: complete motor paralysis.<sup>8</sup>

**Table 1: Comparative demographic data between the three groups**

Demographic data	4-in-1 block group (n=31)	FNB group (n=31)	ACB group (n=31)	F/Z/x2	p-value
Age (y)	57.7 ± 6.8	60.5 ± 7.2	58.7 ± 5.9	1.4 <sup>F</sup>	0.25
Height (cm)	176.6 ± 7.4	174.2 ± 7.3	176.5 ± 5.6	1.2 <sup>F</sup>	0.3
Weight (kg)	91.25 ± 6.85	91.64 ± 7.4	92.9 ± 7.1	0.47 <sup>F</sup>	0.62
BMI (kg/m <sup>2</sup> )	30.11 ± 3.6	29.4 ± 3.4	29.98 ± 2.6	0.37 <sup>F</sup>	0.69
Duration of surgery (min)	96.45 ± 29.2	99.35 ± 26	93.9 ± 16.8	0.39 <sup>F</sup>	0.68
Gender (male)	21 (35%)	19 (31.7%)	20 (33.3%)	0.28 <sup>X2</sup>	0.87
ASA	1 (1-2)	1 (1-2)	1 (1-2)	0.06 <sup>Z</sup>	0.96

Data expressed as mean ± SD, median (IQR), proportion  
 F=one way a nova, Z= Kruskal-Wallis test, X2= Chi-square

**Table 2: Comparison of visual analog scale (VAS) score between the three groups**

VAS score	4-in-1 block group (n=31)	FNB group (n=31)	ACB group (n=31)	Kruskal-Wallis test z	p-value
2 h	0 (0-1)	1 (0-1)	1 (0-1)	2.7	0.16
4 h	0 (0-1)	2 (1-3) ¶	2 (2-3) ¥	49.5	< 0.001*
8 h	1 (1-2)	3 (2-4) ¶	3 (3-3.75) ¥	28.4	< 0.001*
12 h	3 (2-3)	3 (3-3) ¶	3 (3-3) ¥	9.3	0.003*
16 h	3 (3-4)	3 (3-4)	3 (3-3)	0.57	0.67
24 h	3 (3-4)	4 (3-4)	4 (3-4)	2.4	0.19

Data expressed as median (IQR): Interquartile range, ¶= post-hoc analysis significant between 4-in-1 block group and FNB group, ¥ = post-hoc analysis significant between 4-in-1 block group and ACB group  
 VAS: visual analog scale; FNB: femoral nerve block; ACB: adductor canal block; \*significant

**Table 3: Comparison of total dose of nalbuphine consumption between the three groups**

Rescue analgesic	4-in-1 block group (n=31)	FNB group (n=31)	ACB group (n=31)	F- test	p-value
Postoperative nalbuphine consumption (mg)	7.6 ± 5.1	11.9 ± 5.3 ¶	11.8 ± 9 ¥	4.2	0.018

Data expressed as mean ± SD, F=one way a nova, ¶= post-hoc analysis (Tukey-Kramer test) significant between 4-in-1 block group and FNB group, ¥ = post-hoc analysis (Tukey-Kramer test) significant between 4-in-1 block group and ACB group

**Table 4: Comparison of straight leg raise (SLR) test between the three groups**

SLR test	4-in-1 block group (n=31)	FNB group (n=31)	ACB group (n=31)	X2	p-value
At 12 h	24 (77.4%)	11 (35.4%)	23 (74.1%)	14.39	< 0.001
At 24 h	31 (100%)	31 (100%)	31 (100%)	0	1

Data expressed as proportion, X2= Chi-square

**Table 5: Comparison of Timed Up-and-Go (TUG) test between the three groups**

Test	4-in-1 block group (n=31)	FNB group (n=31)	ACB group (n=31)	F	p-value
TUG test (sec)	25.5 ± 7.5	31.19 ± 9.5 ¶ ¥	24.9 ± 7	5.7	0.005

*Data expressed as mean ± SD, F=one way a nova, ¶= post-hoc analysis significant between 4-in-1 block group and FNB group, ¥ post-hoc analysis significant between FNB group and ACB group*

The patient's ambulation ability was evaluated 24 h postoperatively using the Timed Up-and-Go (TUG) test, it measures the time (in seconds) needed by the patient to get up from a chair, walk for three meters, and return back to the sitting position on the chair. In this test, a score of ≤ 10 sec indicates normal mobility, ≤ 20 sec indicates good mobility without gait aid, and ≤ 30 sec indicate difficult mobility, and a gait aid is needed. Patients were observed closely and allowed to use a 4-wheel walker as a walking aid during the test, to guard against fall.<sup>9,10</sup>

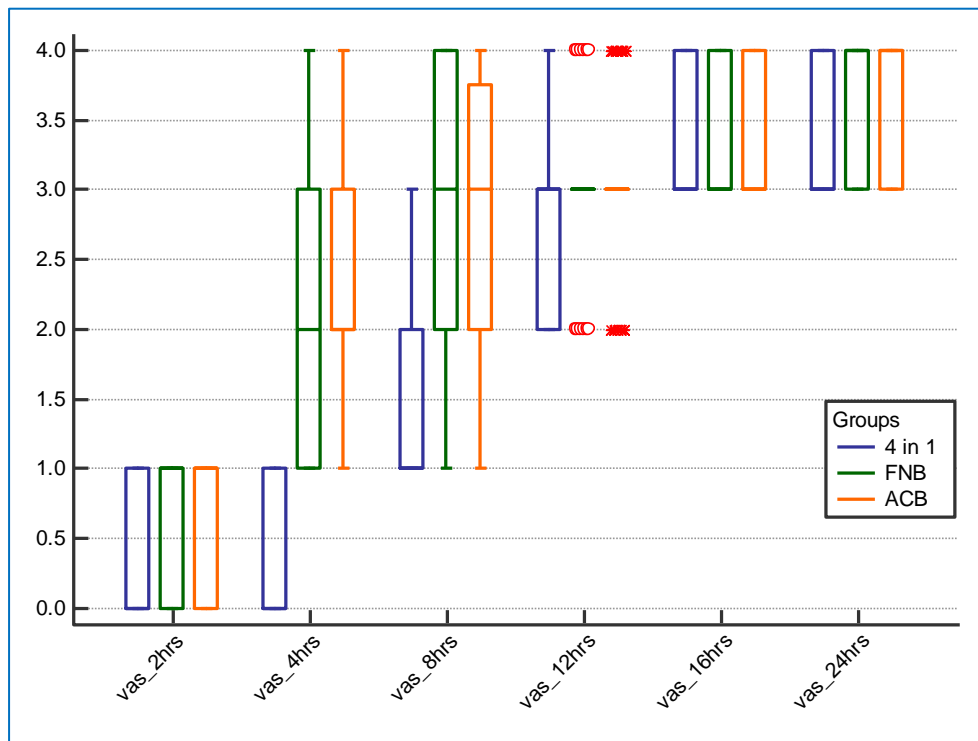
**2.1.5. Statistical Analysis:**

Sample size was calculated using the PASS 11 program Using the PASS 11 program, assuming mean VAS score after 24 h in study groups = 3.9- 4.4 and 5.4 with SD of 1.9, a sample size of 31 patients in each group (total 93) can detect the difference between the three groups in a one way ANOVA study with power 80% and α-error 0.05.(2) (11)

Data were analyzed using Statistical Package for Social Science (SPSS) version 22.0. Quantitative data were expressed as mean ± standard deviation (SD) or median and interquartile range (QR). Qualitative data were expressed as frequency and percentage. The following tests were used: One-way analysis of variance (ANOVA), Post-hoc test, Chi-square (X<sup>2</sup>) test, Kruskal-Wallis test. The confidence interval was set to 95% and the margin of error accepted was set to 5%. P < 0.05 was considered significant.

**3. Results**

Groups were compared regarding their demographic data as for (age, height, weight, BMI, sex, duration of surgery, and ASA) and it showed no significant statistical differences between groups (Table 1). The three groups were compared as regard pain control postoperatively at intervals (2, 4, 8, 12 ,16 and 24 h) using VAS score, results showed lower scores in patients received 4-in-1



**Figure 2: Box and whisker between groups as regard VAS score**

block compared to patients received FNB or ACB (Table 2) (Figure 2). Also, as regard to the total dose of Nalbuphine used in each group in the first 24 h postoperatively; the 4-in-1 block group showed less Nalbuphine consumption compared to FNB and ACB groups (Table 3). Quadriceps muscle strength and early ambulation were assessed using the Straight Leg Raise (SLR) test at (12h, 24h) postoperative and Timed Up-and-Go (TUG) test at 24 h postoperative. SLR test percentages at 12 h are significantly higher



in the 4-in-1 block and ACB groups compared to the FNB group. Yet, no significant difference was identified after 24 h between the three groups (Table 4). TUG test values are significantly lower in 4-in-1 block and ACB groups compared to the FNB group (Table 5).

## 4. Discussion

As mentioned before, femoral nerve blocks or Adductor canal blocks alone cannot achieve total analgesia around the knee after TKA (especially posterior regions of the knee) as the innervation of the knee is by both the lumbar plexus (femoral and obturator nerves) and the sacral plexus (sciatic nerve)(3) and since 4-in-1 block targets (saphenous nerve, obturator nerve, sciatic nerve, and nerve to vastus medialis), having the advantage of additional sciatic nerve blockade made it more effective than FNB alone or ACB alone in controlling postoperative pain after TKR. It also spares the quadriceps muscle adding another advantage to it as it facilitates early mobilization and ambulation. As the main aim of pain management after TKR is achieving a balance between analgesia and muscle strength.

In this study we performed a randomized trial to compare the three regional techniques; 4-in-1 block, femoral nerve block (FNB), and adductor canal block (ACB) under ultrasound guidance following total knee replacement surgery. The comparison regarding postoperative analgesic efficacy and postoperative quadriceps muscle strength. Postoperative analgesic efficacy in terms of VAS score for pain assessed at intervals (2h, 4h, 8h, 12h, 16h, and 24h) postoperatively. Also, total consumption of nalbuphine, as a rescue analgesia was calculated in the first 24 h postoperatively. Quadriceps muscle strength was tested using SLR test at (12 h, 24 h) postoperative and TUG test at 24 h postoperative.

Comparison between the three groups as regards pain control using VAS score; 2 h postoperative, 4-in-1 block group showed more analgesic effect but with no significant difference ( $p$ -value 0.16). At (4h, 8h, and 12h) 4-in-1 block group showed more analgesia with more significant difference ( $p$ -value <0.001, <0.001, 0.003). But, after that at (16h and 24h), there is no significant difference between the three groups ( $p$ -value 0.67, 0.19). Regarding the total dosage of Nalbuphine consumption in the first 24 h postoperative the 4-in-1 block group showed less Nalbuphine consumption compared to FNB and ACB groups ( $p$ -value 0.018). Comparing quadriceps muscle strength between the three groups using SLR test at (12h, 24h) and TUG test at 24 h postoperative. The SLR test percentages at 12 h are significantly higher in the 4-in-1 block and ACB groups compared to the FNB group (24 (77.4%) and 23 (74.1%) versus 11 (35.4%), respectively with a  $p$ -value <0.001). Yet, no significant difference was identified after 24 h between the three groups. The TUG test values are

significantly lower in the 4-in-1 block and ACB groups compared to the FNB group ( $p$ -value 0.005).

Coinciding with our study findings, many meta-analysis studies were supporting that adding sciatic nerve block (SNB) to FNB or ACB can reduce postoperative opioid consumption and postoperative pain (VAS score) in the first 24 h after TKR. Grape *et al.*, in their meta-analysis, had assessed the analgesic efficacy of SNB when combined with FNB postoperatively after TKR. Twelve randomized controlled trials were included, a total of 600 patients. They found that the addition of SNB to FNB achieves effective analgesia in the first 12 h postoperative, with no impact on functional outcomes.<sup>12</sup>

Zorrilla-Vaca & Li, their meta-analysis compared the benefits of sciatic nerve block (SNB) as a complement to FNB in TKR. In this study, the pain scores at movement (for 12 h) or at rest (for 4 h) and opioid consumption are significantly decreased when SNB is added to FNB in TKR.<sup>13</sup>

Seo *et al.*, in their study, compared continuous adductor canal block (ACB) alone (group A) and the combination of continuous ACB and popliteal sciatic nerve block (PSNB) block (group B) in controlling early postoperative pain after TKR. They concluded that combining ACB with PSNB was found to be more convenient than ACB alone in the management of continuous postoperative pain.<sup>14</sup>

Eldegwy & Negm, in their study they compared ultrasound guided combined ACB and SNB versus local anesthetic infiltration for analgesic efficacy within the first 24 h after TKA. They concluded that; Combined adductor canal with SNB could significantly reduce VAS scores, morphine consumption, and first request for analgesia in comparison with local analgesic infiltration alone following TKA.<sup>15</sup> Favouring our results, Faiaz & Kamath, in their study patients were randomized to have either FNB or ACB in ACL reconstruction surgeries under GA. They tested analgesic efficacy by VAS pain score and cumulative diclofenac consumption whereas, they assessed patient ambulation by measuring quadriceps function at 2 h, 12 h and 24 h after surgery by comparing it with the opposite side using the Medical Research Council grading for muscle strength. Their final results showed that ACB is considered superior to FNB as an analgesic modality because it provides pain relief almost as FNB does, but without affecting the quadriceps motor strength caused by FNB.<sup>16</sup>

Ghodki *et al.*, in their study, patients were randomized to receive either ACB or FNB in arthroscopic ACL repair under GA. A 20 ml of ropivacaine 0.5% was injected in each block. They assessed the analgesic efficacy using the numerical rating scale (NRS) score for pain and total opioid consumption. The quadriceps motor power was assessed by SLR and TUG tests. They concluded that

ACB is preferred over FNB for sparing motor power, but regarding NRS pain score, no significant difference was found between the two groups, this may be due to using ropivacaine with higher concentration.<sup>8</sup>

Conversely, there is a systematic review comparing the analgesic outcomes in randomized controlled trials comparing FNB (with and without sciatic nerve block (SNB)). Concluded that adding sciatic nerve block to single-shot FNB (SSFNB) did not reduce consumption of morphine or the scores of pains. But in these trials, a nerve stimulator was used for the nerve blocks, none used ultrasound guidance and only two studies discussed the comparison of SSFNB against SSFNB plus Sciatic.<sup>17</sup>

Chuan *et al.*, in their study where TKR patients received either continuous ACB or continuous FNB by infusing ropivacaine 0.2% via a catheter using pump infusions through catheters inserted under guidance of ultrasound. They found that VAS pain scores, total opioid consumption, and TUG test values displayed no significant differences between both groups. So, they concluded that both FNB and ACB were even regarding the quality of analgesia and quadriceps strength. Differences between their results and our study results may be due to using ropivacaine in continuous infusions.<sup>9</sup>

Similarly, Macrinici *et al.*, in their study estimated that TUG test values were higher in FNB while MVIC (Maximal voluntary isometric contraction) was lower in FNB compared to ACB. However, VAS pain scores and 6-minutes walking test values showed no significant differences between both groups.<sup>18</sup>

## 5. Conclusions

4-in-1 block a novel technique was found to be superior in pain control after total knee replacement surgeries compared to femoral nerve or adductor canal blocks alone, it also facilitates early ambulation and functional recovery as it preserves quadriceps motor strength.

## Ethics approval and consent to participate

This study was approved by the research ethics committee at the Faculty of Medicine, Ain Shams University (FMASU MD 63a / 2020 / 2021) and registered retrospectively with Pan African Clinical Trial Registry, identifier: PACTR202110830502351. Written informed consent was obtained from all patients.

## Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## 6. Competing interests

Authors declare that there were no conflicts of interest.

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## 8. Authors' contribution

All authors have contributed intellectually to the manuscript and all authors have read and approved the final manuscript.

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