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Research Article

Comparison of efficacy between the genicular nerve block and the popliteal artery and the capsule of the posterior knee (IPACK) block for total knee replacement surgery: A prospective randomized controlled study

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ABSTRACT

Objective: The aim of this study was to compare the efficacy of popliteal artery and the capsule of the posterior knee (IPACK) block and genicular nerve block on postoperative pain scores, the need for rescue analgesics, range of motion (ROM), walking distance, and perioperative monitorization variables in patients undergoing total knee replacement (TKR) surgery.

Methods: Sixty American Society of Anesthesiologists (ASA) physical status I-III patients were enrolled in this study and then were randomly assigned into three groups: the IPACK block group (17 female, 3 male; mean age=67.5±1.4 years), genicular nerve block (16 female, 4 male; mean age=68±1.76 years), and the control group (13 female, 7 male; mean age=63±1.67years). All the patients underwent TKR under spinal anesthesia. The visual analog scale (VAS) score, mobility, pre- and intra-operative monitorization of systolic and diastolic holding area, non-invasive blood pressure, heart rate, and SPO 2 were compared between the groups.

Results: Patients in the IPACK and genicular block groups had a significantly lower visual analogous scale (VAS) at postoperative 4 hours ($p<0.01$), 8h ($p<0.01$), 12h ($p<0.01$), and 24h ($p<0.05$). VAS score was significantly lower in the genicular block group at the postoperative 4h (5.5±0.55) and 8h (5.0±0.53) in the mobile state compared to the IPACK (8.0±0.47 and 8.0±0.43, respectively) and the control group (9.5±0.20; 10±0.28, respectively) ($p< 0.01$). The use of patient-controlled-analgesia (PCA) devices and button push count for analgesics demand were significantly lower in the genicular block group on the immediate postoperative period ($p<0.01$ at the postoperative 0 to 4 h). The total consumption of morphine equivalents on the postoperative day 0 was significantly lower in the genicular block group ($p<0.01$, and $p<0.001$ for IPACK and control groups, respectively). The degree of flexion was significantly higher in the genicular block group at the postoperative 12h compared to the IPACK and the control group ($p<0.001$). The length of hospital stay was significantly lower in the genicular block group compared to the IPACK and the control group ($p<0.05$ for both variables).

Conclusion: IPACK and genicular blocks both are effective in improving patient comfort during and after TKR surgery and reducing the potential need for systemic analgesic and opioids. The genicular block seems to be a promising technique that can offer improved pain management in the immediate and early postoperative period without adverse effects on systemic and motor variables.

Introduction

Total knee replacement (TKR) is among the most commonly performed orthopedic procedures, and a six-fold increase in the number of TKR cases worldwide is projected within a decade as the aging of the populations (1). As the number of the TKR procedures increases, various approaches increasing the satisfaction and comfort of the patient and the surgeon are of interest in order to provide improved pain management, in-hospital stay, and recovery with the development of modern anesthesiology and pain management techniques.

The utilization of analgesic strategies as peripheral nerve block through the local infiltration of anesthetic agents has been shown to be related to a better postoperative recovery and physical performance scores, decreasing the need for opioids and recovery analgesics in recent studies (2-4).

The genicular nerves include branches from the femoral, common peroneal, saphenous, tibial, and obturator nerves which innervate the knee capsule (5, 6). The superolateral, superomedial, and inferomedial branches of the genicular nerve were reported to be in proximity to the periosteum of tibia and femur, and the superolateral, inferolateral, superomedial, and inferomedial quadrants of the anterior knee joint were shown to be innervated by superior lateral, inferior lateral, superior medial and inferior medial branches of the genicular nerve, respectively alongside the branches of peroneal and femoral nerves (7).

Thus, a genicular nerve block specifically targets these branches which innervate the knee joint for the management of postoperative pain in TKR patients.

On the other hand, the interspace between the Popliteal Artery and Capsule of the Knee (IPACK) block provides analgesia on the posterior knee joint, and the application of a genicular or IPACK block has been proven to be associated with promising outcomes following the TKR surgery (8).

Ultrasound guidance is highly recommended for the proper visualization of the anatomic landmarks and exposing the presence of any variation of the nerve tract (9).

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With the globally increasing demand for better pain management for the common procedures, about which method of analgesia leads to better outcomes is of importance. Thus in this study, we aimed to compare the efficacy of genicular block and the IPACK block on postoperative pain scores, the need for rescue analgesics, range of motion (ROM), and walking distance in TKR cases. We also evaluated the effect of analgesia types on the perioperative monitorization variables. We hypothesized that, given the nature of the genicular block, postoperative pain scores, mobility, and patient comfort might be superior in the genicular nerve block compared to the IPACK and the control group in patients who underwent TKR surgery.

Materials and Methods

The study was conducted at Bursa Uludağ University hospital, and approved by the institutional review board (2019-21/38). The interventions were performed in accordance with The Declaration of Helsinki and written informed consent was obtained from all subjects.

The study included 60 patients equally divided into three subgroups. The groups were as follows: the IPACK block group, the genicular nerve block, and the control group.

Exclusion criteria were as follows: revision TKR surgery, emergency procedures, hepatic or renal insufficiency, chronic or autoimmune disease, age <18 and >80 years old, patients undergoing general anesthesia, allergy or intolerance to bupivacaine, patients with a flexion contracture and an American Society of Anesthesiologists (ASA) class IV since these patients were not eligible for the evaluation of perioperative variables due to their lung capacity, and more prone to complications during and after the surgery (10).

Patients who were found to be eligible were randomized by a computer-based methodology and assigned to three groups as having either regional genicular or IPACK block or a control group of patients who did not receive additional regional analgesic agents in the preoperative period (Figure 1). Patient and preoperative variables were adjusted for age and gender.

All patients were evaluated by an orthopedic surgeon prior to the surgery in terms of a presence of the knee ligamentous laxity, and all patients had a varus deformity with lateral laxity.

In addition, the degree of the tibiofemoral angle, radiologic knee society score (RKSS), the degrees of the ROM, Kellgrane-Lawrance, Knee injury and Osteoarthritis Outcome Score (KOGS), Knee Society Score (KSS), The Western Ontario and McMaster Universities Arthritis Index (WOMAC), Oxford Knee Score (OKS) and preoperative visual analog scale (VAS) were evaluated using the appropriate scoring systems (11-16).

Heart rate (HR), non-invasive arterial pressure (NIBP), and Peripheral Capillary Oxygen Saturation (SPO2) monitoring were started in the surgery prep room. All study subjects were premedicated with iv midazolam 1-2 mg and antibiotic prophylaxis, according to the hospital protocol prior to the block procedures.

All regional blocks were performed under ultrasound guidance (GE Medical Sytems, Phoeniz, AZ, USA) using the bupivacaine solution (18 mL 0.25% isobaric bupivacaine with 2 mL dexamethasone) prior to the surgery and the patient being taken to the operating room. Patients were accompanied by the anesthesiology team after the blocks and monitored. The dose of the anesthetic agent used for the regional blocks was calculated using the primary reference literature and clinical practice guidelines (17, 18).

Before starting the block procedure, the operative area between the inguinal ligament and the popliteal crease was sterilized with iodine. The patients were in a supine position, with their knee joint was positioned in flexion, and external rotation of the hip was established. The 12 MHz linear transducer of the ultrasound was used for the visualization of the anatomic landmarks.

The procedure for the IPACK blocks initiated by the visualization of the popliteal artery and posterior surface of the distal femur. Then, the image of the femoral condyles and the popliteal artery was obtained. A 20G ultrasound-visible echogenic stimulation needle with a tip length of 100 mm for peripheral nerve blocks (Stimuplex Ultra 360 Braun Aesculap Japan Co. Ltd. Japan) was inserted in a medial to the lateral plane, parallel to the femur in the middle area between the popliteal artery and the femur. Twenty mL of the local anesthetic solution was given into this space in increments, ensuring the adequate and equal distribution of the anesthetic agent.

For the genicular blocks, the ultrasound transducer was placed parallel to the femur shaft and the epicondyle was identified. The superolateral, superomedial, and inferomedial genicular arteries, which follow a similar route with their each genicular nerve were visualized close to the periosteal areas. A 20G needle (Echoplex, Vygon, Ecouen, France) with a tip length of 50 mm was directed in the plane

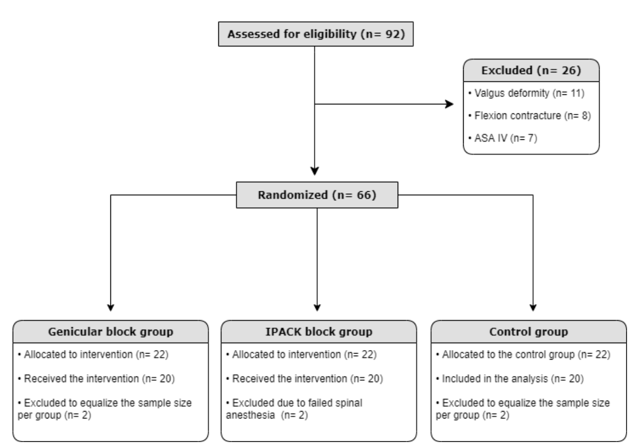

Figure 1. The flowchart of the study design. IPACK: the infiltration between popliteal artery and capsule of the knee

HIGHLIGHTS

- Total knee replacement (TKR) is one of the most commonly performed orthopaedic procedures
- Improved pain management with the development of modern anesthesiology and pain management techniques are required for the patients who underwent TKR.
- Patients in the IPACK and genicular block groups had significantly lower VAS scores on the postoperative period.
- The use of PCA devices and button push count for analgesics demand was significantly lower in the genicular block group.
- The intraoperative 60 min diastolic Holding Area NIBP and pre- and intraoperative heart rate were significantly higher in the control group.
- The genicular block is an efficient technique that offers superior pain management in the immediate and early postoperative period without unfavorable outcomes.

of the ultrasound probe in the long-axis view. After confirming the placement of the needle-tip next to a genicular artery, the superior lateral, superior medial, and inferior medial genicular nerves were given a total amount of 20 mL local anesthetic in equal increments at multiple sites. The injection points were previously described by Qudsi-Sinclair et al as the medial and lateral diaphyseal-metaphyseal transition points of the femur, and the medial diaphyseal-metaphyseal transition point of the tibia (19).

Anesthesia for the TKR was provided by spinal block at the L3/4 interspaces with hyperbaric bupivacaine (2.2 mL; 0.5%) solution. Spinal blocks were performed in the operating room by the same anesthesiologist who performed the regional block.

Postoperative pain and the time of mobilization were the primary outcome measures, as the (VAS) (scale from 0 to 10, as 0=no pain and 10 = worst imaginable pain) was assessed by the patient without any intervention. Postoperative VAS scores were questioned and recorded at the postoperative 4, 8, 12, and 24th hours after the surgery in both resting and mobile states.

Despite various time points for the VAS evaluation visits in the literature, we designed the follow-up visits in an interval of 4-hours within 12 hours after the surgery in order to better evaluate the patients' condition during the immediate postoperative period.

The degree of the flexion angles and the number of the knee exercises repeat count were calculated on the 12th and 24th hours of the postoperative period.

For these group of patients, we adopted a fast-track postoperative recovery protocol, which includes the first mobilization on the same day of the surgery (20). Patients were asked to get up from the bed and give their full weight on their operated knee as early as possible following the surgery. On the postoperative 4h, patients took a predetermined path between two checkpoints with a high-weight walker as assisted by the surgical ward nurse and an orthopedics surgery resident for 10-15 minutes. Passive range of motion exercises up to 90 degrees and isometric quadriceps contraction exercises were also performed as many numbers as the patient could tolerate on the postoperative 12h and 24h. The length of the walking distance was calculated by counting the times of rounds between two checkpoints. VAS scores on the mobile state were questioned promptly after the mobilization, and patients were asked to evaluate their pain status during their ambulation when they returned to bed rest. The time of the first mobilization and the walking distance were noted.

Intraoperative measures were the secondary outcomes, demonstrating the stress and pain level of the patient. Pre- and intraoperative monitorization of systolic and diastolic Holding Area NIBP, HR, SPO2 were performed on the 0, 5, 15, 30, 60 minutes of the surgery, and the data were recorded.

All patients took a standard analgesic regimen of Acetaminophen with a dosage of 15 mg/kg every six hours. The patients were given patient-controlled anesthesia (PCA) devices (morphine 1 mg/mL) with a lock-out time of 15 minutes and asked to use them pushing the button when needed. The devices were set to a maximum dose of 24 mg morphine per day. The post-operative button-push count for PCA demand and PCA usage dosage were calculated and recorded on different time points.

The length of hospital stay was calculated starting from postoperative day 0.

Statistical analysis

Statistical analysis was done using GraphPad version 8.0.2.

Deriving the mean and SD from a recent study at a significance level of 0.05 and power of 0.8, the sample size was determined as 16 for each group by the power analysis (8). Considering a drop-out rate of 30%, we randomized 22 patients for each group initially.

Quantitative variables are represented by the mean and standard deviation. The distribution of the variables was tested using the Kolmogorov-Smirnov test. The comparison of the variables between the groups was performed using one-way ANOVA. Bonferroni correction was applied for posthoc analyses of the statistical calculations of multiple variables. A chi-square test was employed for categorical variables. A significance level of p<0.05 was set for statistical significance.

Results

The age, BMI, gender, presence of a knee ligamentous laxity, operation time, preoperative flexion and extension degree, KOGS, and Kellgrane-Lawrance Grade of the study participants did not differ between the groups (p=0.56, 0.74, 0.64, 0.87, 0.76, 0.38, 0.44, 0.74, 0.36, respectively).

The number of ASA III patients was significantly higher in the IPACK block group. The KSS, OKS, and WOMAC scores were higher in the control group (p<0.05) (Table 1).

Preoperative VAS score when resting was significantly higher in the control group (p<0.01), however the preoperative VAS score on the mobile state was similar between the groups (p=0.19). Patients in the IPACK and genicular block groups had a significantly lower VAS score on the postoperative 4h (resting alone; p<0.01), 8h (resting alone; p<0.01), 12h (resting and mobile; p<0.01), 24h (resting and mobile; p<0.05) compared to the control group. VAS score was significantly lower in the genicular block group on the postoperative 4h and 8h in the mobile state compared to the IPACK and the control group (p<0.01).

The use of PCA devices and button push count for analgesics demand were significantly lower in the genicular block group compared to those of IPACK and the control groups on the postoperative 0-4h (p<0.01). The use of PCA devices and button push count for analgesics demand was significantly lower in the both IPACK block and genicular block groups compared to the control group on the postoperative 4-8 h (p<0.001), 8-12h (p<0.001), 12-16 h (p<0.001) and 16-20h (p<0.05). We did not observe any difference in these variables between the groups in the postoperative 20-24h (0.27, 0.64, respectively). The total consumption of morphine equivalents in 24h was 6.83±6.77 mg in the genicular block group, 9.23±7.35 mg in the IPACK group, and 20.73±4.27 mg in the control group (p<0.01, and p<0.001 for genicular vs IPACK and control groups, respectively). The need for postoperative rescue analgesics was not significantly different between the groups (p=0.87).

The degree of flexion was significantly higher in the genicular block group on the postoperative 12th compared to the IPACK and the control group (p<0.001), but similar between all groups on the postoperative 24h (p=0.92).

The time of the first mobilization did not differ between the study groups, however, knee exercises repeat count on the postoperative 12h and 24h was significantly higher in the IPACK and the genicular block groups compared to the control group (p=0.84, p<0.01 and p<0.05, respectively). Walking distance was significantly higher in the genicular block group compared to the IPACK and the control group (p<0.01).

The length of hospital stay was significantly lower in the genicular block group (4.75± 0.85days) when compared to the IPACK (5.7±1.03 days) and the control group (5.35±0.93 days; $p<0.05$) (Table 2).

There was no difference between groups in terms of systolic and diastolic pre-operative, intraoperative 0 min, 5 min, 15 min, 30 min Holding Area NIBP. The intraoperative 60 min diastolic Holding Area NIBP and pre- and intraoperative heart rate were significantly higher in the control group. The pre- and intraoperative SPO_2 did not differ between the study groups (Table 3).

None of the patients had any signs of analgesia related complications. Spinal anesthesia failed in two patients in the IPACK group, and two patients in the genicular block and the control groups were dropped off from the study to equalize the sample size for each group.

Discussion

In this study, we evaluated whether the addition of either IPACK or genicular blocks to our institution's analgesia protocol improved the pain scores and physical activity scores following TKR surgery. Our study demonstrates that, after adjusting for age, gender, and BMI, both IPACK and genicular blocks were related to significantly better pain scores in the postoperative period. However, although the time for the first mobilization did not differ between the study groups, the genicular block provided better analgesia on the postoperative 4h and 8h while patients were in ambulation, supporting the aim of our study hypothesizing the superiority of the genicular block to the IPACK and control groups for the patients who underwent TKR surgery.

The increase in the number of TKR surgeries performed worldwide resulted in a rising demand for pain management in the early postoperative period by anesthesiologists, surgeons and the patients. Regional anesthesia and analgesia procedures have been shown to reduce hospital stay, complications, morbidity, and readmissions. Besides, the use of regional anesthesia in patients undergoing TKR has been shown to be associated with decreased need for transfusion, and risk of blood transfusion events when compared with general anesthesia (21).

Genicular block is a relatively novel analgesia technique for the patients who underwent TKR surgery. However, the pain-reducing

Table 1. Comparison of the demographic and anthropometric variables between the study groups

	IPACK block	Genicular block	Control	p
Age (years)	67.5±1.4	68±1.76	63±1.67	NS
BMI (kg/m²)	31.8±1.3	33.5±1.5	34.4±1.69	NS
F/M	17/3	16/4	13/7	NS
ASA				
I	3	7	5	NS
II	9	12	15	NS
III	8	1	0	<0.05
Preop knee ligamentous laxity				
Yes	6	4	4	NS
No	14	16	16	
Operation Time (min)	60±8.29	60±1.88	60±7.62	NS
Need for rescue analgesics				
Yes	6	4	4	NS
No	14	16	16	
Pre-op Tibiofemoral Angle (°)	-3.5±1.88	-4.4±1.33	-3.25±0.89	NS
Post-op Alpha Angle (a)- Femoral Component - Coronal plane (Radiologic Knee society score=RKSS)	93.65±0.70	94.25±0.96	92.7±0.90	NS
Post-op Beta Angle (b) - Tibial Component - Coronal plane (Radiologic Knee society score=RKSS)	88.8±0.42	90.10±0.27	90.4±0.23	NS
Post-op Valgus angle (a+b) - Coronal plane (Radiologic Knee society score=RKSS)	182.1±1.64	183.3±1.01	182.9±0.91	NS
Post-op Gamma Angle (G) - Femoral component- Sagittal Plane (Radiologic Knee society score=RKSS)	9.6±6.31	7.35±0.48	6.85±0.47	NS
Post-op Delta Angle (D) - Tibial Component - Sagittal Plane (Radilogic Knee society score=RKSS)	88.2±0.40	86.9±0.77	87.2±0.73	NS
Post-op Patellar Tilt Angle - Lateral Angle (Laurin Angle) (Radilogic Knee society score=RKSS)	11.85±0.24	11.65±0.24	11.90±0.30	NS
Preop flexion (°)	90±4.68	90±3.73	95±4.86	NS
Preop extension (°)	0±1.09	0±1.84	0±0.82	NS
Preop VAS (Resting)	5.55±2.5	4.25±2.49	6.6±1.31	<0.01
Preop VAS (Mobile)	8.35±1.31	7.80±1.44	8.20±1.11	NS
Knee Society Score (KSS)	41±4.17	45±4.46	70±4.15	<0.01
The Oxford Knee Score (OKS)	21±13.77	24.5±2.86	41±3.42	<0.01
The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)	37.9±4.56	40±4.41	71.4±4.27	<0.01
Pre-op Kellgrane-Lawrance Grade				
III	7	6	9	NS
IV	13	14	11	
Pre-op KOGS (Knee osteoarthritis Grading System)				
3B	10	8	6	NS
4A	6	9	10	
4B	4	3	4	

NS: Not significant

effect of radiofrequency ablation and genicular block has been reported by different study groups in patients with knee osteoarthritis (6, 22-24). Thus, the implementation of the genicular nerve block for the management of surgical pain following TKR surgery would yield beneficial outcomes in this patient group. The innervation of the knee joint and its ligaments is relatively complex with the involvement of branches from the femoral, common peroneal, saphenous, tibial and obturator nerves, known as genicular nerves. Furthermore, the inferomedial, superomedial, and superolateral branches of the genicular nerve are highly proximal to the bone, as the periosteum

Table 2. Comparison of the VAS scores and mobility status on different time points between the study groups

	IPACK block	Genicular block	Control	p
Preop VAS (Resting)	5.55±2.5	4.25±2.49	6.6±1.31	<0.01
Preop VAS (Mobile)	8.35±1.31	7.80±1.44	8.20±1.11	NS
VAS 4h (Resting)	5.5±0.52	4.0±0.47	9.0±0.32	<0.01
VAS 4h (Mobile)	8.0±0.47	5.5±0.55	9.5±0.20	<0.01*
VAS 8h (Resting)	6.0±0.44	4.0±0.48	8.0±0.33	<0.01
VAS 8h (Mobile)	8.0±0.43	5.0±0.53	10±0.28	<0.01*
VAS 12h (Resting)	6.5±0.49	4.0±0.47	7.5±0.29	<0.01
VAS 12h (Mobile)	8.0±0.37	5.0±0.45	9.0±0.28	<0.01
VAS 24h (Resting)	6.0±0.52	4.5±0.49	6.0±0.31	<0.05
VAS 24h (Mobile)	7±0.50	5±0.45	8±0.34	<0.05
Post-op PCA usage (0-4 h) (mg)	3.7±5.51	0.3±0.73	22.6±2.06	<0.01*
Post-op button-push count for PCA Demand (0-4 h) (#)	1.85±2.75	0.15±0.36	14.35±3.73	<0.01*
Post-op PCA usage (4-8 h) (mg)	4±5.73	1.3±1.86	23.10±2.38	<0.001
Post-op button-push count for PCA Demand (4-8 h) (#)	2±2.86	0.6±0.88	13.75±3.02	<0.001
Post-op PCA usage (8-12 h) (mg)	7.7±5.74	5.2±4.42	21.50±3.94	<0.001
Post-op button-push count for PCA Demand (8-12 h) (#)	3.85±2.87	2.6±2.21	12.2±3.45	<0.001
Post-op PCA usage (12-16 h) (mg)	10.6±5.69	8.1±5.37	21.50±2.66	<0.001
Post-op button-push count for PCA Demand (12-16 h) (#)	5.3±2.84	4.05±2.68	11.25±2.07	<0.001
Post-op PCA usage (16-20 h) (mg)	13.6±5.82	11.3±5.85	19.50±3.88	<0.05
Post-op button-push count for PCA Demand (16-20 h) (#)	6.85±3.01	5.65±2.92	9.95±2.23	<0.05
Post-op PCA usage (20-24 h) (mg)	15.8 ±6.75	14.8±5.59	16.20±5.73	NS
Post-op button-push count for PCA Demand (20-24 h) (#)	8.25 ±3.89	7.55±3.12	8.15±2.94	NS
Flexion 12h (°)	37.5±6.29	60±3.67	15±1.68	<0.001
Flexion 24h (°)	90±3.36	90±3.45	90±3.45	NS
First mobilization	12±1.01	12±0.85	12±1.13	NS
Knee exercises repeat count 12h	2±0.25	3±0.17	1±0.15	<0.01
Knee exercises repeat count 24h	4±0.46	4±0.23	3±0.16	<0.05
Walking distance (meters)	11.5±5.16	16.25±5.10	10.50±4.56	<0.01*
Hospital stay (days)	5.7±1.03	4.75± 0.85	5.35±0.93	<0.05**

*Significant difference between the genicular block and the control group
** *Significant difference between the genicular block and the IPACK and control group

Table 3. Comparison of the monitorization parameters on different time points between the study groups

	IPACK block	Genicular block	Control	p
Pre-op Holding Area NIBP (systolic)	158.5±12.8	167.5±28.3	163.4±18	NS
Pre-op Holding Area NIBP (diastolic)	87.6±10.4	93.7±14.1	92.3±10.2	NS
Per-op 0 min. NIBP (systolic)	164.7±22.2	165.9±30.1	160.5±27.4	NS
Per-op 0 min. NIBP (diastolic)	89.9±12.8	95.7±13.78	94±10.9	NS
Per-op 5 min. NIBP (systolic)	147.4±23.3	157.6±32.7	156.3±27.3	NS
Per-op 5 min. NIBP (diastolic)	83.5±13.9	87.9±16	89.2±13.1	NS
Per-op 15 min. NIBP (systolic)	137.8±21.2	147.1±27.7	149.5±24	NS
Per-op 15 min. NIBP (diastolic)	76.6±11.3	82.8±13.4	84.7±13.3	NS
Per-op 30 min. NIBP (systolic)	131.9±18	141.4±23.3	138.4±22.6	NS
Per-op 30 min. NIBP (diastolic)	75.2±11.2	79.5±10.4	79.9±12	NS
Per-op 60 min. NIBP (systolic)	135±18.7	138.5±19.8	145.1±22.8	NS
Per-op 60 min. NIBP (diastolic)	77.5±12.8	78.4±10.1	85.9±11.4	<0.05
Pre-op Holding Area HR (Heart Rate)	77±10.9	79.9±14.8	94.5±11	<0.05
Per-op 0 min. HR (Heart Rate)	78.9±12	82.8±17	95.7±12	<0.05
Per-op 5 min. HR (Heart Rate)	78.5±12.1	80.4±17.3	94.4±12.8	<0.05
Per-op 15 min. HR (Heart Rate)	75.5±10.76	77.2±16	87±11.8	<0.05
Per-op 30 min. HR (Heart Rate)	69.8±12	70.9±13.8	81.2±13.2	<0.05
Per-op 60 min. HR (Heart Rate)	69.2±11	70.7±13.7	81.9±10.2	<0.05
Pre-op Holding AreaSPO2 (Peripheral Capillary Oxygen Saturation)	94.9±2.11	95.7±2.4	96±2	NS
Per-op 0 min. SPO2 (Peripheral Capillary Oxygen Saturation)	95±2.44	96.1±2.5	96.3±2	NS
Per-op 5 min. SPO2 (Peripheral Capillary Oxygen Saturation)	95.6±2.3	96.2±1.8	96.4±1.8	NS
Per-op 15 min. SPO2 (Peripheral Capillary Oxygen Saturation)	96.6±1.69	96±2.4	96.7±2.4	NS
Per-op 30 min. SPO2 (Peripheral Capillary Oxygen Saturation)	97±1.23	96.4±2.3	96.2±2	NS
Per-op 60 min. SPO2 (Peripheral Capillary Oxygen Saturation)	97.2±2.94	97.3±2	98±1.17	NS

injury during the TKR surgery is one of the major contributors of postoperative pain in these patients.

To our best knowledge, there are a limited number of studies comparing IPACK and genicular block published in the literature, demonstrating the outcomes after an IPACK or genicular block in pain management following TKR. In our practice, TKR patients start ambulation immediately after the surgery whether approved by the operating and anesthesiology team, thus we were able to observe the effect of regional analgesia on motor functions. Although IPACK block improved pain scores following the TKR surgery, we did not observe this benefit during ambulation, since patients with genicular block recorded a longer walking distance on the immediate postoperative period. The degree of flexion was significantly higher in the genicular block group on the postoperative 12h compared to the IPACK and the control group. These data suggest a better pain control efficiency of the genicular block in the immediate and early postoperative period, allowing a better physical activity profile, and early ambulation. In addition, the length of hospital stay was significantly lower in the genicular block group, while the IPACK group and control group had similar duration of hospitalization, suggesting that a genicular block provides a better patient comfort allowing an earlier discharge time. Thus, we suggest that the shorter length of hospital stay in the genicular block group was a consequence of its superiority over the IPACK block, providing an improved life quality during the early postoperative period.

The complications of peripheral neural blocks have been well-documented as peripheral nerve injury due to various etiologies including the direct traumatic effect of the needle, toxic effect of the anesthetic agent, prolonged compression of a hematoma or abscess, excessive traction of the limb, causes that can result in the ischemia of peripheral nerves. Besides, systemic toxicity, vasovagal reactions, and failure of the block would be expected in various conditions (25). We monitored intraoperative NIBP, heart rate, and SPO2, and demonstrated that NIBP was significantly higher in the control group on the 60 min of the surgery. In addition, the heart rate of the patients in the control group remained significantly higher during the surgery compared to the patients with IPACK and genicular blocks. Since all the patients in our study groups underwent spinal anesthesia, this difference might be a consequence of the addition of another regional block in our analgesia protocol. We conclude that the cause of increased heart rate in the control group was the induction of the sympathoadrenal system by a nociceptive stimulus, and the administration of an IPACK or genicular block had blocked the sensory response in the knee joint.

One interesting finding of our study was that the opioid consumption via PCA devices was significantly lower in the genicular block group between the postoperative 0-4h period, suggesting superior pain management for genicular block in the early postoperative period, which is supported with the VAS scores on the postoperative 4h in the mobile state. Although the VAS scores were significantly different between the patients with block and the control group on the postoperative 24h, we did not observe a difference in the use of PCA devices and button push count for analgesics demand between three groups in this time period. It is worth mentioning that we anticipate approximately four hours of maintenance analgesia due to the ongoing effect of spinal block, and that the patients might be benefited from the spinal and the IPACK and genicular blocks simultaneously.

Our study has several limitations to declare. The surgical team was not blinded to the pain management methodology and the evaluation of the intra- and postoperative data were performed by the anesthesiology team, and the surgical team was not involved in this part of the study. We did not categorize the patients according to their BMI, and the duration of the analgesia might be a possible consequence of the distribution rate of medications in the adipose tissue. However, it is worth mentioning that, BMI did not differ between the study groups.

Another limitation of our study was the lack of patients with a valgus knee, and all patients had a valgus deformity. Since the patients with a preoperative flexion contracture might have varying levels of postoperative pain and physical activity, we only employed patients with varus deformity. Thus, future studies comparing the variables of this study on patients with different contracture degrees and/or varus-valgus knee deformities are needed.

We did not experience an analgesia-related complication in the study groups. However, the follow-up period was the first postoperative 24h in the study set-up, and complications after this period were not recorded.

A sham injection of a saline solution was not administered to the control subjects, which might offer a placebo analgesic effect on the control group. However, the gaps between the pain scores and the need for rescue analgesics were considerably broad between the control and the block groups, and a sham injection would not possibly contribute to an adequate pain management in the control subjects. Furthermore, given the novel nature of the genicular block, our study provides promising data on the use of genicular nerve block for postoperative pain management in the TKR procedures, and its use in the outpatient setting. Although adductor canal block (ACB) and sciatic nerve block have been previously performed for the postoperative analgesia after TKR surgery, IPACK and genicular blocks are superior to them in terms of the larger extent of the analgesia area and motor nerve involvement. Moreover, ACB had an analgesic effect only on the anterior and medial parts of the knee joint, and posterior pain is not addressed with this protocol (26, 27). Also, both ACB and sciatic nerve blocks have a detrimental effect on muscle functions by their involvement of the motor branches of the tibial and peroneal nerves, complicating the ambulation period, and postoperative neurological complications including foot drop have been reported (8, 25). On the other hand, IPACK addresses the region between the popliteal artery and the posterior capsule, and the genicular block provides efficient analgesia also in the posterior knee joint without a motor deficit (26). Although we did not observe any motor deficits in any of our patients in all groups, a cadaveric study demonstrated that IPACK block might extend to the tibial and common peroneal nerves, and might have a potential effect on motor functions (28). In their cadaveric study, Tran et al injected methylene blue dye solution using proximal and distal injection techniques in order to map the area of the IPACK block under ultrasound guidance. They observed that the proximal injection one fingerbreadth above the base of the patella resulted in a more anteromedial dye distribution, whereas the distal approach at the superior border of the femoral condyles had a better anterolateral dispersion (29). The IPACK block is easier than the genicular block in terms of application, as the injection of 20 mL of local anesthetic is administered at once, while three different injections are required for the genicular block. Also, popliteal artery is easy to scan, whereas genicular arteries are smaller to visualize under ultrasound-guidance.

In conclusion, both IPACK and genicular blocks improve patient comfort during and after the TKR surgery and reduce the potential need for systemic analgesics and opioids, the genicular block is a promising technique that offers improved pain management in the immediate and early postoperative period.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Bursa Uludağ University Medical Faculty (2019-21/38).

Informed Consent: Written informed consent was obtained from the all patients.

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References

1. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007; 89: 780-5. [Crossref]
2. Li JW, Ma YS, Xiao LK. Postoperative pain management in Total Knee Arthroplasty. Orthop Surg 2019; 11: 755-61. [Crossref]
3. Morales-Avalos R, Davila-Amar D, Martinez-Avila EC. Update on Post-Operative Analgesia in Total Knee Replacement. J Anesth Surg Care 2019; 1: 1-4.
4. Binici Bedir E, Kurtulmuş T, Başyiğit S, Bakır U, Sağlam N, Saka G. A comparison of epidural analgesia and local infiltration analgesia methods in pain control following total knee arthroplasty. Acta Orthop Traumatol Turc 2014; 48: 73-9. [Crossref]
5. Kim DH, Choi SS, Yoon SH, et al. Ultrasound-Guided Genicular Nerve Block for Knee Osteoarthritis: A Double-Blind, Randomized Controlled Trial of Local Anesthetic Alone or in Combination with Corticosteroid. Pain Physician 2018; 21: 41-52. [Crossref]
6. Choi WJ, Hwang SJ, Song JG, et al. Radiofrequency treatment relieves chronic knee osteoarthritis pain: a double-blind randomized controlled trial. Pain 2011; 152: 481-7. [Crossref]
7. Tran J, Peng PWH, Lam K, Baig E, Agur AMR, Gofeld M. Anatomical study of the ınnervation of anterior knee joint capsule: ımplication for ımage-guided ıntervention. Reg Anesth Pain Med 2018; 43: 407-14. [Crossref]
8. Patterson ME, Vitter J, Bland K, Nossaman BD, Thomas LC, Chimento GF. The effect of the IPACK block on pain after primary TKA: a double-blinded, prospective, randomized trial. J Arthroplasty 2020;35: S173-S7. [Crossref]
9. Sankineani SR, Reddy ARC, Eachempati KK, Jangale A, Gurava Reddy AV. Comparison of adductor canal block and IPACK block (interspace between the popliteal artery and the capsule of the posterior knee) with adductor canal block alone after total knee arthroplasty: a prospective control trial on pain and knee function in immediate postoperative period. Eur J Orthop Surg Traumatol 2018; 28: 1391-5. [Crossref]
10. Daabiss M. American Society of Anaesthesiologists physical status classification. Indian J Anaesth 2011; 55: 111-5. [Crossref]
11. Meneghini RM, Mont MA, Backstein DB, Bourne RB, Dennis DA, Scuderi GR. Development of a modern knee society radiographic evaluation system and methodology for total knee arthroplasty. J Arthroplasty 2015; 30: 2311-4. [Crossref]
12. Kohn MD, Sassoon AA, Fernando ND. Classifications in Brief: Kellgren-Lawrence Classification of Osteoarthritis. Clin Orthop Relat Res 2016; 474: 1886-93. [Crossref]
13. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)–development of a self-administered outcome measure. J Orthop Sports Phys Ther 1998; 28: 88-96. [Crossref]
14. Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989; (248): 13-4. [Crossref]
15. Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br 1998; 80: 63-9. [Crossref]
16. Delgado DA, Lambert BS, Boutris N, et al. Validation of digital visual analog scale pain scoring with a traditional paper-based visual analog scale in adults. J Am Acad Orthop Surg Glob Res Rev 2018; 2: e088. [Crossref]
17. Schwartz DR, Kaufman B. Ch 67: Local Anesthetics. In Hoffman RS, Howland M, Lewin NA, Nelson LS, Goldfrank LR. Eds. Goldfrank's Toxicologic Emergencies, 10e New Yok, NT: McGraw-Hill; 2015.
18. Neal JM, Barrington MJ, Fettiplace MR, et al. The Third American Society of Regional Anesthesia and Pain Medicine Practice Advisory on Local Anesthetic Systemic Toxicity: executive summary 2017. Reg Anesth Pain Med 2018; 43: 113-23. [Crossref]
19. Qudsi-Sinclair S, Borrás-Rubio E, Abellan-Guillén JF, Padilla Del Rey ML, Ruiz-Merino G. A comparison of genicular nerve treatment using either radiofrequency or analgesic block with corticosteroid for pain after a total knee arthroplasty: a double-blind, randomized clinical study. Pain Pract 2017; 17: 578-88. [Crossref]
20. Castorina S, Guglielmino C, Castrogiovanni P, et al. Clinical evidence of traditional vs fast track recovery methodologies after total arthroplasty for osteoarthritic knee treatment. A retrospective observational study. Muscles Ligaments Tendons J 2018; 7: 504-13. [Crossref]
21. Zhu Z Tong P. Association between type of anesthesia and risk of blood transfusion events in primary unilateral total knee arthroplasty: a secondary analysis based on a cohort study in Singapore. J Knee Surg 2020; doi: 10.1055/s-0040-1701486. [Crossref]
22. Kim DH, Lee MS, Lee S, Yoon SH, Shin JW, Choi SS. A prospective randomized comparison of the efficacy of ultrasound- vs fluoroscopy-guided genicular nerve block for chronic knee osteoarthritis. Pain Physician 2019; 22: 139-46. [Crossref]
23. Arıcan Ş, Hacibeyoğlu G, Akkoyun Sert Ö, Tuncer Uzun S, Reisli R. Fluoroscopy-guided genicular nerves pulsed radiofrequency for chronic knee pain treatment. Agri 2020; 32: 38-43. [Crossref]
24. Dale MC, Checketts MR. Complications of regional anaesthesia. Anaesth Intensive Care 2013; 14: 142-5. [Crossref]
25. Yadeau JT, Goytizolo EA, Padgett DE, et al. Analgesia after total knee replacement: local infiltration versus epidural combined with a femoral nerve blockade: a prospective, randomised pragmatic trial. Bone Joint 2013; 95-B: 629-35. [Crossref]
26. Sinha SK, Abrams JH, Arumugam S, et al. Femoral nerve block with selective tibial nerve block provides effective analgesia without foot drop after total knee arthroplasty: a prospective, randomized, observer-blinded study. Anesth Analg 2012; 115: 202-6. [Crossref]
27. Cullom C, Weed JT. Anesthetic and analgesic management for outpatient knee arthroplasty. Curr Pain Headache Rep 2017; 21: 23. [Crossref]
28. Niesen AD, Harris DJ, Johnson CS, et al. Interspace between popliteal artery and posterior capsule of the knee (IPACK) injectate spread: a cadaver study. J Ultrasound Med 2019; 38: 741-5. [Crossref]
29. Tran J, Giron Arango L, Peng P, Sinha SK, Agur A, Chan V. Evaluation of the iPACK block injectate spread: a cadaveric study. Reg Anesth Pain Med 2019; rapm-2018-100355. [Crossref]