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Research Article

Anesthesia for vertebral compression fractures treated with percutaneous kyphoplasty: Comparison of erector spinae plane block, extrapedicular infiltration anesthesia, and conventional local infiltration anesthesia

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ABSTRACT

Objective: Local anesthesia with sedoanalgesia and general anesthesia are widely used in percutaneous kyphoplasty (PKP) for vertebral compression fractures (VCF). The aim of this study was to compare erector spinae block (ESP) with conventional local infiltration anesthesia (CLIA) and extrapedicular infiltration anesthesia (EPIA) with respect to analgesic efficacy in patients who underwent elective PKP for VCF.

Methods: A total of 90 American Society of Anesthesiologists (ASA) 1-3 patients were randomly assigned into 3 groups: group CLIA (n=30), group EPIA (n=30), and group ESP (n=30). The same amount of local anesthetic mixture (6 mL lidocaine 1% and 14 mL bupivacaine 0.5%) was used for regional anesthetic techniques in all groups. Fentanyl 0.1 μg/kg and midazolam 0.1 mg/kg were administered intravenously (IV) before prone positioning. Pain was evaluated using the visual analog scale (VAS) and sedation level using the Ramsay Sedation Scale (RSS) during the procedure. Primary outcome measure were VAS and RSS scores. Secondary outcome measures were hemodynamic changes and additional analgesic and sedative consumptions.

Results: Mean baseline VAS scores were similar between groups (5.62 ± .39; $P > .05$). Intraoperative mean VAS scores were significantly higher in group CLIA compared to EPIA and ESP groups at all timepoints ($P < .01$). Time-bound changes in VAS scores showed a progressive decrease from baseline until the end of the procedure in EPIA (5.60 ± 1.38 to 1.10 ± 0.85; $P < .01$) and ESP groups (5.30 ± 1.44 to 1.17 ± 0.95; $P < .01$), while an increase was detected from baseline to the 20th minute in group CLIA (5.97 ± 1.35 to 7.07 ± 0.94; $P < .01$) that followed a decrease until the end of the procedure (3.47 ± 0.86; $P < .01$). The mean RSS scores were similar at baseline and at the end of the procedure in all groups ($P > .01$), but significantly lower in group CLIA compared to EPIA and ESP groups at the other timepoints ($P < .001$). Time-bound changes in RSS scores showed a progressive increase from baseline until the 20th minute of the procedure that followed a decrease until the end of the procedure in EPIA (5.60 ± 1.38 to 1.10 ± 0.85; $P < .01$) and ESP groups (5.30 ± 1.44 to 1.17 ± 0.95; $P < .01$).

Conclusion: Better anesthetic advantages of ESP and EPIA over CLIA concerning intra-operative analgesia, analgesic and sedative consumption were demonstrated. ESP and EPIA can be used as a suitable anesthetic method in VCF patients undergoing single-level PKP, with stable hemodynamic parameters and analgesia in the intra-operative period.

Level of Evidence: Level I, Therapeutic study.

Introduction

Vertebral compression fractures (VCFs) are the most common fractures associated with decreased bone density in the aging population.[1-3] The prevalence accounts for approximately 25% in postmenopausal women and increases to 40% in the population aged 80 years or more, but men older than 65 years are also at increased risk of compression fractures.[1-6]

The management of VCF involves conservative treatments including bed rest, immobilization, and analgesics followed by gradual mobilization and bracing. Minimal invasive techniques such as percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) have gained popularity due to sufficient vertebral augmentation with a lower risk of complications compared to the surgical techniques including decompression and stabilization. The PVP is performed by the utilization of percutaneous injection of specially formulated acrylic bone cement (commonly polymethylmethacrylate) into the collapsed vertebral body under fluoroscopic guidance.[7,8] Percutaneous kyphoplasty is a modification of this technique that uses a balloon to guide the cement and also increases the height of the collapsed bone.[7,8] Both techniques are considered to be effective for pain relief and functional recovery, but recent studies indicated that PKP is superior to PVP due to pain relief in a shorter period, the improvement of the kyphotic angle, and a lower cement leakage rate.[1-8]

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There are many techniques reported in the literature for the anesthetic management of PKP and PVP including general anesthesia (GA), local anesthesia (LA), monitored anesthetic care with sedoanalgesia, and epidural anesthesia.[9-12] Among them, GA and LA are widely used. Although GA has been proven to be efficacious in PKP surgery, cardiopulmonary complications may increase in elderly patients with comorbidities.[10] Also, neurological complications may not be diagnosed during the procedure. Therefore, GA anesthesia with tracheal intubation and controlled ventilation is generally preferred for multi-level PKP or PVP procedures which make positioning of an awake patient with severe back pain extremely difficult.[9-12] Local anesthetic infiltration techniques offer several advantages over GA for single-level PVP or PKP procedures such as rapid onset, lower anesthetic adverse effects, early recovery and discharge, and cost-effectivity.[9-12] In conventional LA infiltration, the skin, subcutaneous tissue, and lumbodorsal muscle are infiltrated with LA at the point 1 cm lateral to the pedicle and then the LA was injected toward the laminar periosteum at the pedicular projection point on the lamina.[9, 13-15] However, conventional LA infiltration was criticized because it may not be sufficient for a painless procedure because LA ranges from the skin to the laminar surface where extrapedicular periosteum and soft tissues are not anesthetized.[9,13] Therefore, this technique often requires supplemental intravenous sedoanalgesia. Liu et al reported the extrapedicular infiltration anesthesia (EPIA) technique which is added to conventional local infiltration anesthesia (CLIA) to anesthetize the entire extrapedicular periosteum and soft tissues.[9,13] Extrapedicular infiltration anesthesia included an additional step to CLIA where the anesthetic needle directed toward the lateral half of the pedicle and LA was injected along the lateral superior articular process and the superior border of the transverse process. It was reported that this technique reduced pain scores and additional analgesic requirement during the procedure.[9-13] In recent years, ultrasound-guided paravertebral plane blocks has been introduced in the anesthesia practice. The erector spinae plane (ESP) block was first described in 2016 as a novel pain management technique for thoracic neuropathic pain.[15] In this block, LAs are injected between the erector spinae muscle (ESM) and transverse process of the vertebra. Dorsal and ventral rami of spinal nerves and sympathetic nerve fibers are blocked between 5-10 vertebrae levels due to the cranio-caudal spread of the LA. ESP block has been found effective for pain relief in mastectomy, thoracotomy, abdominal surgery, and as well as in spinal surgery.[15,16] The ESP block application for patients with PKP has been rarely reported in the literature.[17-20] Therefore, when supported by similar new studies, this study will add a new anesthetic technique to the literature for patients with PKP.

The aim of this study was to compare primary local anesthesia infiltration methods, including CLIA and EPIA with ESP block to investigate analgesic and sedative efficacy in patients undergoing single-level PKP. The study hypothesis was that ultrasound-guided ESP block was more effective than CLIA and EPIA in patients undergoing single-level PKP.

HIGHLIGHTS

- Erector spinae block (ESP) block can be used as anesthesia methods in kyphoplasty.
- The ESP block is with similar efficacy to extrapedicular infiltration anesthesia (EPIA) in kyphoplasty.
- The EPIA and ESP block have superior efficacy compared to CLIA in kyphoplasty.

Material and methods

Study design

This study was conducted as a prospective, single-center, randomized controlled clinical trial in the orthopedic operating rooms of an academic training and research hospital between January 26, 2023 and March 31, 2025 after University of Health Sciences' ethics committee approval for clinical research (January 25, 2023- protocol no. 2022/156). The trial was registered in the clinicaltrials.gov database, and the registration number is NCT07091513 (Protocol ID 2022/156). A written informed consent was obtained from all patients participating in the trial. The manuscript adheres to the Consolidated Standards of Reporting Trials (CONSORT) statement. The trial ended after the pre-planned number of patients who concluded the intended follow-up period. Patients were randomly assigned to 1 of 3 parallel groups, initially in a 1:1:1 ratio to receive 1 of the 3 anesthetic managements for the procedure. The CONSORT flow diagram is shown in Figure 1. According to the CONSORT flow diagram, 98 of 100 patients assessed for eligibility were randomized to ESP (n=34), EPIA (n=32), or CLIA (n=32) groups. Loss to follow-up occurred in 4, 2, and 2 patients, respectively. Although the intervention was discontinued in some cases, no additional exclusions were made; a total of 90 patients (30 per group) were analyzed.

Participants

The American Society of Anesthesiologists (ASA) physical status class 1-3 patients were included in the study who were between 40 and 85 years and scheduled for an elective, single-level thoracic or lumbar vertebrae kyphoplasty for VCF. The diagnosis was confirmed with physical examination and radiological imaging including direct radiographs, computed tomography, and magnetic resonance imaging. The exclusion criteria were patient refusal, pregnancy, history of previous lumbar surgery, coagulation disorders, anticoagulation medication, abnormal coagulation tests, allergy to the local anesthetics and study drugs, cognitive disorder, chronic pain therapy, and multiple-level vertebrae fractures. It was decided that the patients were dropped out after trial commencement who could not tolerate their position or developed sudden deterioration in vital parameters during the intervention which required emergency treatment. Three staff anesthesiologists and 1 orthopedic surgeon participated in the study who had more than 10 years of experience. Patients were invited on the day before the surgery and a research assistant evaluated the pain of patients at rest using the visual analog scale (VAS) before the procedure. The anesthesiologist who evaluated the visual analog scale (VAS) analysis was a different anesthesiologist who did not know which group the patients were in.

Patients were randomly assigned to 1 of 3 parallel groups in a 1:1:1 ratio using the block randomization method. The randomization sequence was developed using a computer-generated table of random groups. Group allocation was concealed using individual sealed opaque envelopes that were numbered in sequential order. As individuals were enrolled in the study, the next envelope in the sequence was extracted and the participant was assigned to the groups accordingly.

All patients were randomly divided into the 3 study groups that were formed according to anesthesia protocol: 30 patients underwent anesthesia with CLIA, 30 patients with EPIA, and 30 patients with ESP. Patient characteristics including sex, age, weight, height, and basal vital parameters were recorded. Saline or Ringer's lactate solution

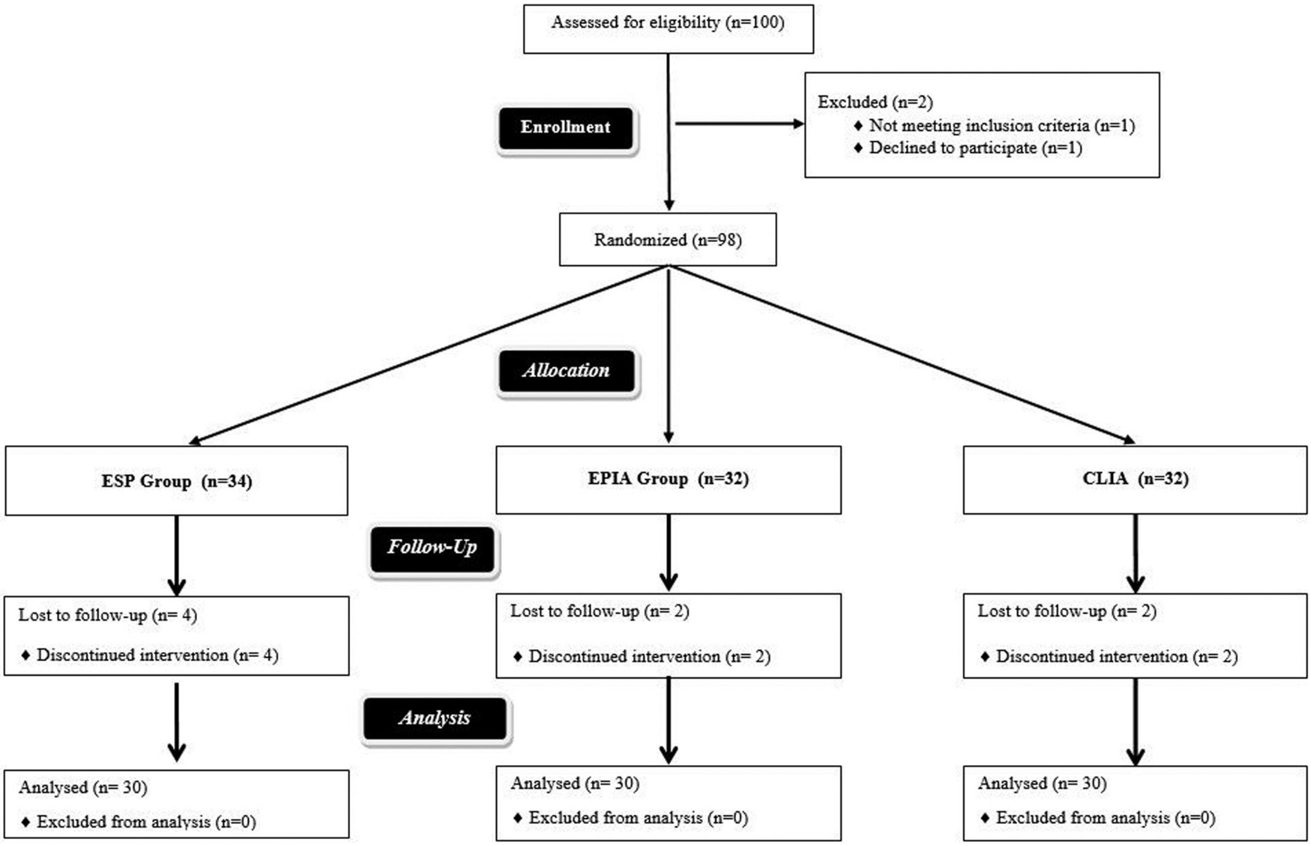

Figure 1. Consort flow diagram. Of 100 patients assessed for eligibility, 98 were randomized to ESP (n=34), EPIA (n=32), or CLIA (n=32). Loss to follow-up occurred in 4, 2, and 2 patients, respectively. Despite intervention discontinuation in some cases, no additional exclusions were made; a total of 90 patients (30 per group) were analyzed.

(1-3 mL.kg^{-1}.h^{-1}, up to 1 L) was intravenously (IV) administered for hydration. In the operating room, the patients were monitored with noninvasive blood pressure (BP), oxygen saturation (SpO2), and electrocardiogram (ECG). Baseline vital parameters were recorded. Patients were given 0.1 mcg/kg fentanyl and 0.1 mg/kg midazolam and carefully positioned prone on the operation table. Each patient was analyzed with pre-operative and intra-operative VAS scores to evaluate pain perception. Briefly, after explanation of the use of VAS, patients were told that they would be asked to complete the scale at baseline (immediately before surgical preparation) and on the 15th, 20th, 30th and 45th minutes of the surgical procedure. According to the VAS rating scale, the baseline is the value immediately before anesthetic administration. Subsequent values (15th, 20th, 30th, and 45th minutes) are the values after anesthetic administration. A VAS value of 0 was defined to identify the absence of pain and 10 was defined as maximum pain. After anesthesia administration, patients with severe pain (defined as a VAS score ≥4) received 0.05 mcg/kg fentanyl as an additional analgesic. Patients did not receive additional analgesics before local anesthetic injection. The sedation levels of patients were evaluated with the Ramsay sedation scale (RSS) at baseline and on the 15th, 20th, 30th and 45th minutes of surgery. The RSS helps in evaluating sedation levels and distinguishing responses

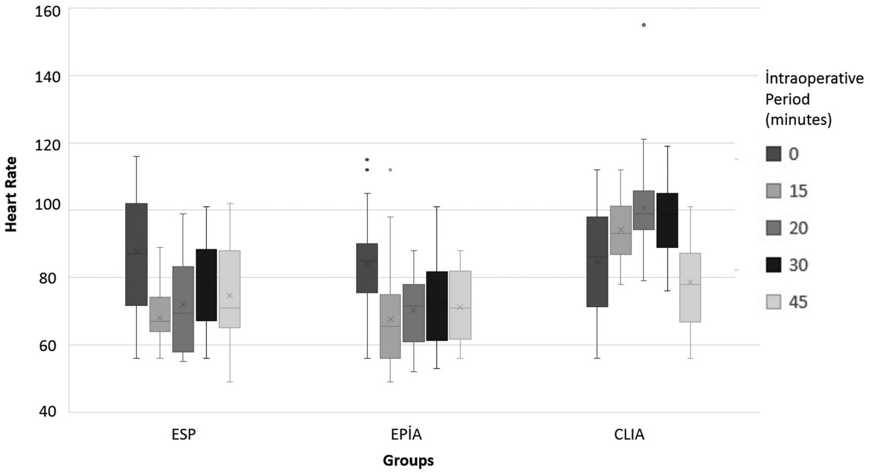

Figure 3. Comparison of heart rate of patients before and during surgery.

to verbal and physical stimuli. Therefore, the RSS was evaluated together with VAS in these patients who underwent sedoanalgesia.

The RSS divides a patient's level of sedation into 6 categories ranging from level 1 (anxious, agitated, or restless) to level 6 (deep sedation without any response). The targeted sedation level of patients was RSS 2 or 3. Patients with a sedation score of 1 received additionally 0.05 mg/kg midazolam. Hemodynamic evaluations, including non-invasive measurement of mean arterial BP, heart rate (HR), and SpO_2, were monitored at baseline and on the 15th, 20th, 30th, and 45th minutes of the surgery. Additional analgesic and sedation amounts applied during the procedures were also recorded.

In CLIA and EPIA groups, the projection point of the pedicle was located as the first step, 5 mL of 1% Lidocaine hydrochloride was used to infiltrate the skin, subcutaneous tissue, and parts of the lumbodorsal muscles, from 1 cm lateral point to pedicle projection point. In the CLIA group, the anesthetic needle was angled 10 to 15 degrees with the sagittal plane and was directed towards the laminar periosteum at the pedicular projection point in the lamina, and a mixture of 1% Lidocaine hydrochloride (6 mL) and 0.5% bupivacaine (14 mL) was injected. In the EPIA group, the anesthetic needle was directed towards the lateral half of the pedicle along the lateral superior articular process and the upper border of the transverse process (angulation 5-10 degrees with the sagittal plane and 5-10 degrees with the coronal plane), followed by the injection of the same 20 mL mixture. In the ESP group, a high-frequency linear transducer (HFL50XP, SonoSite Inc., Bothell, WA, USA) was located vertically approximately 3 cm lateral to the projection point with identification of the spinous process, lamina, transverse process, and the erector spinae muscle. The skin and subcutaneous tissues were infiltrated using 5 mL of 1% Lidocaine hydrochloride. A 22-G peripheral nerve block needle (50 mm) (SonoTAP, Pajunk, Geisingen, Germany) was inserted in-plane from caudal to cranial between the fascia of the erector spinae muscle and the transverse process under ultrasound guidance. After hydro-localization using 1 mL of normal saline, this plane was opened. The same 20 mL mixture of LA was injected after negative aspiration of blood.

The ESP was performed by the same anesthesiologist experienced in regional anesthesia, while CLIA and EPIA were performed by the same orthopedist experienced in VCF before the patient was cleaned and sterilized. The interval between the start of surgery after ESP, EPIA, and CLIA was determined to be 10 minutes.

Primary outcome measure were VAS and RSS scores. Secondary outcome measures were hemodynamic changes and additional analgesic and sedative consumptions. One of the 3 anesthesiologists performed ESP block because he was experienced in regional anesthesia. The other, unaware of the group, performed VAS and RSS analyses. The other anesthesiologist monitored intraoperative hemodynamic parameters. This eliminated bias and improved standardization.

Sample size

The effect size of the difference between the means of VAS, RSS, and the amount of additional analgesics to be obtained from the 5 repeated measures according to the 3 different anesthesia techniques would be at least 0.25 (i.e., medium impact for variance test) with a 2-sided type 1 (alpha) error rate of 0.05 and 80% power. The calculations performed in the G*Power program showed that each of the groups should have at least 30 people (37.7), and there should be a total of 90 people. The study was started with 100 patients; 10 dropped out, and 90 patients completed the study.

Statistical analysis

All analyses were performed on SPSS v21 (SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test with Lilliefors correction was used to determine whether quantitative variables were normally distributed. Continuous variables are given as mean and standard deviation (SD). Frequency and percentage were used for the depiction of categorical variables. The distribution of categorical variables with regard to groups was analyzed and compared by Pearson chi-square test. The between-groups differences were analyzed with 1-way ANOVA for parametric variables and with the Kruskal–Wallis test for non-parametric variables. Time-bound (temporal) changes were assessed with the repeated measures ANOVA test or the Wilcoxon test depending on normality of distribution. Post hoc comparisons were performed via the utilization of the Bonferroni correction. $P < .05$ values were accepted as statistically significant.

Results

A total of 90 patients with VCF who underwent PKP surgery were included in this study. The mean age of the patients was 75.31 ± 7.47 years and the majority were female (n=60, 66.7%). Mean body mass index was 25.37 ± 4.03 kg/m^2. Patient characteristics are shown in Table 1. No differences were found between groups in terms of age, gender, body mass index, duration of surgery, and ASA classification (all, $P > .05$).

Mean baseline VAS scores were 5.30 ± 1.44 in the ESP group, 5.60 ± 1.38 in the EPIA group, and 5.97 ± 1.35 in the CLIA group. At the end of surgery (45th minute), VAS scores were found to be 1.17 ± 0.95 in patients with ESP, 1.10 ± 0.85 in patients with EPIA, and 3.47 ± 0.87 in patients with CLIA. The mean VAS scores in the ESP, EPIA, and CLIA groups were similar at baseline ($P^1 = .184$); however, at all time points during surgery (15th, 20th, 30th, and 45th minute), the VAS values of the CLIA group were significantly higher than the respective values of the ESP and EPIA groups ($P < .001$). When the time-bound changes in VAS scores were assessed within each group, it was found that the ESP and EPIA groups both demonstrated a progressive decrease in scores from baseline to the 45th minute ($P < .001$). However, in the CLIA group, the VAS score was 5.97 ± 1.35 at baseline but increased to 7.07 ± 0.94 at the 20th minute, followed by a progressive reduction to 3.47 ± 0.86 at the 45th minute. It was also determined statistically that the mean VAS

Table 1. Patient Characteristics of the Study Population

	ESP (n=30)	EPIA (n=30)	CLIA (n=30)	*P*
Age (years)^F	74.86 ± 7.56	76.30 ± 7.30	74.76 ± 7.70	.678
Body mass index (kg/m^2)^H	25.50 ± 3.40	25.53 ± 5.94	25.08 ± 1.64	.520
Duration of surgery	45.33 ± 3.21	45.16 ± 4.08	45.10 ± 2.76	.531
ASA^K				
1	n=5, 16.7%	n=2, 6.7%	n=2, 6.7%	.072
2	n=19, 63.3%	n=25 83.3%	n=17, 56.7%	
3	n=6, 20.0%	n=3, 10.0%	n=11, 36.7%	
Sex^K				
Female	n=20, 66.7%	n=20, 66.7%	n=20, 66.7%	1.000
Male	n=10, 33.3%	n=10, 33.3%	n=10, 33.3%	

F was used for 1-way ANOVA for parametric variables, H for non-parametric variables for Kruskal–Wallis *H*-test, and K for categorical variables for Pearson chi-square test.
ASA, American Society of Anesthesiologists levels; CLIA, conventional local infiltration anesthesia group; ESP, erector spinae plane block anesthesia group; EPIA, extrapedicular infiltration anesthesia group.

scores of the CLIA group at 20 minutes were significantly higher than all other time points ($P < .001$), while the baseline and 15th minute values were also significantly higher than the 30th and 45th minute VAS scores (Table 2).

The mean RSS values of all groups were similar at baseline and on the 45th minute measurement. In the ESP and EPIA groups, RSS values during surgery were found not to be significantly increased from baseline ($P^1 = .732$). However, the groups showed significant differences in the 15th, 20th, and 30th minute values, with CLIA results significantly lower than the ESP and EPIA values at the same time points ($P^1 < .001$). In the CLIA group, mean RSS values at the 30th (1.80 ± 0.41) and 45th minutes (2.03 ± 0.49) were significantly higher than the values obtained at baseline (1.40 ± 0.50) and on the 15th (1.43 ± 0.50) and 20th (1.17 ± 0.38) minutes (< 0.001). At baseline and the 45th minute, the mean scores of RSS in ESP, EPIA, and CLIA groups were similar, but at other intra-operative times, the CLIA group RSS were significantly lower than the ESP and EPIA groups (Table 3). Changes in visual analog scale (VAS, solid lines) and Ramsay sedation scores (RSS, dashed lines) over time between groups are shown in Figure 2. The ESP and EPIA provided consistent pain reduction and stable sedation, while CLIA showed higher pain scores and fluctuating sedation levels.

The heart rate values of groups were similar at baseline and on the 45th minute measurement. In all 3 groups, mean heart rate was reduced at 45 minutes compared to baseline values of each group. While the mean heart rate in the ESP, EPIA and CLIA groups were similar at baseline and at the 45th minute, at other time points, heart rate was significantly higher in the CLIA group ($P < .001$) (Figure 3. It was also found that, while both the ESP and EPIA groups demonstrated a similar temporal trend in heart rate values (a steep decrease from baseline at 15 minutes, followed by a marginal increase and plateau), the CLIA group had an opposite response (increased heart rate relative to baseline at all time points except for the 45th minute). The mean BP values in the ESP and EPIA groups were found to be similar at all measurement time points. The mean BP in the CLIA group was significantly lower at baseline than other measurements. While BP values in ESP, EPIA, and CLIA groups were similar at the beginning and at 45 minutes, the CLIA group demonstrated significantly higher values at all other time-points ($P < .001$) (Figure 4). Finally, no statistically significant differences were found, neither between groups ($P = .720$) nor between different time points in each group ($P = .187$), in terms of SpO_2 levels in arterial blood.

Table 2. Comparison of VAS Scores of Patients in Before and During Surgery

	ESP (n=30)	**EPIA (n=30)**	**CLIA (n=30)**	P^1
Baseline	5.30 ± 1.44Aa	5.60 ± 1.38Aa	5.97 ± 1.35Aa	.184
Intra-operative 15 minutes	2.87 ± 0.86Ba	2.47 ± 1.07Ba	4.77 ± 0.73Bb	.000
Intra-operative 20 minutes	1.90 ± 0.66Ca	1.77 ± 0.90Ca	7.07 ± 0.94Cb	.000
Intra-operative 30 minutes	1.70 ± 0.47Ca	1.67 ± 0.60Ca	3.83 ± 0.79Db	.000
Intra-operative 45 minutes	1.17 ± 0.95Da	1.10 ± 0.85Ca	3.47 ± 0.86Db	.000
P^2 value	.000	.000	.000	

P^1 values represent differences between groups at each measurement time and were analyzed with 1-way ANOVA; lowercase letters indicate significant differences between groups from left to right. P^2 values represent changes in each group over time and were analyzed with repeated-measures ANOVA; uppercase letters indicate significant differences between times from top to bottom.
CLIA, conventional local infiltration anesthesia group; ESP, erector spinae plane block anesthesia group; EPIA, extrapedicular infiltration anesthesia group.

Table 3. Comparison of Ramsay Sedation Scores of Patients in Before and During Surgery

	ESP (n=30)	**EPIA (n=30)**	**CLIA (n=30)**	P^1
Baseline	1.37 ± 0.49Aa	1.47 ± 0.51Aa	1.40 ± 0.50Aa	.732
Intra-operative 15 minutes	2.33 ± 0.48Ba	2.30 ± 0.47Ba	1.43 ± 0.50Ab	.000
Intra-operative 20 minutes	2.37 ± 0.49Ba	2.27 ± 0.45Ba	1.17 ± 0.38Bb	.000
Intra-operative 30 minutes	2.07 ± 0.25Ba	2.10 ± 0.30Ba	1.80 ± 0.41Cb	.001
Intra-operative 45 minutes	2.10 ± 0.30Ba	2.07 ± 0.25Ba	2.03 ± 0.49Ca	.778
P^2 value	.000	.000	.000	

P^1 values represent differences between groups at each measurement time and were analyzed with 1-way ANOVA; lowercase letters indicate significant differences between groups from left to right. P^2 values represent changes within each group over time and were analyzed with repeated measures ANOVA; uppercase letters indicate significant differences between times from top to bottom.
CLIA, conventional local infiltration anesthesia group; ESP, erector spinae plane block anesthesia group; EPIA, extrapedicular infiltration anesthesia group.

In the ESP and EPIA groups, only 1 additional analgesic was used in the great majority of patients; whereas, in the CLIA group, 4 or 5 analgesics were used. Furthermore, while only 1 sedative drug was applied to each patient in the ESP and EPIA groups, higher amounts of sedatives were used in the CLIA group (Table 4).

Discussion

This study aimed to compare primary anesthesia techniques, including CLIA, EPIA, and ESP block, with regard to their analgesic and sedation efficacy in PKP surgery, and also to determine their influence on hemodynamic stability during surgery. A better anesthetic outcomes was found with the EPIA and ESP approaches when compared to the CLIA method. It was showed that VAS scores demonstrated a progressive decline during surgery in both the EPIA and ESP groups. Furthermore, the results demonstrated lower mean VAS scores and RSS in recipients of ESP and EPIA compared to CLIA. All anesthesia methods had greatly similar heart rate and peripheral oxygen saturation values. Finally, it also showed no additional needs for analgesia and sedation in recipients of EPIA or ESP.

Compared to the EPIA and ESP groups, there was a temporary increase in pain at minute 20 in the CLIA group. Local anesthetic application in the CLIA group was more medial than in the other groups. It is believed that more lateral focus of the surgical intervention during the 20th minute during the PKP procedure caused temporary pain during this period. This suggests that the anesthesia provided by the EPIA and ESP groups covered a wider area than in the CLIA group. Furthermore, considering the results of this study, ultrasound guidance is required for ESP. Therefore, it was believed that in cases where ultrasound is unavailable, EPIA rather than CLIA would be more appropriate for ESP.

The minimally invasive surgical methods used for VCF, namely PKP and vertebroplasty, are shown to be effective interventions that result in good clinical and radiological outcomes, exemplified by height restoration of fractured vertebrae and significant pain relief. [1-4, 21] However, Wang et al, in their meta-analysis comparing vertebroplasty and PKP for single level VCF, reported that PKP was superior to vertebroplasty due to various advantages, including the lower risk for local cement leakage, volume of cement injected, better short-term pain relief, and the reduced possibility for new vertebral body fracture.[22] Therefore, only PKP was performed for the treatment of VCF in the

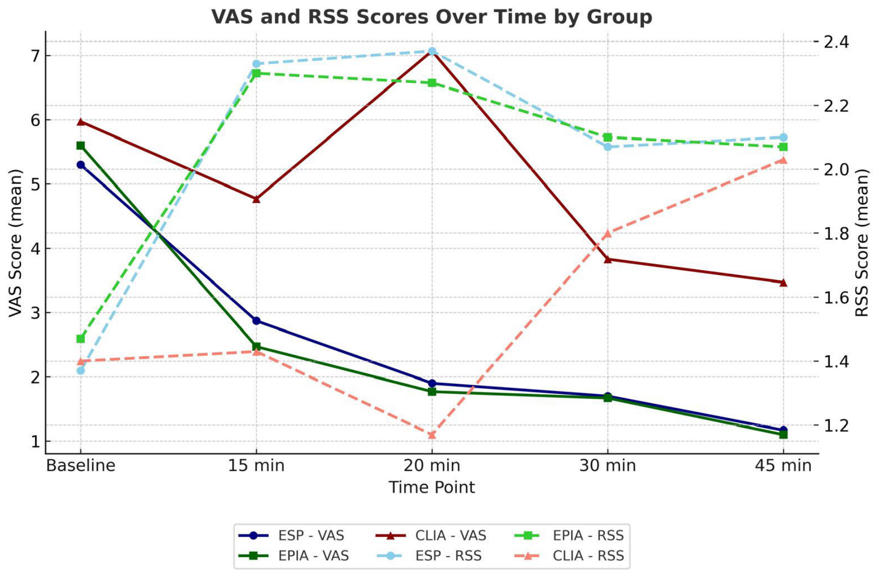

Figure 2. Time-dependent changes in visual analog scale (VAS, solid lines) and Ramsay sedation scores (RSS, dashed lines).

study groups. Although PKP can be performed under local or general anesthesia, selection of the anesthetic method is usually decided according to the number of segments to be treated and the comorbidities of the patients. [9, 12, 13, 14, 17, 23, 24]

In order to enable accurate comparison of the methods of local anesthesia, only patients with single-level VCF were included in which local anesthesia is usually the preferred option and the advantage of shorter surgery time. Outcomes on intra-operative pain, comfort and sedation status were obtained, and possible neurological symptoms of patients. In local anesthesia procedures, the patient may suffer from severe pain during surgery while the puncture needle passes through the extra-pedicular region.[13] An effective local anesthesia standard has been explored in previous studies, and it has been suggested that intra-operative pain scores should be kept lower than 3.[25] The patients' responses to local anesthesia was observed and surgical intervention by following intra-operative pain scores. Similar pain scores at baseline in all groups was found, but mean VAS scores were significantly reduced at different intra-operative times in the ESP and EPIA groups. While CLIA patients experienced higher VAS scores in the first 20 minutes, those undergoing EPIA and ESP did not. It is believed this may be due to the earlier and more effective dorsal/ventral spinal nerve infiltration effect in the EPIA and ESP groups compared to the CLIA group, due to the local anesthetic spreading more laterally and in the transverse plane.

It was also found that the EPIA and ESP groups required significantly less additional analgesics during surgery than the CLIA group. This suggests that the use of ESP and EPIA provides more effective analgesia for PKP than CLIA. Similar RSS was showed in all groups; however, while different amounts of sedatives were often required in the CLIA group, no increased requirement for additional sedatives was found in the EPIA and ESP groups. This suggests that well-tolerated effective sedation for PKP was obtained with the EPIA and ESP methods, without a need for additional drugs. In this study, all patients undergoing kyphoplasty were in the aging population and a decrease in lung capacity was expected. In addition, the procedures were performed in the prone position, resulting in decreased functional residual capacity, thoracic compression, and also de-oxygenation.[8,9,12,13,14] Furthermore, sedatives may worsen oxygenation and increase afterload in the right ventricle due to hypercapnia and pulmonary vasoconstriction, which necessitates adequate airway protection during monitored anesthesia care.[8, 9,12,13,14]

In the study, the patients' SpO$_2$ values were greater than 95%, and there was no statistical difference between the groups. It also showed

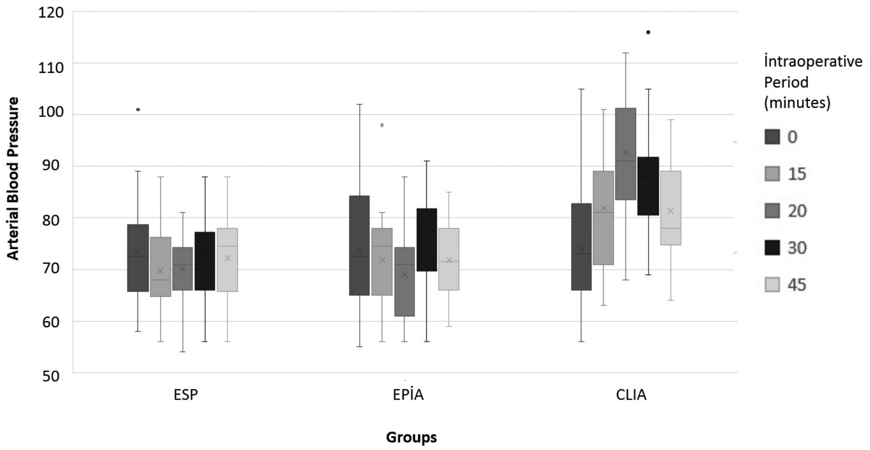

Figure 4. Comparison of mean arterial blood pressure values of patients before and during surgery.

Table 4. Additional Analgesic and Sedation Amounts of the Study Groups

	ESP (n = 30) (%)	EPIA (n = 30) (%)	CLIA (n = 30) (%)
Additional analgesics			
0	n=1, 3.3	n=3, 10.0	n=0, 0.0
1	n=21, 70.0	n=22, 73.3	n=0, 0.0
2	n=8, 26.7	n=5, 16.7	n=0, 0.0
3	n=0, 0.0	n=0, 0.0	n=5, 16.7
4	n=0, 0.0	n=0, 0.0	n=13, 43.3
5	n=0, 0.0	n=0, 0.0	n=12, 40.0
Additional sedative drugs			
1	n=30, 100	n=30, 100	n=4, 13.3
2	n=0, 0	n=0, 0	n=10, 33.3
3	n=0, 0	n=0, 0	n=14, 46.7
4	n=0, 0	n=0, 0	n=2, 6.7

CLIA, conventional local infiltration anesthesia group; ESP, erector spinae plane block anesthesia group; EPIA, extrapedicular infiltration anesthesia group.

similar HR values and BP in the EPIA and ESP groups. However, an increase in BP values was found in the CLIA group over time. These suggest that hemodynamic variables should be carefully monitored, especially in patients receiving CLIA for anesthesia. The ESP was described for acute thoracic neuropathic pain by Forero in 2016.[15] It involved a paraspinal fascial block that included administration of local anesthetic in the plane to the inferior of the erector spinae muscle and superficial to the transverse process, resulting in the blockade of the ventral and dorsal rami of the spinal nerve. [16, 26] Since the injection site is far from the pleura and other important structures such as major blood vessels and the spinal cord, this method emerged as a simple and safe method that required less expertise. It was also found that ESP block had very few contraindications, supporting its advantageous status.[17,20] It was reported to be less difficult than thoracic epidural anesthesia or thoracic paravertebral block.[20]In addition, significant cranial caudal spreading with a single injection point is an additional advantage of ESP in the treatment of multiple fractures.[17,20] ESP block may also enable coughing, could increase lung expansion, has been reported to result in superior analgesia, and eases weaning off mechanical ventilation and early ambulation.[17,20] ESP block has been reported to be effective for pain control in acute or chronic painful conditions including chest, shoulder, abdominal, or even pelvic pain.[27]Studies revealed that ESP block could also be used as a primary method of regional anesthesia for a wide variety of surgical procedures in the thoracic and abdominal areas, and also in percutaneous nephrolithotomies, ventral hernia repairs, and caesarean section.[18,27] However, studies investigating the role of ESP block in VCF are few.[17,19,20,28] They showed decreased VAS score after ESP block treatment.

The results of the study showed that ESP was comparable in efficacy to EPIA, while both methods demonstrated significantly better results compared to anesthesia with CLIA. Therefore, the ESP block procedure seems to be a safe, effective anesthesia method for single-level PKP surgery. It does not increase the risk for significant intraoperative hemodynamic complications. Results of this study may provide a reference for the use of ESP block in PKP surgery. It was noted that the patient did not require additional local anesthetic during surgery, or any pain medications after the operation. This study is one of the few studies that will contribute to the literature on the anesthesia method to be applied to VCF cases undergoing PKP surgery with ESP block as the primary anesthesia method.

Li et al recently published a randomized controlled trial comparing paravertebral block (PVB) with local anesthetic infiltration in VCF cases undergoing PKP surgery. They concluded that PVB provided better analgesia than local anesthetic infiltration.[29] In another randomized controlled trial, they administered 100 mg of tramadol intramuscularly to patients undergoing PKP. They concluded that intramuscular injection of tramadol under local anesthesia, half an hour before surgery, had a clear preventive analgesic effect on PKP in single-segment VCFs.[30,31] Another randomized controlled trial compared thoracolumbar interfascial block (TLIPB) with local anesthesia in VCFs treated with PKP and local anesthesia alone. TLIPB is a block partially similar to the ESP block in the study. Consequently, they found that adding TLIPB to local anesthesia reduced perioperative pain and reduced the use of perioperative rescue analgesics. They demonstrated that TLIPB, when added to local anesthesia, is an effective and safe anesthetic method for PKP in VCFs.[32] The few RCTs mentioned above have examined regional anesthesia techniques in patients with PKP. However, RCTs comparing conventional techniques with erector spinae block are very few. The study is a valuable study that addresses an important gap in the literature in this regard.

There were some limitations in this study. Firstly, the study had a relatively small sample size. Secondly, only ASA grade 1-3 patients were included. The ASA ≥IV patients were not assessed in this study, which limits the generalizability of the findings. Besides, only surgical intervention to patients with single-level VCF were performed; therefore, the possible use of ESP in multi-level VCF remains an unknown topic. EPIA and CLIA were performed by an orthopedist, while ESP was performed by an anesthesiologist. Moreover, the study covers only the intraoperative period because the blocks applied are short-acting and because patients operated under local anesthesia were not admitted to the post-anesthesia care unit. However, the lack of postoperative evaluation for prolonged effects and complications is a limitation of the study. The inclusion of only ASA 1-3 patients and the lack of a multilevel PCP in this study limit its generalizability. However, ESP, a fascial plane block, has been shown to spread local anesthetic both anteroposteriorly and superiorly inferiorly along the erector spinae muscle fascia.[32]Therefore, it is believed that this block can be safely used in multilevel PCPs if validated in randomized controlled trials with these patients.

In conclusion, the current study demonstrated important advantages of ESP block and EPIA over CLIA, especially in terms of intraoperative analgesia, analgesic, sedative requirements, RSS and BP values. The ESP block and EPIA can be used as suitable anesthesia methods in patients undergoing single-level PKP for the treatment of VCF.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee oUniversity of Health Sciences Türkiye, Gülhane Training and Research Hospitalpproval no: 2022/15 Date: 25.01.2023).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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