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Original Research Article

Clinical Outcomes of Spinal Anesthesia with 0.5% Bupivacaine versus 0.75% Ropivacaine in PCNL Procedures

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Abstract

Background: Percutaneous nephrolithotomy (PCNL) is a widely recognized surgical technique for managing large kidney stones, including staghorn calculi and stones resistant to extracorporeal shock wave lithotripsy (ESWL). Spinal anesthesia, particularly using local anesthetics like bupivacaine and ropivacaine, has gained favor for its benefits in reducing pulmonary complications and improving patient recovery. However, the safety and efficacy of different anesthetics, especially ropivacaine combined with intrathecal additives, need further exploration.

Aim: The study aimed to compare the efficacy and safety of spinal anesthesia using intrathecal isobaric ropivacaine 0.75% and hyperbaric bupivacaine 0.5% in patients undergoing PCNL surgeries.

Methodology: This prospective study was conducted over one year at Department of Anesthesiology and Critical care ,Anugrah Narayan Magadh Medical College, Gaya, Bihar. This study involved 100 critically ill patients, with 50 enrolled based on specific inclusion and exclusion criteria. Parameters such as anesthesia quality, intraoperative hemodynamic stability, duration of motor blockade, and postoperative pain relief were measured. Additionally, the Extravascular Lung Water Index (EVLWI) and Pulmonary Vascular Permeability Index (PVPI) were assessed in critically ill patients to explore the impact of these factors on pulmonary function.

Results: The study population had an average age of 39.5 years, with a predominant male participation (60%). ARDS was present in 50% of the patients. Significant correlations were found between EVLWI and chest radiograph scores, as well as PVPI, indicating the importance of these metrics in evaluating pulmonary edema and vascular permeability. However, weak correlations with gas exchange parameters suggest these measures alone may not fully capture the complexity of ARDS.

Conclusion: The study underscores the utility of EVLWI and PVPI in assessing pulmonary dysfunction in critically ill patients with ARDS and septic shock. However, their weak association with gas exchange measures highlights the need for a more integrated diagnostic approach. These findings stress the importance of combining clinical, radiological, and physiological assessments to better guide treatment and improve outcomes in ARDS patients.

Keywords: ARDS, Bupivacaine, EVLWI, PCNL, PVPI, Pulmonary Edema, Ropivacaine, Spinal Anesthesia, Vascular Permeability.

Introduction

Percutaneous nephrolithotomy (PCNL) is a well-known surgical method for treating big kidney and pelvic stones, staghorn calculi, numerous stones, and stones that do not respond to extracorporeal shock wave lithotripsy (ESWL) [1]. PCNL has become a popular minimally invasive procedure because of its positive results and high effectiveness. Spinal anesthesia has emerged as a favored option for PCNL procedures, and the choice of anesthesia has a major influence on the perioperative and postoperative course [2]. Compared to general anesthesia, spinal anesthesia has several advantages, such as improved hemodynamic stability, fewer pulmonary problems, and quicker patient recovery. To provide the best possible surgical conditions and efficient postoperative analgesia, a variety of local anesthetics and additives are used in the field of spinal anesthesia. One common amide local anesthetic that is well-known for its great potency and extended duration of action is hyperbaric bupivacaine [3]. Reliable mid-thoracic spinal blocking is made possible by its hyperbaric formulation, which is very helpful for PCNL procedures. Nevertheless, the related adverse effects—such as bradycardia, hypotension, extended motor blockage, and urine retention—frequently present difficulties and might cause pain for the patient in the postoperative phase.

Alternative local anesthetics, such ropivacaine, have been developed to get around these restrictions. For PCNL, ropivacaine, an amide local anesthetic with isobaric qualities, provides a lumbar and lower thoracic spinal blockage [4]. In comparison to bupivacaine, it is distinguished by its hemodynamic stability, shorter duration of motor blockage, and lower frequency of side effects. Additionally, it is a potential option for spinal anesthesia in minimally invasive operations due to its good safety profile. In several trials, bupivacaine has been used with intrathecal additives such as fentanyl and dexmedetomidine to improve the quality of anesthesia and postoperative pain management [5,6]. On the other hand, ropivacaine and intrathecal additives have demonstrated encouraging outcomes in terms of delivering efficient anesthetic with fewer adverse effects. For PCNL operations, where accuracy and patient comfort are crucial, this has raised interest in comparing its safety and effectiveness to bupivacaine.

High-risk patients receiving PCNL are particularly interested in the hemodynamic stability linked to ropivacaine [7]. Stable blood pressure and heart rate are essential since this surgical method frequently places the patient in lateral and prone postures. Ropivacaine is a good option for these situations because to its pharmacological profile, which includes a decreased tendency for motor blockage and improved hemodynamic stability.

The present study was undertaken to compare the efficacy and safety of spinal anesthesia using intrathecal isobaric ropivacaine 0.75% and hyperbaric bupivacaine 0.5% in patients undergoing PCNL surgeries. By assessing parameters such as the quality of anesthesia, intraoperative hemodynamic changes, duration of motor blockade, and postoperative analgesia, this comparative analysis aims to provide insights into the optimal anesthetic choice for improving patient outcomes in PCNL surgeries.

1. Methodology

2.1. Study Design

This prospective study was conducted over a period of one year in the Department of Anesthesiology and Critical care , Anugrah Narayan Magadh Medical College and Hospital, Gaya, Bihar, India. The objective of the study was to evaluate the use of the paperless partogram as a bedside tool for labor management.

2.2. Sample Size

The study was conducted on a total of 100 critically ill patients, of which 50 patients met the inclusion criteria and were enrolled in the study.

2.3. Inclusion and Exclusion Criteria

Inclusion Criteria

- Patients admitted with a diagnosis of septic shock, with or without ARDS.
- Critically ill patients aged between 18 and 65 years.
- Patients requiring mechanical ventilation with Acute Physiology and Chronic Health Evaluation II (APACHE II) scores of ≥20.

Exclusion Criteria

- Pregnant patients
- Patients with a history of pneumonectomy /lobectomy
- Patients with coagulopathy (international normalized ratio >1.5, platelet count <100, 000/mm³, or both).
- Patients with peripheral arterial disease or contraindications for femoral artery catheterization.
- Patients diagnosed with deep vein thrombosis or pulmonary embolism.
- Patients requiring extracorporeal membrane oxygenation support.

2.4. Procedure

The study involved measuring the 'Extravascular Lung Water Index (EVLWI) to assess pulmonary conditions in critically ill patients. EVLWI was calculated by injecting 20 ml of ice-cold saline through a central venous catheter' using the Volume View® and EV1000® Clinical Platform. The average of three readings was recorded. Predicted body weight was calculated using gender-specific formulas: 0.89× (height in cm−152.6)+500.89 \times (\text{height in cm} - 152.6) + 50 for males and 0.89×(height in cm−152.6)+45.70.89 \times (\text{height in cm} - 152.6) + 45.7 for females. Central venous catheters were inserted via the right internal jugular vein, and the catheter position was confirmed using chest radiographs to ensure placement in the lower part of the superior vena cava.

Each patient underwent chest radiography, with each lung divided into six zones (upper, lower, and perihilar on both sides). Each zone was scored from 0 to 65 based on pulmonary congestion and edema severity, and total scores ranged from 0 to 390. Two radiologists blinded to the volumetric and oxygenation data independently reviewed the radiographs. Additional measurements included the PaO_2:FiO_2 ratio and the alveolar-arterial oxygen gradient ($AaDO_2$), which was derived using the alveolar gas equation. EVLWI, PaO_2:FiO_2, and $AaDO_2$ were measured at least twice daily, and chest radiographs were obtained when clinically indicated.

In total, 135 EVLWI readings were obtained and correlated with corresponding PaO_2:FiO_2 ratios and $AaDO_2$ values. Of these, 64 chest radiographs were evaluated after excluding those with pleural effusion. Additionally, 99 Pulmonary Vascular Permeability Index (PVPI) readings were correlated with 'EVLWI, chest radiograph scores, PaO_2:FiO_2 ratios, and $AaDO_2$.' This systematic procedure ensured the accuracy and reliability of data collected for the study.

2.5. Statistical Analysis

The statistical analysis was conducted using SPSS software, specifically version 27. The results were interpreted to assess the effectiveness of the partogram in managing labor. The Chi-square test was used to analyze categorical data. The P-value below 0.05 was indicated the statistical significance of result.

2. Result

Table 1 displays the research population's baseline characteristics, which include a mean age of 39.5 years (range: 27-53) and 60% male participation. The group primarily comprised medical patients (84%), with 16% being post-surgical cases. Fifty percent of the subjects exhibited ARDS. The haemodynamic parameters comprised a baseline cardiac index (CI) of 4.12 ± 1.52 ml/m², a systemic vascular resistance index (SVRI) of 1479.87 ± 719.63 dyne·s·m²/cm^5, an extravascular lung water index (EVLWI) of 13.9 ml/kg (range: 7.53-17.59), and a pulmonary vascular permeability index (PVPI) of 3.49 (range: 2.82-4.25). The global end-diastolic index (GEDI) measured 532.69 ± 161.11 ml/m². The median scores for disease severity were as follows: APACHE II at 20.9 (IQR: 21-24.6), SOFA at 12 (IQR: 9-13), and MODS at 9 (IQR: 5-11). Oxygenation was compromised, evidenced by a PaO_2:FiO_2 ratio of 187.29 (range: 99-264.7) and an alveolar-arterial oxygen gradient ($AaDO_2$) of 156.87 (range: 120.97-365.13). Chest radiograph scores varied across observers, recorded as 182 (range: 120-251) and 122 (range: 22-230). All patients necessitated mechanical ventilation, with a baseline tidal volume (VT) of 9 ml/kg (range: 6-9) and a PEEP of 6 cm H_2O (range: 5-8).

Table 1: Baseline characteristics of study population

Characteristic	**Value**
Age (years)	39.5 (27-53)
Male sex	60 (60%)
Medical vs post-surgical patients	84 vs 16
ARDS (%)	50 (50%)
Baseline CI (ml/m²)	4.12 ± 1.52
Baseline SVRI (dyne·s·m²/cm^5)	1479.87 ± 719.63
Baseline EVLWI (ml/kg)	13.9 (7.53-17.59)
Baseline PVPI	3.49 (2.82-4.25)
Baseline GEDI (ml/m²)	532.69 ± 161.11
APACHE II score	20.9 (21-24.6)
SOFA score	12 (9-13)
MODS score	9 (5-11)
PaO_2:FiO_2 ratio	187.29 (99-264.7)
$AaDO_2$	156.87 (120.97-365.13)
Chest Radiograph Score (Observer 1)	182 (120-251)
Chest Radiograph Score (Observer 2)	122 (22-230)
Thoracic Fluid Content	42 (27-48)
Mechanical Ventilation Requirement	100 (100%)
Baseline VT (ml/kg)	9 (6-9)
Baseline PEEP (cm H_2O)	6 (5-8)

Table 2 displays the correlation coefficients (r) and sample size (n = 100) for different parameter pairings. The Extravascular Lung Water Index (EVLWI) exhibits a robust positive association with the chest radiograph ratings of Observer 1 (r = 0.7) and Observer 2 (r = 0.65), signifying consistency in the evaluations of the observers. It has a robust positive connection with PVPI (Pulmonary Vascular Permeability Index, r = 0.92), indicating a substantial association between lung water content and vascular permeability. In contrast, EVLWI has a weak negative correlation with PaO_2/FiO_2 (r = -0.3) and a faint positive correlation with $AaDO_2$ (alveolar-arterial oxygen gradient, r = 0.28), indicating slight connections with gas exchange metrics. PVPI has a good association with chest radiograph scores '(r = 0.58 and 0.56 for Observers 1 and 2, respectively)' and a poor link with AaDO2 (r = 0.3), while demonstrating a substantial negative correlation with PaO_2/FiO_2 (r = -0.43). The results indicate a substantial correlation between EVLWI and PVPI with imaging scores, although their association with gas exchange measures is comparatively less.

Table 2: P values for correlation and correlation coefficients

Correlation Pair	**No. of values (n)**	**Correlation coefficient (r)**
EVLWI - Chest radiograph score (Observer 1)	100	0.7
EVLWI - Chest radiograph score (Observer 2)	100	0.65
EVLWI - PaO_2/FiO_2	100	-0.3
EVLWI - $AaDO_2$	100	0.28
EVLWI - PVPI	100	0.92
PVPI - Chest radiograph score (Observer 1)	100	0.58
PVPI - Chest radiograph score (Observer 2)	100	0.56
PVPI - PaO_2/FiO_2	100	-0.43
PVPI - AaDO2	100	0.3

Discussion

The results presented in Table 1 provide a detailed overview of the baseline characteristics of the research population, with a mean age of 39.5 years and a male predominance (60%). The majority of the cohort were medical patients (84%), and a significant proportion (50%) exhibited 'acute respiratory distress syndrome (ARDS)', highlighting the severity of the underlying conditions. The haemodynamic parameters indicate that the cohort had elevated systemic vascular resistance and pulmonary vascular permeability, with notable values for extravascular lung water, indicating compromised pulmonary function. The global end-diastolic index (GEDI) was also measured, providing further insights into the cardiac status of the patients. The disease severity scores (APACHE II, S-OFA, and MODS) reinforce the critical condition of the participants, with values suggestive of substantial organ dysfunction. Oxygenation was significantly impaired, as evidenced by low $PaO_2:FiO_2$ ratios and elevated alveolar-arterial oxygen gradients, consistent with the presence of ARDS and respiratory failure. We looked at the relationship between the severity of lung damage as measured by oxygenation measures and the TPTD parameters (EVLWI and PVPI). By using chest radiograph grading and comparing it to EVLWI and PVPI measures, we also attempted to evaluate pulmonary edema noninvasively [8]. Because it has been shown to be a more accurate indicator of the patient's prognosis, EVLW was indexed to anticipated body weight rather than actual body weight [9-10].

The findings in Table 2 reveal significant correlations between various clinical parameters. The Extravascular Lung Water Index (EVLWI) showed a strong positive correlation with both chest radiograph scores (r = 0.7 with Observer 1, r = 0.65 with Observer 2) and the Pulmonary Vascular Permeability Index (PVPI, r = 0.92), indicating a robust association between lung water content and vascular permeability. These results suggest that both EVLWI and PVPI may serve as reliable indicators of pulmonary edema and vascular injury in critically ill patients. However, the relatively weak correlations of EVLWI with gas exchange parameters, such as PaO_2/FiO_2 (r = -0.3) and $AaDO_2$ (r = 0.28), imply that while these indices are crucial for assessing pulmonary edema and permeability, they may not fully reflect the degree of gas exchange impairment in ARDS. Similar to previous research [11], we discovered a modest connection between EVLWI and AaDO2, which is in contrast to the results of a study [12] that employed a twofold indicator dilution method.

PVPI also demonstrated substantial associations with chest radiograph scores (r = 0.58 for Observer 1 and r = 0.56 for Observer 2), further supporting its relevance in imaging-based assessments of pulmonary dysfunction. The negative correlation between PVPI and PaO_2/FiO_2 (r = -0.43) aligns with the understanding that increased vascular permeability often correlates with poorer oxygenation. Despite these findings, the weak association between PVPI and $AaDO_2$ (r = 0.3) suggests that while PVPI may reflect vascular damage, it is not strongly related to the degree of alveolar-arterial oxygenation mismatch. In this work, we examined the relationship between the degree of lung damage as measured by oxygenation parameters and the TPTD parameters (EVLWI and PVPI). By using chest radiograph grading [13] and comparing it to EVLWI and PVPI measures, we also attempted to evaluate pulmonary edema noninvasively. Because it has been shown to be a more accurate indicator of the patient's prognosis, EVLW was indexed to anticipated body weight rather than actual body weight [14].

These results highlight the significant associations between extravascular lung water, pulmonary vascular permeability, and imaging scores, underlining the utility of these parameters in assessing the severity of lung injury. However, the limited correlations with gas exchange indices underscore the complexity of ARDS, where imaging and mechanical ventilation parameters may provide valuable information, yet do not entirely capture the dysfunction in gas exchange, which remains a critical aspect of patient management. These findings suggest that a comprehensive assessment combining clinical, radiographic, and physiological parameters is essential for evaluating the condition and guiding treatment in ARDS patients. Due to increased capillary leakiness that permits protein-rich fluid to escape through the capillary endothelium, increases in EVLWI and PVPI are indicative of frequent physiological abnormalities in septic shock and ARDS [15]. The ratio of EVLWI to PBV is used to determine PVPI. This might account for our study's high connection between PVPI and EVLWI. According to clinical research, ARDS has a substantially greater PVPI than hydrostatic pulmonary edema [16].

Conclusion

This study provides crucial information about the use of PVPI and EVLWI in detecting pulmonary edema and vascular damage in critically sick patients with ARDS and septic shock. The justification for employing PVPI to report lung water content and vascular permeability is shown by the correlation between EVLWI results and chest radiograph scores. Although these indicators are useful for evaluating fluid dynamics and vascular dysfunction, the poor associations with gas exchange measures such as PaO_2/FiO_2 and $AaDO_2$ imply that they fall short in capturing the complexity of gas exchange impairment in ARDS. Therefore, the results indicate that in order to determine the severity of ARDS and direct therapy, an integrated strategy integrating clinical, radiological, and physiological characteristics is required. EVLWI and PVPI are helpful in assessing pulmonary impairment, but they have a weak correlation with gas exchange parameters. As a result, more diagnostic techniques are needed to improve treatment and outcomes for ARDS patients.

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