Original Article

Effect of The Gel Positioning Pads Placement on Airway Pressure During Prone Percutaneous Nephrolithotomy: A Prospective Randomized Controlled Trial

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Abstract

OBJECTIVES: To study the mean airway pressure levels when positioning the gel pad support transversely versus vertically during percutaneous nephrolithotomy (PCNL) surgery performed in the prone position.

MATERIALS AND METHODS: A randomized controlled trial (RCT) was conducted on patients aged 18 years and older who were diagnosed with kidney stones requiring treatment via percutaneous nephrolithotomy in the prone position, with no contraindications for surgery. A total of 76 participants were randomly divided into two groups, 38 participants each, using block-of-four randomization via computer software. The experimental group received vertical gel pad placement, while the control group received transverse gel pad placement. Data were collected using a pressure recording sheet for airway pressure, peak inspiratory pressure (PIP), and plateau pressure (Pplat) after anesthesia induction and following the prone position change at 1, 5, 30, and 60 minutes, and at the conclusion of the surgery in the supine position. The differences between the experimental and control groups were analyzed using Chi-squared (χ^2) tests or Fisher's exact tests for categorical variables. The mean changes in airway pressure, peak inspiratory pressure, and end-inspiratory pressure at the specified time points were compared using Student's t-tests. A p-value of < 0.05 was considered statistically significant. The study was conducted from May 2021 to June 2024.

RESULTS: The study found no statistically significant differences ($p < 0.05$) in the mean airway pressure, peak inspiratory pressure, and plateau pressure at 1, 5, 30, and 60 minutes after anesthesia induction and transitioning to the prone position, as well as at the conclusion of surgery in the supine position, between the transverse and vertical gel pad placement groups during percutaneous nephrolithotomy. Additionally, there were no significant differences in complications or blood loss volume between the experimental and control groups.

CONCLUSION: The transverse and vertical positioning of gel pad supports during surgery in the supine and prone positions did not affect airway pressure. This suggests that both transverse and vertical gel pad positioning can be safely and effectively applied during surgery, ensuring optimal and safe treatment for patients.

Keywords: airway pressure, PCNL, prone position, gel positioning pads

Urolithiasis, or urinary stone disease, can occur in both the upper urinary tract, including the kidney and ureter, and the lower urinary tract, including the bladder and urethra. Approximately 78% of urinary stones are composed primarily of calcium.[1] The diagnosis of urinary stones can be achieved using various methods such as ultrasound and X-rays. However, the gold standard diagnostic method is non-contrast computed tomography (CT), which has a sensitivity of over 96% and specificity of over 92%.[2]

Renal calculi, or kidney stones, are a prevalent condition worldwide, affecting approximately 7–13% of the population in North America and

5–19% in Southeast Asia.[3] In Thailand, kidney stones are particularly common in the northeastern region.[4] Several factors contribute to stone formation, including genetic predisposition, race, environmental factors, dietary habits, prolonged exposure to heat during work, structural or functional abnormalities of the urinary tract, urinary tract infections, and metabolic disorders.

The major impact of urinary stones extends beyond causing pain and severe infections. If left untreated, they can lead to long-term complications, such as permanent kidney dysfunction.[5] Early detection and timely, appropriate treatment are therefore essential to prevent these adverse outcomes.

Percutaneous Nephrolithotomy (PCNL) was first introduced in 1981[6] and has since become a widely utilized surgical procedure for kidney stone treatment. The technique has continuously evolved, with advancements in equipment and surgical methods. According to the European Association of Urology (EAU) guidelines, PCNL is primarily indicated for kidney stones larger than 2 cm[7], staghorn calculi[8], and calyceal diverticular stones,[9] making it the gold standard for treating these conditions. The procedure achieves a high stone-free rate, emphasizing its effectiveness.

During PCNL, patient positioning plays a critical role in ensuring surgical efficiency and smoothness. The prone position remains the preferred choice among surgeons due to the ease of access to the upper renal pole and the larger working area it provides compared to other positions.[10] Alongside preoperative preparations and surgical planning aimed at achieving stone-free outcomes, monitoring and preventing complications are equally important. Improper positioning or inadequate support during surgery can lead to complications, ranging from pressure ulcers and nerve injuries to severe conditions such as organ damage or life-threatening situations.

One critical respiratory complication during PCNL is pneumothorax (air in the pleural cavity), which requires immediate intervention. Although this condition is often linked to direct pleural or pulmonary injury during surgery, it can also be caused by excessive airway pressure. Cases of bilateral pneumothorax during unilateral PCNL have been reported, suggesting the involvement of surgical techniques or physiological factors. Indicators of pneumothorax include abnormally high airway pressure and reduced blood oxygen levels, confirmed through physical examination or radiographic imaging. While the incidence of pneumothorax is low compared to other complications like infections or bleeding, its potential relationship with airway pressure dynamics remains unclear.

Existing studies have examined the impact of patient positioning and body support devices, particularly shoulder and hip pads, during prone-position surgeries. These studies indicate that reducing chest and abdominal compression can influence airway pressures.[11] However, research on the effects of gel pad placement during PCNL on airway pressures is limited. Prior studies have primarily focused on baseline airway pressures in different patient populations (e.g., normal vs. overweight individuals) but did not explore the influence of body support devices on intraoperative pressures.

In spinal surgeries performed in the prone position, adjustments to body support devices have been shown to affect chest and abdominal pressures, potentially altering hemodynamics and respiratory physiology. However, these devices and procedures differ significantly from those used in PCNL, limiting the generalizability of findings. Nonetheless, some evidence suggests that modifying body support devices can impact intra-abdominal and intrathoracic pressures, potentially influencing systemic physiological responses. Further investigation into the role of support devices during PCNL is necessary to optimize patient outcomes and minimize complications.

Current Practice and Rationale for the Study, The Division of Urology, Department of Surgery, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, currently performs standard percutaneous nephrolithotomy (PCNL) in the prone position. During these procedures, gel pads are used to support the patient's torso, placed either transversely or vertically. While these practices follow established standards, the impact of gel pad positioning on airway pressures during surgery has not been fully elucidated.

This study aims to collect and analyze data on airway pressure changes in patients during supine and prone positions in PCNL. The primary objective is to determine whether the placement of supportive devices influences airway pressures and to identify the gel pad configuration that minimizes these pressures.

The findings are anticipated to contribute new knowledge that can be applied at both organizational and national levels, enhancing the safety and appropriateness of patient care. By identifying optimal practices for gel pad positioning, this research seeks to further refine surgical techniques and improve patient outcomes in PCNL.

Therefore, the researcher is interested in studying the effect of torso gel pad positioning on airway pressure in patients undergoing percutaneous nephrolithotomy (PCNL) in the prone position.

Objective

This study aims to investigate the effect of torso gel pad positioning on airway pressure in patients undergoing percutaneous nephrolithotomy (PCNL) in the prone position, with the primary objective of evaluating the average airway pressure levels associated with the placement of gel pads in transverse and vertical positions.

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In addition, the study seeks to compare differences in airway pressure between the two placement orientations, assess the average changes in airway pressure resulting from postural shifts with each gel pad position, and explore the incidence of complications associated with PCNL performed in the prone position.

Research Framework

Independent Variables	Dependent Variables	Confounding Variables
• Transverse position	• Peak inspiratory pressure: PIP	• Gender
• Vertical position	• Plateau pressure: Pplat	• Age
	• Blood loss	• Body Mass Index (BMI)
	• complication	• Comorbidities

Materials and Methods

This research is an experimental study of the randomized controlled trial (RCT) type.

Population and Sample Group

Population: The population consists of patients aged 18 years and older who have been diagnosed with kidney stones and have indications for treatment via percutaneous nephrolithotomy (PCNL) in the prone position, without contraindications for surgery.

Sample Group: The sample group consists of patients aged 18 years and older who have been diagnosed with kidney stones and have indications for treatment via percutaneous nephrolithotomy (PCNL) in the prone position, without contraindications for the procedure. These patients will be diagnosed and treated at Vajira Hospital during the study period, which is from May 2021 to June 2024.

Inclusion Criteria

1. Patients aged over 18 years.
2. Diagnosed with kidney stones that require treatment via percutaneous nephrolithotomy (PCNL) in the prone position.
3. No contraindications for surgery via percutaneous nephrolithotomy in the prone position.

Exclusion Criteria

1. Patients younger than 18 years.
2. Patients who do not consent to participate in the research.
3. Patients who are unable to undergo surgery as scheduled.
4. Patients with conditions that affect lung compliance, such as: Chronic obstructive pulmonary disease (COPD), Asthma, and Chronic bronchitis.

Criteria for Discontinuing the Study

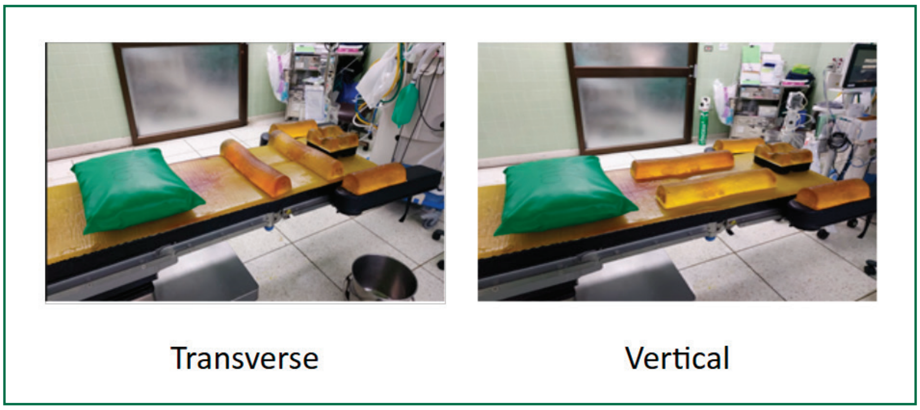
This study, which investigates the effect of the positioning of the gel support cushion on airway pressure during surgery for kidney stone removal via percutaneous nephrolithotomy in the prone position, may involve risks of complications after surgery, such as fever, need for blood transfusions, pneumothorax, sepsis, vascular occlusion, perirenal abscess, infection at the surgical site, or urine leakage from the surgical wound. These risks are common in patients undergoing the same surgical procedure.

The research team has established standard protocols for patient care and complication prevention. However, if serious complications occur during the surgery, such as abscess formation in the renal tissue after needle insertion, shock due to sepsis or excessive blood loss, bowel injury, detection of air or fluid in the pleural cavity, or acute myocardial infarction, the researchers will provide immediate treatment according to established protocols and remove the participant from the study.

Additionally, if the data obtained is incomplete or if the number of participants is insufficient to yield meaningful results, this may also lead to the discontinuation of the study.

Sample Size

This study used sample size estimation from the G*Power program version 3.1.9.4 for comparing the means of two groups with a t-test. The significance level was set at $\alpha = 0.05$, with a power of the test at 90% (Power of test 90%), and an allocation ratio of 1 between the experimental group and the control group. The researcher set the effect size (d) to 0.8 (Large Effect size).[12] Since there were no reference studies for the statistical value used in calculating the effect size, the sample size calculated from the program indicated that at least 34 participants per group would be required. However, the sample size was adjusted to account for potential dropouts and non-compliance within the study process, with a 10% adjustment using a sample size adjustment formula. As a result, the required sample size was determined to be at least 38 participants per group. Therefore, this study used a sample size of 38 participants in the experimental group and 38 participants in the control group, and the groups will be randomly assigned as experimental or control using the block of four randomization method with a computer program[13], which arranges the sequence of treatments to be received as follows.



Gel Pad Positioning Sequence (Transverse vs. Vertical) Used During Percutaneous Nephrolithotomy in the Prone Position.			
V T V T	T V T V	V T V T	V V T T
T V V T	V T T V	T V T V	V T T V
V T V T	V T V T	T T V V	T V V T
T V T V	V V T T	V T V T	T T V V
T V T V	T V T V	V T V T	
T = Transverse, V = Vertical			

Research Procedure

1. The researcher screens patients seeking treatment at the urology surgery clinic to identify patients suspected of having kidney stones who meet the criteria for surgery. Initial diagnostic tests are performed, including urine tests and tests to assess kidney function (BUN, Creatinine), or other tests as appropriate. The patients are scheduled for a follow-up to confirm the diagnosis with a CT scan and subsequent follow-up visits for monitoring their condition.
2. On the follow-up visit, the researcher evaluates and selects patients based on the inclusion and exclusion criteria. Once it is confirmed that the patient meets the eligibility as a volunteer and qualifies for surgery, the researcher explains the surgical procedure, its benefits, possible side effects, and corrective measures. The patient is provided with information about the study, the importance of participation, and details about the data collection process. The researcher reassures the patient that the treatment will follow standard protocols, provides complete information, and allows the volunteer to make an independent decision.
3. On the scheduled visit to the outpatient department to assess pre-surgery preparations, the volunteer, having understood the information, signs the consent form for participation in the research project. If the volunteer declines to participate, treatment will proceed according to standard practice.
4. On the day of the hospitalization for surgery preparation, the participants are grouped into the experimental or control groups according to the pre-prepared Block of Four Randomization method. They are then prepared for surgery according to standard procedures. The experimental group will receive the treatment with the body cushion placed vertically, while the control group will have the cushion placed transversely.
5. Performing Surgery on the Patients
   - 5.1 When the patient enters the operating room, the patient is assessed according to the standard procedure.
   - 5.2 The anesthesiologist and nursing team administer anesthesia to the patient.
   - 5.3 The surgical team positions the patient for surgery, starting with the supine position. A ureteroscope is inserted via the urethra, and a ureteric catheter is placed.
   - 5.4 The surgical team and nursing staff involved in the surgery fill out the data recording form before turning the patient into a prone position on the prepared support equipment. The surgical position is then assessed for safety and accuracy. If no severe complications arise that require stopping the surgery, the patient is not turned back to the supine position. No photographs of the patient will be taken during the surgery.
   - 5.5 The surgical team proceeds with the surgery according to the standard procedure. The anesthesiologist/nursing staff fill out the data recording form.
   - 5.6 When the surgery is complete, the patient is turned back to the supine position. The anesthesiologist/nursing staff fill out the data recording form before removing the breathing tube and transferring the patient out of the operating room according to standard procedures.

Data Collection

The data is gathered and recorded in the data recording form using computer software.

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Post-Surgery Care

The patient is monitored for complications, and follow-up appointments are scheduled for 2 and 6 weeks after surgery.

Data Analysis

The collected data is recorded, analyzed, and interpreted using statistical methods.

Research Conclusion

The research findings are summarized, the research project is closed, and the research results are presented for publication and dissemination.

Measurement Tools for Variables

The researcher designed the measurement tools for the variables using a Case Record Form that aligns with the objectives of the study. The form records data starting before surgery, including airway pressure levels, peak inspiratory pressure, pressure at the end of inspiration after anesthesia, and pressure readings after the patient is turned to a prone position at 1, 5, 30, and 60 minutes, as well as after the surgery in the supine position, extending through the post-surgery period. The data for Part A, B, and D will be filled out by the researcher or the surgical team, while Part C will be completed by the anesthesiologist and nursing staff who monitor the patient throughout the surgery.

Data Collection

The data is stored in coded form, without identifying personal names. Research documents are accessible only to the researcher and research assistants. The analysis of study results will be presented in a summarized form, without identifying individuals.

Only data relevant to the research is collected, according to the Case Record Form. The data collectors and those filling out Parts A, B, and D of the Case Record Form will be the researcher or the surgical team. Part C will be completed by the anesthesiologist and nursing staff who monitor the patient throughout the surgery.

The collected data can only be accessed by the researcher. No copies or transfers of patient records that could identify the patient will be made to other individuals. Patient lists and data forms will be destroyed immediately once the 5-year retention period is completed.

Data Analysis

1. General Characteristics of the Sample Group: The analysis and presentation of the data are divided into two sections based on the type of data as follows:
   - 1.1 Qualitative Data includes gender, comorbid diseases, smoking history, and complications. This data is reported by frequency distribution and percentage, and differences between the experimental and control groups are compared using the Chi-squared test or Fisher's exact test, as appropriate for the data.
   - 1.2 Quantitative Data includes age, body mass index, surgery duration, and blood loss. This data is reported by mean and standard deviation or median and interquartile range, depending on the suitability of the data. Differences between the experimental and control groups are compared using the Student's *t*-test.

2. Comparison of Mean Changes in Airway Pressure: The comparison of mean changes in airway pressure, peak inspiratory pressure, pressure at the end of inspiration after anesthesia, and pressure readings after the patient is turned to a prone position at 1, 5, 30, and 60 minutes, as well as after the surgery in the supine position between the experimental and control groups, will be conducted using the Student's t-test.

All data analysis will be conducted using the IBM SPSS Statistics for Windows, Version 26.0 (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY, USA: IBM Corp.) software, with statistical significance set at the 0.05 level.

Protection of the Rights of the Sample Group

The researcher obtained approval for human research ethics from the Subcommittee for Research Proposal Review at the Faculty of Medicine, Vajira Hospital, Navamindradhiraj University, and also obtained permission to conduct the research from the Ethics Committee for Research at the Faculty of Medicine, Vajira Hospital, Navamindradhiraj University. The project number is 118/63, which will expire on 17/03/2024 (COA number 048/2564).

Results

The general characteristics of the experimental and control groups were predominantly male, aged 40–60 years, with a body mass index (BMI) ≥ 25.00 kg/m² (obese), having comorbidities, and mostly non-smokers. Statistical analysis using the Chi-square test, Fisher's exact test, and Student's t-test showed no significant differences between the experimental and control groups in any of the general characteristics assessed (all $p > 0.05$), as presented in Table 1.

Comparison of airway pressure levels between the transverse (control group) and vertical (experimental group) positioning of the gel body support pad during percutaneous nephrolithotomy in the prone position is presented in Table 2. Analysis using Student's t-test demonstrated no statistically significant differences in mean changes in airway pressure, including peak inspiratory pressure (PIP) and plateau pressure (Pplat), between the two groups at any measurement time point (all $p > 0.05$).

In the experimental group, mean PIP values after anesthesia and following transition to the prone position at 1, 5, 30, and 60 minutes, and at the end of surgery in the supine position were 16.6, 18.8, 19.2, 17.9, 19.2, and 18.5 cmH2O, respectively. Corresponding mean values in the control group were 17.4, 19.1, 19.0, 17.7, 21.0, and 18.5 cmH_2O.

For Pplat, mean values in the experimental group were 16.8, 18.2, 17.7, 17.8, 17.8, and 17.9 cmH_2O at the same time points, compared with 17.9, 18.2, 17.9, 18.5, 19.2, and 19.0 cmH_2O in the control group. These findings indicate that airway pressures remained comparable between the vertical and transverse positioning methods throughout surgery.

Table 1: Number, percentage, and statistical test results comparing the general characteristics between the experimental and control groups (N = 76; n = 38 per group).

Variable	Control group (T) n = 38, n (%)	Experimental group (V) n = 38, n (%)	Test statistic	*p*-value
Gender			χ^2 = 1.943	0.163
Male	25 (65.8)	19 (50.0)		
Female	13 (34.2)	19 (50.0)		
Age (years)			t = 0.905	0.280
21–40	6 (15.8)	8 (21.1)		
41–60	21 (55.3)	20 (52.6)		
> 60	11 (28.9)	10 (26.3)		
Mean ± SD	53.16 ± 13.07	49.92 ± 12.84		
Min - Max	22 - 77	22 - 77		
BMI (kg/m²)			t = 0.517	0.113
< 18.5	0 (0.0)	1 (2.6)		
18.5 – 22.99	9 (23.7)	13 (34.2)		
23.0 – 24.99	5 (13.2)	9 (23.7)		
≥ 25.0	24 (63.1)	15 (39.5)		
Mean ± SD	26.46 ± 4.46	24.71 ± 5.03		
Min - Max	17.10 - 40.10	17.10 - 40.10		
Underlying disease			χ^2 = 12.976	0.674
None	10 (26.3)	15 (39.5)		
Yes	28 (73.7)	23 (60.5)		
Smoking history			Fisher's Exact test = 1.485	0.222
Yes	9 (23.7)	4 (10.5)		
No	29 (76.3)	34 (89.5)		

Notes: None of the p-values are below 0.05, so there are no statistically significant differences between groups at baseline.
This indicates that the control and experimental groups were comparable in terms of gender, age, BMI, underlying disease, and smoking history.

Table 2: Comparison of the mean and standard deviation of airway pressure levels between transverse and vertical positioning of the gel body support pad during percutaneous nephrolithotomy surgery in the prone position, and differences between the experimental and control groups (N = 76; n = 38 per group).

Variable	Control group (T) (n = 38) Mean ± SD	Experimental group (V) (n = 38) Mean ± SD	Test statistic	*p*-value
Peak inspiratory pressure (PIP)				
After anesthesia	17.4 ± 2.9	16.6 ± 2.7	t = 1.272	0.207
Prone position, 1 min	19.1 ± 4.1	18.8 ± 3.4	t = 0.302	0.763
Prone position, 5 min	19.0 ± 3.9	19.2 ± 3.1	t = 0.194	0.846
Prone position, 30 min	17.7 ± 3.1	17.9 ± 3.2	t = 0.545	0.588
Prone position, 60 min	21.0 ± 4.9	19.2 ± 3.7	t = 1.870	0.065
Supine, end of surgery	18.5 ± 4.2	18.5 ± 4.2	t = 1.137	0.259
Plateau pressure (Pplat)				
After anesthesia	17.9 ± 3.1	16.8 ± 3.1	t = 1.517	0.134
Prone position, 1 min	18.2 ± 3.9	18.2 ± 3.9	t = 0.463	0.645
Prone position, 5 min	17.9 ± 3.8	17.7 ± 3.1	t = 0.263	0.793
Prone position, 30 min	18.5 ± 3.8	17.8 ± 3.2	t = 0.815	0.418
Prone position, 60 min	19.2 ± 3.7	17.8 ± 3.0	t = 1.998	0.050
Supine, end of surgery	19.0 ± 7.1	17.9 ± 5.9	t = 0.706	0.483

Notes: Most comparisons show no **statistically significant differences** ($p > 0.05$).
A borderline result was observed for **plateau pressure at 60 minutes in prone position** ($t = 1.998$, $p = 0.050$).
The trend suggests slightly lower airway pressures in the experimental group (vertical support pad), though not consistently significant.

Comparison of the mean duration of surgery and intraoperative blood loss volume between the transverse gel body support positioning group (control group) and the vertical gel body support positioning group (experimental group) is shown in Table 3. The mean duration of surgery was 123.9 minutes in the control group and 118.5 minutes in the experimental group. Regarding blood loss, most patients in both groups experienced blood loss < 300 cc, accounting for 81.6% in the control group and 65.8% in the experimental group. Statistical analysis revealed no significant differences between the two groups in either surgical duration or blood loss volume ($p > 0.05$).

The overall complication rate of percutaneous nephrolithotomy surgery in the prone position is presented in Table 4. Complications occurred in 10.5% of patients in the experimental group (vertical gel body support) and 13.2% of patients in the control group (transverse gel body support), with no complications observed in the remaining participants. Statistical analysis using Fisher's Exact test showed no significant association between the body support positioning method and the occurrence of complications (p = 1.000). These findings indicate that the choice of body support positioning did not influence the incidence of intraoperative complications.

Table 3: Comparison of the mean and standard deviation of duration of surgery and blood loss volume between the experimental and control groups (N = 76; n = 38 per group).

Variable	Control group (T) n = 38, n (%)	Experimental group (V) n = 38, n (%)	Test statistic	*p*-value
Duration of surgery (min)			$\chi^2 = 0.114$	0.578
< 120 minutes	20 (52.6)	25 (65.8)		
≥ 120 minutes	18 (47.4)	13 (34.2)		
Mean ± SD	123.9 ± 47.2	118.5 ± 35.9		
Min - Max	45 - 260	45 - 260		
Volume of blood loss (cc)			$\chi^2 = 0.558$	0.338
< 300	31 (81.6)	25 (65.8)		
≥ 300	7 (18.4)	13 (34.2)		
Mean ± SD	236.8 ± 206.5	289 ± 209.3		
Min - Max	50 - 1000	50 - 1000		

Notes: No statistically significant differences were observed between the two groups for either duration of surgery or blood loss volume ($p > 0.05$).
The experimental group had a higher proportion of patients with blood loss ≥ 300 cc, but this did not reach significance.
Both groups had similar distributions of surgery duration (< 120 vs ≥ 120 minutes).

Table 4: Relationship between the body support positioning method and the occurrence of complications (N = 76).

Body support positioning method	No complication n (%)	Complication n (%)	Total n (%)
Control group (T) (n = 38)	33 (86.8)	5 (13.2)	38 (100.0)
Experimental group (V) (n = 38)	34 (89.5)	4 (10.5)	38 (100.0)
Total (N = 76)	67 (88.2)	9 (11.8)	76 (100.0)

Statistical test: Fisher's Exact test = 0.000, df = 1, $p = 1.000$
Notes: No significant association was found between the body support positioning method and complication occurrence ($p = 1.000$).
The frequency of complications was similar between the control group (13.2%) and experimental group (10.5%).

Discussion

The general characteristics of the sample groups, both the control and experimental groups, showed no significant differences in terms of gender, age, body mass index (BMI), comorbid conditions, and smoking history. Most patients were male, aged between 41-60 years, with a BMI ranging from overweight to obese, with a mean of 25.58 kg/m². The comorbidities included diabetes and hypertension, which align with the studies by Soucie et al.[14] and Pearl et al.[15], as cited in Suphang Srithong[16], which found that kidney stones are more common in men, approximately 2-3 times higher than in women, and more prevalent in the 40-60 age group. This also aligns with the study by Thawat Thammaporn[17] which found that the majority of kidney stone patients had a mean BMI of 25.4 ± 3.81 kg/m².

Regarding the comparison of the mean changes in airway pressure levels, peak inspiratory pressure (PIP), and plateau pressure (Pplat) after anesthesia, and after transitioning to the prone position at 1, 5, 30, and 60 minutes, and at the end of surgery in the supine position, within the vertical gel body support positioning group (experimental group) and the transverse gel body support positioning group (control group), using Student's t-test, the average values of PIP and Pplat were found to be statistically insignificant ($p > 0.05$).

The vertical and transverse gel body support positioning groups may provide appropriate weight support, preventing an increase in intrathoracic pressure and avoiding additional pressure on the abdominal area. This prevents compression of the chest area, which aligns with the studies of Edgcombe et al.,[18] and Kwee et al.,[19] which found that the prone position increases abdominal and pelvic pressure, leading to elevated intra-abdominal pressure, compressing the large veins (inferior vena cava), and reducing venous return. Compression of the thorax decreases the blood volume in the lower chambers of the heart, reducing stroke volume and cardiac output, which could potentially lead to a decrease in blood pressure when transitioning to the prone position. Additionally, changes in the respiratory system, including increased PIP and decreased respiratory compliance by 30-35%, were noted.

The studies highlight the importance of appropriately positioning weight support devices over the thorax and abdomen to reduce changes in lung compliance. Furthermore, the use of surgical support devices with a larger area for abdominal relaxation compared to the standard prone position may help reduce venous congestion and decrease pressure on both the circulatory and respiratory systems. Similarly, the study by Koh et al.,[20] found that increased airway pressure was caused by abdominal organs pushing the diaphragm upward toward the patient's head, and the compression of the thorax reduced thoracic expansion (decreased respiratory compliance). This demonstrates that proper positioning to reduce pressure on the thorax and abdomen is related to airway pressure.

The complication rate of percutaneous nephrolithotomy (PCNL) surgery in the prone position from a sample group of 76 individuals was 11.8%, with 9 complications observed. The experimental and control groups showed complication rates of 10.5% and 13.2%, respectively. The researcher further studied the 9 patients who experienced complications, and found that the complications were as follows: 6 patients had hypotension, and 3 patients had pleural effusion. Other complications, such as pulmonary barotrauma, did not occur during surgery.

When comparing the differences between the transverse and vertical gel body support positioning methods, no significant difference in the occurrence of complications was found between the two methods. Several studies have reported similar complication rates during PCNL surgery in the prone position, such as Michel et al.,[21] who stated that the overall complication rate during PCNL surgery could be as high as 87%, with most complications being mild, such as pleural or abdominal fluid accumulation (7.2%) and blood transfusions (11.2-17.5%). Mourmouris et al.,[22] and Li et al.,[23] conducted systematic reviews and meta-analyses of randomized controlled trials (RCTs) comparing the prone and supine positions in PCNL surgeries to determine which method had the higher risk of complications and morbidity. The results were consistent, showing no significant difference in the occurrence of pleural effusion between the two positions.

This is consistent with the study by Kwee et al.,[19] which reviewed the literature on prone position surgery and complications, finding that most complications were related to pressure on the body organs in the prone position. Abdominal and pelvic pressure increased intra-abdominal pressure, compressing the inferior vena cava and reducing venous return. Thoracic compression led to a decrease in blood volume in the heart's lower chambers, reducing stroke volume and cardiac output, which could lower blood pressure during the transition to the prone position. The study highlighted the importance of using appropriately positioned support devices for the thorax and abdomen to reduce lung compliance changes, as well as surgical equipment that allows more relaxation in the abdominal area compared to the standard prone position, which may help reduce venous congestion and lower pressure on both the circulatory and respiratory systems.

As for other complications, such as pulmonary barotrauma, it did not occur in the sample group during surgery. This may be because all patients in the sample group had an average Plateau pressure (Pplat) of less than 20 cmH2O. According to research reviews by George et al.,[24] and Malik et al.,[25] Pplat is an important pressure value that helps assess the likelihood of airway injury, as it is the pressure exerted on the alveoli and small airways, reflecting lung compliance. Patients with higher lung or thoracic compliance, combined with a Pplat greater than 35 cmH2O, may be at a higher risk of barotrauma. On the other hand, Peak Inspiratory Pressure (PIP) does not indicate the risk of injury but reflects the airway resistance.

The approach to prevent barotrauma includes maintaining Pplat below 30 cmH2O, a tidal volume (Vt) of 6-8 mL/kg, and cautiously adjusting the Positive End Expiratory Pressure (PEEP).

Blood loss and surgery duration

The surgical procedure for kidney stone removal through percutaneous nephrolithotomy in the prone position is a complex and high-risk procedure, even when performed by experienced urological surgeons. A significant complication is blood loss, as the kidneys are highly vascular organs (receiving 25% of cardiac output). This depends on the size of the stone and the duration of the surgery.[26]

The study found that the blood loss during surgery and the surgery duration in the experimental and control groups did not differ significantly ($p < 0.05$). Both groups had an average blood loss of 259.8 cc and an average surgery duration of 121.2 minutes. This study reflects the outcomes of proper positioning to reduce pressure on the chest and abdomen. The use of either crosswise or lengthwise body support gel pads during percutaneous nephrolithotomy in the prone position did not affect the airway pressure, resulting in no difference in blood loss during the surgery.

A study by Koh et al.,[20] explored the relationship between changes in airway pressure and blood loss during spinal surgery in 33 patients in the prone position. The support pads were placed lengthwise and curved in the prone position. The study evaluated PIP, Pplat, mean blood pressure, and heart rate at 5 minutes post-anesthesia and 15 minutes after turning the patients to the prone position. They found an increase in PIP and Pplat, which correlated with blood loss during spinal surgery, suggesting that increased airway pressure was due to the diaphragm being pushed upwards by the abdominal organs and pressure on the chest decreasing lung compliance.

This indicates that proper positioning to reduce chest and abdominal pressure is related to airway pressure.

Therefore, the results of this study conclude that airway pressure does not change between the supine and prone positions during surgery, and it was proven that the use of crosswise or lengthwise gel pads for body support during surgery does not affect airway pressure. This new knowledge can be applied to treat patients in both organizational and national levels to ensure the most appropriate and safest treatment.

Conclusion

The use of a vertical gel body support pad during percutaneous nephrolithotomy surgery in the prone position did not result in significant differences in airway pressure levels, duration of surgery, blood loss volume, or complication rates compared with the transverse positioning method. Both positioning methods were comparable in terms of intraoperative safety and hemodynamic stability, indicating that either method can be used without increasing patient risk.

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