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Research Article

Comparison of Blood Pressure and Arterial Oxygen Saturation in Dependent and Non-Dependent Limbs in Lateral Position during Nephrectomy Procedures

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ABSTRACT

Background: With advancements in medical technology, surgery has become a primary therapeutic option for numerous diseases. A successful surgical procedure requires proper anesthesia and accurate monitoring of vital signs, particularly blood pressure and arterial oxygen saturation. In the lateral decubitus position (LDP), hydrostatic forces may cause differences in blood pressure between the dependent and non-dependent limbs. This study aims to investigate non-invasive blood pressure (NiBP) and arterial oxygen saturation positional differences between dependent and non-dependent limbs.
Methods: 17 males and 22 females undergoing nephrectomy with convenience sampling, aged 18–70 years, with ASA physical status I or II were selected. Patients with peripheral vascular disease, cardiac disorders (e.g., atrial fibrillation, coarctation), inability to measure BP in one arm, significant preoperative BP asymmetry, uncontrolled hypertension, and refusal to participate were excluded. Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP), and Arterial Oxygen Saturation (SpO_2) were pre-specified and were consistently measured using non-invasive monitors.
Results: A significant difference was observed in systolic, diastolic, and mean arterial pressures between the two arms following the lateral positioning ($p < 0.001$). However, oxygen saturation levels did not differ before and after positioning.
Conclusion: The findings indicate a significant variation in blood pressure between dependent and non-dependent limbs in LDP, but no change in oxygen saturation. This emphasizes the importance of choosing the correct arm for accurate blood pressure measurement and hemodynamic management.

Introduction

With technological advances in medical science, surgical approaches are now among the main treatment options for various diseases. A successful surgery requires the induction of proper anesthesia followed by continuous and precise monitoring of vital signs throughout the procedure [1]. It is recommended that patients undergoing general or regional anesthesia have their vital signs monitored every 3 to 5 minutes [2]. Blood pressure and arterial oxygen saturation are critical indicators of the patient's

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hemodynamic status during surgery [3-4]. Since major surgical decisions are based on vital signs, especially blood pressure, its accurate measurement during anesthesia is vital, particularly in surgeries involving significant bleeding, fluid administration, and prolonged anesthesia [5]. Blood flow throughout the body is driven by pressure differences within the arterial system [6]. Blood pressure (BP) reflects the mechanical function of the heart and is measured in mmHg. The heart beats between 60 and 100 times per minute, creating pulsatile arterial pressure waves. Systolic Blood Pressure (SBP), maximum arterial pressure during heart contraction; Diastolic Blood Pressure (DBP), minimum arterial pressure during heart relaxation; and Mean Arterial Pressure (MAP), the average of SBP and DBP [7].

Blood pressure can be measured invasively using a catheter or non-invasively using cuff-based or cuffless methods. Due to equipment and expertise limitations, invasive monitoring isn't always feasible, especially in low-resource settings, which makes accurate noninvasive monitoring essential, particularly in patients in lateral or prone positions. Oscillometric devices are the most commonly used non-invasive monitors for blood pressure during anesthesia [8]. These devices detect pulsatile volume changes via pressure sensors to estimate blood pressure [9-10]. Arterial Oxygen Saturation (SaO_2) refers to the percentage of hemoglobin bound with oxygen in arterial blood. It is measured using pulse oximetry or arterial blood gas analysis (ABG), with normal values between 95% and 100%. Decreased SaO_2 indicates hypoxemia and may result from respiratory, pulmonary, or cardiac disorders [11]. Nephrectomy is a major surgery commonly used to treat various renal and urinary tract pathologies. Indications include irreversible kidney damage, chronic infections, trauma, renovascular hypertension, severe parenchymal damage, nephrocalcinosis, pyelonephritis, reflux, congenital dysplasia, and malignancies [12].

The lateral decubitus position (LDP) is frequently used in nephrectomies, as well as thoracic, spinal, pelvic, and retroperitoneal surgeries [13]. In LDP, the patient lies on the nonoperative side with the body supported by anterior and posterior braces [14]. The dependent limb is the lower limb perpendicular to the trunk, while the non-dependent limb rests on padded supports.

Neurovascular compression in the axilla is a concern in LDP; hence, monitoring pulse and blood pressure in the dependent limb is essential. Pressure on vessels and venous congestion may affect pulse oximetry and act as early warning signs of circulatory compromise. Hypotension in the dependent limb may result from axillary artery compression or hydrostatic effects [15]. Previous studies have shown positional changes can affect blood pressure due to hydrostatic pressure. Non-invasive BP readings tend to be higher in the dependent arm, likely due to hydrostatic influence [16]. However, there is a scarcity of studies comparing blood pressure and oxygen saturation between dependent and non-dependent limbs in LDP. This study aims to investigate non-invasive blood pressure (NiBP) and arterial oxygen saturation positional differences between dependent and non-dependent limbs under general anesthesia and their implications on hemodynamic management.

Methods

Ethics

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval code IR.KMU.AH.REC.1403.123 was provided by the Ethics Committee of Kerman University of Medical Sciences, Kerman, Iran (Dr. M. Shabani) on 25 April 2023.

Data Collection

Data were collected using a standardized information form (supplementary 1) that included demographic variables (age, gender, BMI), systolic blood pressure, diastolic blood pressure, mean arterial pressure (MAP), and arterial oxygen saturation (SpO_2) in both dependent and non-dependent limbs. Measurements were recorded in the supine and lateral decubitus positions at 15 minutes, 1 hour, and 2 hours intervals. Vital signs were monitored using a standard monitoring device (SAADAT, ALBORZ B5, Iran).

Study Population

The population included nephrectomy candidates aged 18 to 70 years with ASA physical status I and II, undergoing surgery in the lateral decubitus position at Bahonar Hospital, Kerman, Iran, during 2024–2025. Written informed consent was obtained from all individual participants included in the study. Prior to enrollment, all participants were informed about the nature, purpose, procedures, potential risks, and benefits of the research. They were assured that participation was voluntary and that they could withdraw at any time without affecting their medical treatment (supplementary 2). Patients were excluded if they had peripheral vascular disease, cardiac disorders (e.g., atrial fibrillation, aortic coarctation), inability to measure blood pressure in either upper limb, preoperative systolic BP difference >20 mmHg or diastolic BP difference >10 mmHg, uncontrolled hypertension, or declined participation.

Measurement Protocol

Blood pressure and arterial oxygen saturation were recorded under the following conditions:

- In the supine position before anesthesia induction
- In the supine position after intubation
- In the lateral decubitus position at 15 minutes, 1 hour, and 2 hours post-positioning

Anesthesia Medications

All patients received the same anesthetic drugs:

- Fentanyl: 2 µg/kg
- Midazolam: 0.004 mg/kg
- Thiopental: 4 mg/kg
- Lidocaine: 1 mg/kg
- Atracurium: 0.5 mg/kg

Sampling Method

A convenience sampling method was used. This pilot study included 39 patients (39 dependent limbs and 39 non-dependent limbs).

Statistical Analysis

Statistical analyses were performed using SPSS version 27. Continuous variables were expressed as mean ± standard deviation (SD) and range (minimum–maximum). Categorical variables were reported as frequencies and percentages. Independent samples t-tests and paired t-tests were used to compare values between groups (e.g., dependent vs. non-dependent arms), as recommended by Rasch & Guiard (2004) [17], who support the robustness of parametric tests even with small samples.

Pearson's correlation coefficient was used to examine the relationships between variables such as age, BMI, and blood pressure or oxygen saturation changes. All P values were reported to three decimal places, and a value of $p < 0.05$ was considered statistically significant.

Results

Descriptive Results

In this study, 39 patients were examined. The mean age of the patients was 47.94 ± 12.73 years (range: 29–72 years), and the mean BMI was 26.12 ± 3.34 (range: 19.10–31.30) (Table 1). Seventeen participants (43.6%) were male and 22 (56.4%) were female. Regarding the side of the dependent limb, 19 (48.7%) had the right side as dependent and 20 (51.3%) had the left side.

Analytical Results

The systolic blood pressure in both arms differed significantly after lateral decubitus positioning (Table 2, Figure 1a). Diastolic blood pressure in both arms also showed significant differences after positioning, at 15 minutes and 2 hours after lateral decubitus (Table 2, Figure 1b). Mean arterial pressure also differed significantly between the arms after lateral positioning (Table 2, Figure 1c). Blood oxygen saturation did not differ before and after lateral positioning (Table 3, Figure 2). Since the sample size is relatively small and parametric tests are robust under such conditions, normality testing was not deemed necessary [17]. Correlations of variable changes with age, BMI, and sex indicated that changes in diastolic blood pressure significantly decreased with age, while changes in mean arterial pressure and oxygen saturation significantly increased with age. Regarding BMI, only oxygen saturation changes increased as BMI decreased (Table 4). Gender had no significant association with any of the changes.

Table 1- Demographic information of patients

Variable	Mean ± SD	Min – Max
Age (years)	47.9 ± 12.7	29 – 72
Height (cm)	168.2 ± 9.2	150 – 188
Weight (kg)	74.5 ± 14.6	49 – 105
BMI (kg/m²)	26.1 ± 3.3	19.1 – 31.3

Table 2- Comparison of Systolic, Diastolic, and Mean Arterial Pressure in dependent and non-dependent arms immediately, 15 Minutes, 1 Hour, and 2 Hours after assuming the lateral decubitus position

Time Point	Arm Type	SBP (Mean ± SD)	DBP (Mean ± SD)	MAP (Mean ± SD)	P value SBP	P value DBP	P value MAP
Before induction (supine)	Dependent	151.3 ± 18.1	96.5 ± 11.2	113.7 ± 13.5	0.710	0.790	0.400
	Non-dependent	152.8 ± 19.2	95.8 ± 12.7	116.6 ± 16.5			
After induction (supine)	Dependent	131.0 ± 19.2	87.2 ± 15.0	101.9 ± 17.2	0.870	0.860	0.650
	Non-dependent	131.8 ± 21.3	87.8 ± 16.4	103.7 ± 18.3			
Immediately after lateral	Dependent	132.1 ± 22.3	88.2 ± 16.3	104.2 ± 20.1	0.001	0.001	0.001
	Non-dependent	109.3 ± 15.9	70.8 ± 16.5	82.7 ± 16.1			
15 min after lateral	Dependent	129.4 ± 18.7	89.7 ± 14.5	100.2 ± 15.0	0.001	0.001	0.001

	Non-dependent	107.3 ± 12.8	71.8 ± 13.0	82.7 ± 12.9		
1 hour after lateral	Dependent	135.6 ± 15.8	92.5 ± 15.2	104.9 ± 15.3	0.001	0.001	0.001
	Non-dependent	115.6 ± 14.0	76.4 ± 13.7	88.4 ± 12.3			
2 hours after lateral	Dependent	130.6 ± 20.3	88.7 ± 16.6	103.4 ± 17.6	0.001	0.001	0.001
	Non-dependent	109.9 ± 8.1	68.9 ± 12.5	82.2 ± 14.3			

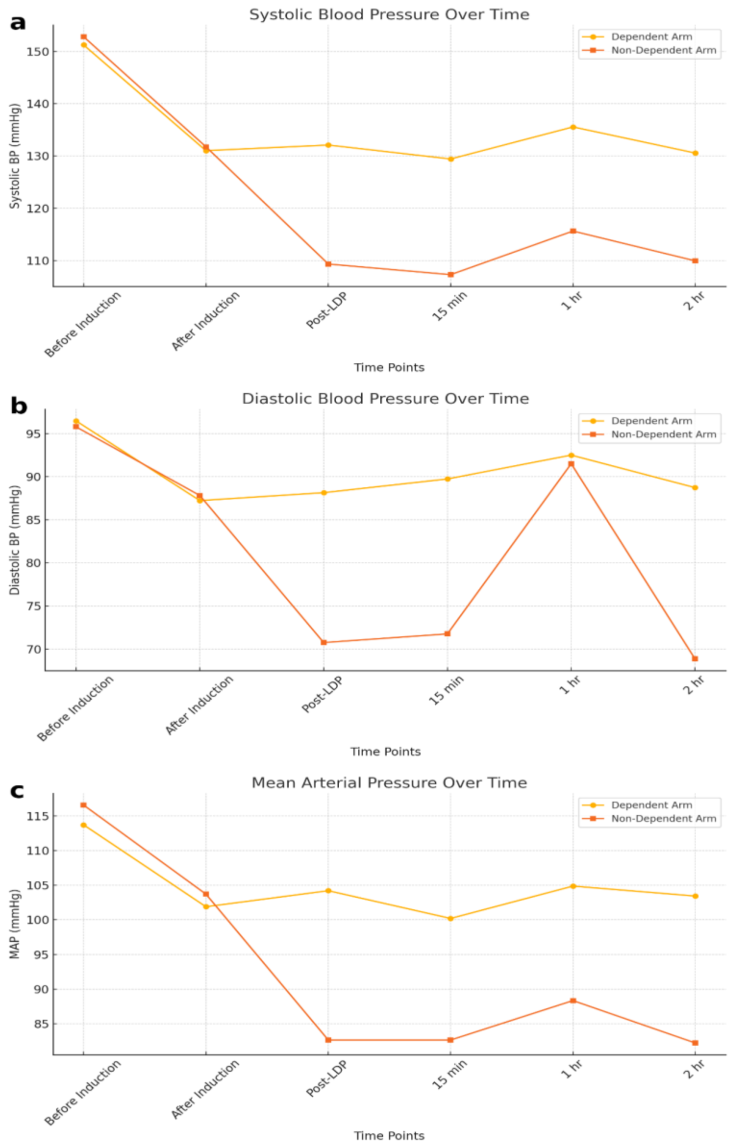

Figure 1- Comparison of a; Systolic, b; Diastolic, and c; Mean Arterial Pressure in dependent and non-dependent arms immediately, 15 Minutes, 1 Hour, and 2 Hours after assuming the lateral decubitus position

Table 3- Comparison of Arterial Oxygen Saturation in dependent and non-dependent arms immediately, 15 Minutes, 1 Hour, and 2 Hours after assuming the lateral decubitus position

Time Point	Dependent Arm (Mean ± SD)	Non-dependent Arm (Mean ± SD)	P value
Before induction (supine)	98.1 ± 2.1	98.1 ± 2.0	1.000
After induction (supine)	99.3 ± 0.9	99.6 ± 1.9	0.450
Immediately after lateral	98.9 ± 1.0	99.0 ± 1.0	0.900

15 minutes after lateral	99.2 ± 0.8	99.2 ± 0.8	1.000
1 hour after lateral	99.2 ± 0.8	99.2 ± 0.8	1.000
2 hours after lateral	99.2 ± 0.8	99.2 ± 0.8	1.000

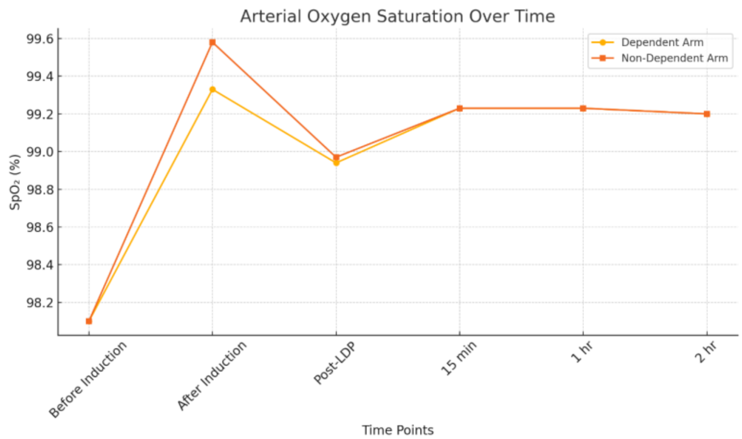

Figure 2- Comparison of Arterial Oxygen Saturation in dependent and non-dependent arms immediately, 15 Minutes, 1 Hour, and 2 Hours after assuming the lateral decubitus position

Table 4- Correlations of variable changes with Age, BMI, and Sex after 2 hours assuming the lateral decubitus position

Variable	Age Correlation (r)	P value	BMI Correlation (r)	P value	Female (Mean)	Male (Mean)	P value
Change in systolic BP	-0.51	0.757	-0.047	0.778	17.59	23.12	0.133
Change in diastolic BP	-0.407	0.010	-0.254	0.119	18.25	22.26	0.275
Change in mean arterial pressure	0.359	0.025	0.257	0.114	21.77	17.77	0.269
Change in arterial oxygen saturation	0.514	<0.001	-0.426	0.007	19.34	20.85	0.667

Discussion

This study investigated the comparison of systolic, diastolic, and mean arterial blood pressure, as well as arterial oxygen saturation, between the dependent and non-dependent upper limbs in patients undergoing nephrectomy in the lateral decubitus position under general anesthesia.

The results of this study showed that placing the patient in the lateral decubitus position led to significant differences in systolic blood pressure between both arms. In addition, diastolic blood pressure also showed significant differences immediately after, 15 minutes after, and 2 hours after assuming this position. Mean arterial pressure was also significantly affected by the lateral position. However, blood oxygen saturation showed no significant difference before and after lateral decubitus position, indicating that body position does not directly impact oxygenation.

The current study is consistent with previous research findings. Since Thakare and colleagues [18], who compared systolic and diastolic blood pressure between the dependent and non-dependent arms in healthy and hypertensive individuals, reported that the blood pressure in the dependent arm is significantly higher than the non-dependent one, especially in individuals with hypertension. These findings align with the current study, although the populations differed. Our study involved patients under general anesthesia. General anesthesia affects hemodynamics by reducing vascular tone and disrupting autonomic nervous system responses, which may amplify the differences in blood pressure between the arms. Nonetheless, hydrostatic effects, reduced venous return, and mechanical pressure on the dependent arm remain probable contributors to these observations in our study. Liu's study also confirmed that arm position affects blood pressure readings. It emphasized that positioning the arm higher or lower than heart level significantly increases or decreases systolic and diastolic pressure, respectively. This aligns with our findings and highlights the need to consider arm position for accurate measurement [19].

Likewise, Netea's research reported significant differences in blood pressure depending on body position. While our study examined differences between dependent and non-dependent arms in lateral decubitus under anesthesia, Netea evaluated seated, supine, and elevation changes without differentiating between arms. These variations indicate the complex effects of body and limb positioning on blood pressure [15].

Liu's study also demonstrated significant effects of arm position on blood pressure readings. Unlike our study, which examined the dependent versus non-dependent arms under anesthesia, Liu evaluated seated subjects without considering arm dependency. Still, both emphasize the importance of arm positioning in obtaining accurate readings [19].

Additionally, Mariotti and colleagues found that positioning the arm beside the body increases blood pressure compared to when it is level with the heart. Their study was conducted on standing subjects and outside a clinical setting, while our research focused on anesthetized patients in the lateral position. Despite the differences, both studies emphasize correct arm positioning [20].

Contrastingly, some studies focused on venous oxygen saturation rather than arterial. One such study found that lowering the arm increased venous oxygen saturation due to increased blood flow, not changes in blood pressure. This differs from our findings, which showed significant differences in systolic, diastolic, and mean arterial pressure between arms, with no difference in arterial oxygen saturation. These discrepancies may stem from different measured variables and experimental conditions [21].

This study has several limitations. The sample size was relatively small and limited to a single center, which may reduce generalizability. Additionally, we did not separate limb-specific hemodynamic changes based on patient comorbidities or intraoperative variables. Future research with a larger, more diverse population is recommended to confirm these findings.

Conclusion

Significant differences in systolic, diastolic, and mean arterial blood pressure were observed between the dependent and non-dependent arms in the lateral decubitus position. No significant changes in arterial oxygen saturation were found.

Recommendations

For more accurate intraoperative blood pressure monitoring during lateral decubitus surgeries, measurements should be taken from the dependent arm. Further studies with larger and more diverse populations are recommended to generalize these findings and optimize hemodynamic management protocols.

Funding

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Ethics approval and consent to participate

This study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and was approved by the Ethics Committee of Kerman University of Medical Sciences, Iran (Ethics approval code: IR.KMU.AH.REC.1403.123). Written informed consent was obtained from all participants prior to their inclusion in the study. All participants were assured of the confidentiality of their data and were informed of their right to withdraw from the study at any time without any consequences to their medical care.

Consent to Participate

Written informed consent was obtained from all individual participants included in the study. Prior to enrollment, all participants were informed about the nature, purpose, procedures, potential risks, and benefits of the research. They were assured that participation was voluntary and that they could withdraw at any time without affecting their medical treatment. The consent process was conducted in accordance with the guidelines approved by the Ethics Committee of Kerman University of Medical Sciences (Approval Code: IR.KMU.AH.REC.1403.123), (Supplementary 2).

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Supplementary

Informed Consent Form for Participation in a Research Study

Study Title: Comparison of Blood Pressure and Arterial Oxygen Saturation in Dependent and Non-dependent Limbs in Lateral Position during Nephrectomy Procedures

In the name of God

I, ..., child of ...., with national ID number ...., born on ...., who am undergoing nephrectomy surgery at Shahid Bahonar Hospital in Kerman, hereby declare that the researchers of this study have provided me with complete and transparent information regarding the objectives, methodology, benefits, and potential risks of the study.

Study Details:

- This study aims to examine changes in blood pressure and arterial oxygen saturation during different positions of nephrectomy surgery.
- My blood pressure and arterial oxygen saturation levels will be measured before and after anesthesia and at various stages following the change to the lateral decubitus position.
- These measurements will be conducted using standard, non-invasive equipment and will not involve any additional medical intervention in my surgery process.

Benefits of Participation:

- Participation in this study may help improve methods for hemodynamic monitoring in surgical patients and enhance anesthesia safety.
- The findings of this research could contribute to improving the quality of anesthesia care for future patients.

Potential Risks:

- This study only involves non-invasive measurements and poses no risk of invasive procedures to me.
- All study procedures will be conducted in accordance with safety and ethical standards. I can withdraw from the study at any stage without it affecting my treatment process.

Confidentiality:

- My personal and medical information will remain completely confidential and will only be used in anonymous and aggregated form in the research findings.

Right to Choose and Withdraw:

- Participation in this study is entirely voluntary. I can withdraw from the study at any time without any negative impact on my treatment.

Confirmation and Signature:

I hereby give my informed consent to participate in this study, with full awareness of its objectives, procedures, benefits, and potential risks.

Patient's Full Name:

Signature and Date: