









Original Article

The effect of reduced tidal volume on post percutaneous nephrolithotomy pulmonary complications: A retrospective case control study.

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Abstract

**Background:** Percutaneous nephrolithotomy (PCNL) is the treatment of choice for large or complex renal stones. The upper pole (supra-costal access) is associated with pulmonary and cardiac complications post-operatively, owing to its proximity to the diaphragm. The prone position also causes restricted chest expansion and decreased pulmonary compliance. In this study, we aim to evaluate pulmonary complications after percutaneous nephrolithotomy by reducing the tidal volume intra-operatively and to assess the appropriate tidal volume for patients undergoing PCNL.

**Methodology:** A retrospective chart review was performed over a period of one year (2019-2020). All patients who underwent PCNL and fulfilled the inclusion criteria were included in the study. They were divided into two groups: low tidal volume (Cases), and normal tidal volume (Controls). The records were evaluated for any pulmonary complications post-operatively, and this was compared between the two groups.

**Results:** A total of 114 patients were included in the study. When patients with low tidal volume were compared to patients with normal tidal volume, no significant difference in pulmonary complications was observed ( $p$ -value < 0.05).

**Conclusion:** There was no significant difference between the two groups, in terms of post-PCNL pulmonary complications, with respect to the tidal volume. Further multicenter studies can better elucidate these findings.

Keywords

Percutaneous Nephrolithotomy, Supra-Costal Puncture, Pulmonary Complications, Risk Factors, Urolithiasis.



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## Introduction

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Percutaneous nephrolithotomy (PCNL) remains the gold standard treatment for large renal stone burden<sup>1</sup>. Numerous advances have been made to improve the morbidity and technical difficulties associated with this common urologic procedure, since it was first described in 1976 by Fernström and Johansson. However, the basic principle remains the same; the need to establish a percutaneous access tract into the kidney, to facilitate stone removal.

In the 21<sup>st</sup> century, there has been significant shift in environmental and dietary factors, which is leading to the production of larger and recurrent stones in unhealthier patients, PCNL is now more relevant than ever. In spite of all the recent advancements, it can result in severe adverse outcomes, some as ominous as Grade III-IV as per the Clavien Dindo classification<sup>2</sup>.

Gaining access into the upper pole via the supra-costal approach is challenging, but it confers some advantages- the tract length is relatively short due to the natural lie and angle of the kidney<sup>3</sup>. The urologist can maneuver effectively, without having to put excessive torque on the nephroscope. However, upper pole access comes with a higher and more ominous rate of complications. When the access is above the 12<sup>th</sup> rib, there is an approximate 10% risk of chest complications. With access above the 11<sup>th</sup> rib, it may be as high as 25%<sup>4</sup>.

These post-PCNL pulmonary complications can include pneumothorax, hydrothorax, and hemothorax as well as nephro-pleural fistula. These can arise due to the proximity of the access tract to the diaphragm and these are also attributed to the use of copious amounts of irrigation fluid which can result in pulmonary congestion and edema<sup>3</sup>. There is paucity of available literature on the post-PCNL pulmonary complications. It requires scrupulous teamwork (anesthesia and surgical teams), to avoid such mishaps. One such technique is employed by the anesthetists intra-operatively, by lowering the tidal volume. This can help minimize the risk of lung injury during supra 12<sup>th</sup> puncture.

In this study, we aimed to evaluate pulmonary complications after percutaneous nephrolithotomy by reducing tidal volume intra-operatively.

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## Methodology

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A retrospective chart review was performed following approval from the institutional ethical review committee. Data was recorded from the medical records of all adult patients who underwent PCNL for renal stone disease, during a period of one year (2019-2020).

A total of 113 patients were included in the study. The inclusion criteria comprised of adult patients with renal stone disease, who underwent PCNL via the supra-costal access technique during the one-year study period. Patients were excluded if they had repeat percutaneous nephrolithotomy, multiple punctures were required to gain access, no postoperative chest X-ray was available, or the medical records were incomplete.

A proforma was designed to record all patient specific demographics (age, gender, BMI, stone burden), and all post-operative pulmonary complications (pneumothorax, hydrothorax). The need for intervention (chest tube insertion, intubation, ICU admission) was also recorded. To protect the identity of patients, all medical record numbers were assigned a study code, and the original data was accessible only by the Primary Investigator. There was no interaction with any patients throughout the course of data collection or review.

All patients were divided into two groups according to the tidal volume recorded and mentioned in the anaesthesia records intra-operatively. The case group comprised of patients who underwent PCNL with low-tidal volume and the control group patients had PCNL with normal tidal volumes.

Data analysis was performed using SPSS version 26.0. Mean and Standard deviation were calculated for continuous variables like BMI, stone size and tidal volume. For quantitative variables mean  $\pm$  SD has been reported. Frequency and percentages

were calculated for all categorical data like gender and group status of the patient. Differences between the two groups were assessed by t-test or Mann Whitney U test for continuous variables. Chi-square or Fisher exact tests were applied for categorical parameters. P-value <0.05 was taken as statistically significant.

## Results

Over a period of one year (2019-2020), a total of 113 adult patients who presented to our center with upper pole urolithiasis, were included in the study. They were divided into two groups: PCNL with low

tidal volume (Cases; n=56), and patients undergoing PCNL with normal tidal volume (Controls; n=57). The mean age was 40.21 years. All procedures were performed in the prone position.

The Cases had more number of female patients (n=20), compared to the Control group. Both groups were comparable with respect to height, weight, and BMI; p-value was not significant for these parameters. The stone burden was also comparable between the two groups (average: 20.0 cm). The preoperative variables of the two groups are summarized in table 1.

**Table 1: Demographic & clinical characteristics of the patients among the study groups.**

Variables		Low Tidal Value (n=56)	Normal Tidal Value (n=57)	Total (n=113)	p-value
<b>Age</b>		41.9±13.9	43.4±14.9	42.6±14.4	0.518
<b>Height</b>		164.5±7.7	165±7.4	164.7±7.5	0.784
<b>Weight</b>		73.3±19.6	71.7±18.3	72.5±18.9	0.60
<b>BMI</b>		25.9±5.6	26.5±25.5	26.2±5.5	0.721
<b>Stone Size</b>		20.7±5.6	21±4.6	20.8±5.1	0.627
<b>Tidal Volume</b>		250.9±31.1	457±76.4	354.9±118.8	0.001*
<b>Intra Operative Respiratory Rate</b>		-	12.1±1.1	16.0±4.0	0.001*
<b>Minute Ventilation</b>		5.0±0.6	5.5±0.9	5.3±0.84	0.178
<b>Hospital Stay</b>		3.5±0.5	3.8±0.5	3.6±0.5	0.003*
<b>Lowest O<sub>2</sub> Saturation</b>		96.2±2.4	98.7±0.99	97.4±2.2	0.001*
<b>Operation Time</b>		114.6±58.7	115.8±52.4	115.2±55.3	0.601
<b>Gender</b>	Male	36(64.3)	45(78.9)	81(71.68)	0.08
	Female	20(35.7)	12(21.1)	32(28.3)	
<b>Stone Side</b>	Right	32(57.1)	44(77.2)	76(67.3)	0.028*
	Left	24(42.9)	13(22.8)	37(32.7)	
<b>Number of Punctures</b>	1	54(96.4)	52(91.2)	106(93.8)	0.25
	2	2(3.6)	5(8.8)	7(6.2)	
<b>Stone Location</b>	Upper Calyx	7(12.5)	14(24.6)	21(18.6)	0.023*
	Mid Calyx	4(7.1)	9(15.8)	13(11.5)	
	Lower Calyx	17(30.4)	6(10.5)	23(20.4)	
	Renal Pelvis	28(50)	28(49.1)	56(49.6)	
<b>Comorbid</b>	HTN	10(17.9)	2(3.5)	12(10.6)	0.06
	DM	3(5.4)	4(7)	7(6.2)	
	IHD	1(1.8)	0(0)	1(0.9)	
	None	42(75)	51(89.5)	93(82.3)	
<b>Stone clearance</b>	Yes	44(78.6)	46(80.7)	90(79.6)	0.77
	No	12(21.4)	11(19.3)	23(20.4)	
<b>DJ Stent</b>	Yes	25(44.6)	21(36.8)	46(40.7)	0.393

	No	31(55.4)	36(63.2)	67(59.3)	
<b>Nephrostomy</b>	Yes	40(71.4)	34(59.6)	74(65.3)	0.188
<b>Tube insertion</b>	No	16(28.6)	23(40.4)	39(34.3)	

Values are given as n(%) or mean±SD

\*p<0.05 is considered significant

Our data indicates that there were coincidentally, more patients with multiple co-morbidities, in the Cases (low tidal volume group), as shown in Table I. Single puncture was adequate to gain access in 96.4% of the Cases (n=54), and in 91.2% of the Controls (n=52). However, the rates of stone clearance were comparable between the two groups (Cases: 44%, Controls: 46%). DJ stent insertion was performed in 44.6% of the Cases (n=25), and 36.8% of the controls (n=21).

A comparison of the various post-operative complications was made between the two groups. No significant difference with respect to tidal volume was noted. Both groups had an almost similar incidence of post-operative pyrexia, bleeding, pulmonary effusion and uro-sepsis. The need for intervention (chest tube insertion, ICU admission) was also similar between the two groups, as demonstrated in table 2. Length of hospital stay also turned out to be similar between the two groups.

**Table 2: Comparison of post-PCNL complication rates between the two groups.**

Variables		Low Tidal Volume	Normal Tidal Volume	Total	p-value
<b>Complication post Op fever</b>	Yes	20(35.7)	12(21.1)	32(28.3)	0.084
	No	36(64.3)	45(78.9)	81(71.7)	
<b>Significant Bleeding</b>	Yes	10(17.9)	8(14)	18(15.9)	0.579
	No	46(82.1)	49(86)	95(84.1)	
<b>Pulmonary Effusion</b>	Yes	4(7.1)	5(8.8)	9(8)	0.74
	No	52(92.9)	52(91.2)	104(92)	
<b>Need of Chest Tube</b>	Yes	2(3.6)	2(3.5)	4(3.5)	0.986
	No	54(96.4)	55(96.5)	109(96.5)	
<b>Post Op ICU Admission</b>	Yes	1(1.8)	2(3.5)	3(2.7)	0.569
	No	55(98.2)	55(96.5)	110(97.3)	
<b>Uro Sepsis</b>	Yes	-	1(1.8)	1 (0.9)	0.319
	No	56(100)	56(98.2)	112(99.1)	

\*p<0.05 is considered significant

## Discussion

Percutaneous nephrolithotomy is the treatment of choice for large (> 2 cm) or complex kidney stones<sup>5</sup>. An upper calyceal access has many advantages- it provides clearer visualization of the renal pelvis, lower pole and the ureter, hence ensuring effective stone clearance. It also helps prevent the use of excessive, inadvertent rotational force on the kidney during stone fragmentation and removal; higher stone-free rate<sup>6</sup>.

Postoperative pulmonary complications are not only associated with high morbidity and mortality after noncardiac surgeries but also have a higher incidence than postoperative cardiovascular complications. Because of its proximity to the diaphragm, PCNL has a higher risk for postoperative pulmonary complications, especially when the procedure's approach is through the upper pole of the kidney.

In our study, the overall incidence of clinically significant postoperative pulmonary complications after percutaneous nephrolithotomy was 14%, as

compared to 32.5%, which was reported by Yu et al., from Korea, in 2016<sup>7</sup>. Furthermore, as the prone position during general anesthesia causes restricted chest expansion and compression of the abdomen, it is surely related to increased airway pressure, decreased pulmonary and thoracic compliance. Meticulous surgical and anesthetic management is therefore required to reduce postoperative pulmonary complications and improve perioperative outcomes. Among different techniques used by anesthetists intra-operatively, lowering down tidal volume can also help to minimize the risk of lung injury during supra 12<sup>th</sup> puncture<sup>8</sup>.

Therefore, in this study, we aimed to evaluate pulmonary complications after percutaneous nephrolithotomy by reducing tidal volume intra-operatively. The incidence of pulmonary complications occurring with supra-costal access for PCNL has been evaluated by many series, worldwide. Munver et al. compared 202 cases of infra- costal PCNL to 98 cases of supra-costal PCNL<sup>9</sup>. The thoracic complication rate for the supra-costal group was 7.1%.

Lojanapiwat et al. compared the rates of pulmonary complications between 294 infra-costal PCNL to 170 cases of supra-costal ones. The rate of hydrothorax was 1.4% for the infra-costal group, compared to 15.3% for the supra-costal group<sup>10</sup>. The rate of pulmonary complications in our series of only supra-costal access was 15.9%, which is comparable with the ones reported in these studies.

One unique aspect of our study is the PCNL puncture technique- We performed the procedure via a supra-costal puncture technique in all the subjects. Previously reported literature identified rates of intrathoracic complications closer to 10–15% with the supra-costal access, compared to 1.5–4.5% with the commoner subcostal access<sup>11</sup>. Some studies suggest that operative position may vary the risk of pleural injury, with caudal displacement of the kidney in a prone-flexed or supine position, making it easier to gain upper pole access without the use of a supra-costal puncture<sup>12</sup>.

A randomized clinical trial from Melbourne, Australia reported their findings about the effect of low intraoperative tidal volume, compared with conventional tidal volume, on decreasing postoperative pulmonary complications in patients undergoing major surgical procedures. They concluded that the rate of pulmonary complications within the first 7 postoperative days was 38% among those randomized to a strategy of mechanical ventilation with low tidal volume compared with 39% among those randomized to a strategy with conventional tidal volume, a difference that was not statistically significant<sup>13</sup>.

Previous series have reported an increase in the length of hospital stay owing to the post-operative pulmonary issues, which result in a higher rate of admission to the intensive care unit or re-admission, longer postoperative hospital stays leading to higher hospital care costs, higher morbidity especially in non-cardiothoracic or abdominal surgery<sup>14</sup>. In the present study, we found no significant difference between the two groups, and neither in the entire study population.

Based on extensive literature search, we found no studies assessing the effect of changes in tidal volume, on the incidence of post PCNL complications. We sought to do so by comparing these changes between two groups of demographically matches individuals. We found no significant difference between the two groups. Our study has certain limitations- we only evaluated supra-costal access tracts. In addition, it is a single center study, relatively smaller sample size and a retrospective design. Nevertheless, it is the first study of its kind, where we looked at a dependable way of minimizing post PCNL pulmonary complications.

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## Conclusion

This study concludes that there is no significant difference in terms of postoperative complications in patients who had reduction in tidal volumes during PCNL. Larger, multi-center studies should be considered to evaluate this cost-effective

method of reducing the incidence of post PCNL pulmonary complications.

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### Conflicts of Interest

The authors have declared that no competing interests exist.

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