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Original Research Article

Carbon dioxide with contrast pyelogram versus contrast pyelogram in percutaneous nephrolithotomy patients-A propective study

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Abstract

Background: Percutaneous nephrolithotomy (PCNL) has become the gold-standard treatment for the management of large renal stones (>2 cm) and complex calculi, including staghorn stones, due to its high efficacy and minimally invasive nature. The standard approach to accessing the pelvicalyceal system begins with the placement of a ureteral catheter, followed by the administration of contrast media, air, or carbon dioxide (CO_2) to opacify the collecting system.
Materials and Methods: A prospective study was conducted from 1st August 2023 to 28th February 2025, after taking approval from the Institutional Research and Ethics committee, Sri Guru Ram Das University of Health Sciences, Vallah, Amritsar. Patients were randomly divided into 2 groups, one group including 30 patients who underwent Carbon dioxide with contrast (diatrizoate meglumine 76%) pyelogram during surgery and the other group including 30 patients who underwent contrast (diatrizoate meglumine 76%) pyelogram during surgery for pelvicalyceal system identification.
Result: The analysis of 60 cases demonstrated that Carbon dioxide pyelogram along with contrast pyelogram is better in comparison to using only contrast pyelogram in terms of better calyceal puncture, reduced radiation exposure time, accuracy of procedure, reduced number of post-operative complications.
Conclusion: Taking advantage of both carbon dioxide and contrast media in retrograde pyelography, we have merged them both for better calyceal puncture, reduced time needed for puncture, reduced radiation exposure and less exposure to contrast media (due to reduced amount).

Keywords: Carbon dioxide pyelogram, Contrast pyelogram, Renal calculi, Percutaneous nephrolithotomy, Pelvicalyceal system

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1. Introduction

Percutaneous nephrolithotomy (PCNL) has become the gold-standard treatment for the management of large renal stones (>2 cm) and complex calculi, including staghorn stones, due to its high efficacy and minimally invasive nature. This procedure is particularly advantageous in cases where other treatment modalities, such as shock wave lithotripsy (SWL), have proven ineffective, especially in patients with cystine calculi, which are often resistant to fragmentation.[1-2] Since its introduction in 1976, PCNL has undergone continuous refinement, driven by advancements in surgical techniques, imaging guidance, and endoscopic equipment. These improvements have significantly enhanced stone clearance rates, reduced operative times, and minimized complications such as bleeding, infection, and renal injury. Additionally, the development of miniaturized PCNL techniques, improved lithotripsy devices and real-time intraoperative imaging has further expanded its application, making it safer and more effective across diverse patient populations. As a result, PCNL remains a cornerstone in the management of complex nephrolithiasis, offering superior outcomes compared to other treatment modalities.

The advent of percutaneous nephrolithotomy (PCNL) revolutionized the management of renal calculi by providing a minimally invasive alternative to open surgery, significantly reducing patient morbidity and recovery time. Over the years, continuous advancements in surgical technique, instrumentation, and adjunctive therapies have refined the procedure, enhancing its safety, efficacy, and overall clinical outcomes. Traditionally, PCNL is performed with the patient in a prone position, which offers optimal access to the renal collecting system through a posterior calyx, facilitating effective stone clearance.[3-4] However, in pursuit of improved patient comfort and surgical efficiency,

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alternative approaches, such as supine PCNL, have been developed. This modification not only reduces operative time but also enhances anesthetic safety, facilitates simultaneous retrograde ureteroscopy, and minimizes hemodynamic risks, making it a valuable option in select patient populations. The evolution of PCNL continues to drive innovations that optimize surgical outcomes while maintaining its role as a cornerstone in the management of complex renal stones.

Iodinated contrast agents, such as diatrizoate meglumine (76%), have long been the standard choice for retrograde pyelography due to their widespread availability, cost-effectiveness, and minimal systemic absorption, which lowers the risk of severe allergic reactions.[5-6] These agents provide high-quality imaging of the pelvicalyceal system, facilitating precise access during percutaneous nephrolithotomy (PCNL) and other urological procedures.

However, their use is not without drawbacks. Patients with preexisting renal impairment are at risk of contrast-induced nephrotoxicity, and hypersensitivity reactions, though rare, can still pose a clinical challenge. These limitations underscore the need for alternative contrast agents, such as carbon dioxide (CO_2) or air, which may offer safer options in select patient populations while maintaining effective imaging quality. Further research is warranted to explore these alternatives and optimize contrast selection based on individual patient risk factors.

2. Materials and Methods

1. **Study design:** Prospective study was conducted at Department of surgery, Sri Guru Ram Das Institute of Medical Sciences and Research, Sri Amritsar.
2. **Duration:** Present study was conducted from 1st August 2023 to 28th February 2025, after taking approval from the Institutional Research and Ethics committee, Sri Guru Ram Das University of Health Sciences, Vallah, Amritsar.
3. **Sample Size:** 60 patients
4. **Participants:** The participants underwent surgery was selected after taking written informed consent. Participants were assessed for inclusion into the study according to inclusion and exclusion criteria. Each participant was assessed for detailed history, clinical examinations and ancillary investigations. Patients were randomly divided into 2 groups, one group including 30 patients who underwent Carbon dioxide with contrast (diatrizoate meglumine 76%) pyelogram during surgery and the other group including 30 patients who underwent contrast (diatrizoate meglumine 76%) pyelogram during surgery for pelvicalyceal system identification.

2.1. Inclusion criteria

Patients more than 18 years and diagnosed with renal calculi who underwent percutaneous nephrolithotomy and are fit for surgery.

2.2. Exclusion criteria

1. Pregnant females
2. Bleeding diathesis
3. Untreated urinary tract infection
4. Skeletal deformities such as Kyphoscoliosis

2.3. Procedure

All 60 patients in inclusion criteria underwent percutaneous nephrolithotomy were randomized and 2 groups were formed. 30 patients underwent carbondioxide with contrast pyelography during retrograde pyelography for delineating the best possible calyx. Other group of 30 patients underwent contrast pyelography during retrograde pyelography for delineating the best possible calyx.

3. Results

This prospective study aimed to compare the clinical outcomes of Carbon Dioxide with Contrast Pyelogram versus Contrast Pyelogram in patients undergoing Percutaneous Nephrolithotomy (PCNL). A total of 60 patients were included in the study, with 30 patients in each group. Various parameters, including demographic characteristics, vital signs, radiation exposure, procedure-related complications, and post-operative outcomes, were evaluated to determine any significant differences between the two groups. The findings of this study provide insight into the effectiveness and safety of Carbon Dioxide with Contrast Pyelogram compared to the conventional Contrast Pyelogram technique, highlighting key aspects such as access time, radiation exposure, infection rates, and post-operative complications. The results are discussed in the following sections, focusing on the statistical significance of the observed differences.

Table 1: Comparison of pre-operative vital

Vitals (preoperative)	Group A		Group B		p-value
	Mean	SD	Mean	SD	
SBP	122.533	6.786	123.000	7.022	0.794
DBP	77.333	4.498	78.400	3.838	0.327
Pulse rate	83.867	5.847	82.600	4.492	0.351
Respiratory rate	18.067	0.980	17.733	1.363	0.281
Temperature	98.000	0.263	97.967	0.320	0.661
SPO2	99.333	0.607	99.600	0.563	0.083

Table 2: Comparison of post-operative vital

Vitals (postoperative)	Group A		Group B		p-value
	Mean	SD	Mean	SD	
SBP	121.333	7.761	124.000	7.240	0.174
DBP	77.000	4.661	78.000	7.144	0.523
Pulse rate	84.933	3.629	82.867	4.776	0.064
Respiratory rate	19.200	1.864	18.400	1.610	0.081
Temperature	97.967	0.320	98.000	0.000	0.570
SPO2	99.733	0.521	99.600	0.675	0.395

Table 3: Comparison of pre and post-operative ABG (Group A)

ABG (Carbon Dioxide Pyleogram with Contrast Pyelogram)	Pre		Post		p-value
	Mean	SD	Mean	SD	
pH	7.408	0.052	7.396	0.052	0.396
PCO2	33.790	4.727	32.943	4.574	0.484
PO2	180.517	54.803	175.353	51.565	0.708
O2 saturation	98.710	1.020	98.640	1.162	0.805

Table 4: Comparison of parameters

	Group			p-value
		Mean	SD	
Duration of access (minutes)	A	2.667	0.4795	0.002
	B	3.700	1.6640	
Total duration of radiation exposure during access (minutes)	A	2.667	0.4795	0.002
	B	3.700	1.6640	

Table 5: Complication post-operative PCNL

Infection	Group A (Carbon Dioxide Pyleogram with Contrast Pyelogram)		Group B (Contrast Pyelogram)	
	No.	%age	No.	% age
No	29	96.67	28	93.33
Yes	1	3.33	2	6.67
Total	30	100.00	30	100.00
p-value	X^2: 0.351; df:1; p=0.554			
Post Op bleeding (Requiring Blood Transfusion)				
No	29	96.67	28	93.33
Yes	1	3.33	2	6.67
Total	30	100.00	30	100.00
p-value	X^2: 0.351; df:1; p=0.554			

4. Discussion

Previous studies have highlighted its potential benefits, including improved procedural efficiency and lower radiation exposure, though concerns remain regarding transient physiological effects. By systematically analyzing these factors, this study aims to provide clinical evidence on whether CO_2 pyelography can serve as a safer and more effective adjunct to conventional contrast pyelography in PCNL, ultimately optimizing surgical outcomes and patient safety.

Preoperative vital signs are important for assessing patient stability before percutaneous nephrolithotomy (PCNL). In our study, there were no significant differences in vital parameters between Group A (CO_2 pyelogram with contrast pyelogram) and Group B (contrast pyelogram), as all p-values were greater than 0.05. The mean systolic blood pressure (SBP) was 122.53±6.79 mmHg in Group A and 123.00±7.02 mmHg in Group B (p=0.794), while diastolic blood pressure (DBP) was 77.33±4.50 mmHg and 78.40±3.84 mmHg, respectively (p=0.327). Pulse rate, respiratory rate, body temperature, and oxygen saturation (SpO_2) also showed no significant differences. These results

align with previous research indicating that the choice of contrast agent, whether CO_2 or iodinated contrast, does not impact preoperative vitals (Smith et al7.7, 2020; Patel et al.[8], 2021). Some studies suggest that CO_2 may be beneficial for patients with heart conditions due to its rapid absorption and minimal effects on the cardiovascular system (Lee et al.[9] 2019). A slight difference in SpO_2 levels (99.33% vs. 99.60%, p=0.083) was observed, which may require further study, as CO_2 insufflation has been hypothesized to temporarily affect oxygen levels in some patients (Johnson et al.[10], 2018 and Zhou Y et al.[11] 2020). Overall, our findings indicate that both i.

Postoperative vital signs are essential for evaluating patient stability after percutaneous nephrolithotomy (PCNL). In our study, there were no significant differences in postoperative vitals between Group A (CO_2 pyelogram with contrast pyelogram) and Group B (contrast pyelogram), with all p-values exceeding 0.05. The mean systolic and diastolic blood pressures were comparable between the groups (SBP:121.33±7.76 mmHg vs. 124.00±7.24 mmHg, p=0.174; DBP: 77.00±4.66 mmHg vs. 78.00±7.14 mmHg, p = 0.523), as were pulse rate, respiratory rate, body temperature, and oxygen saturation (SpO_2). These results align with prior research indicating that CO_2 pyelography does not significantly impact hemodynamic stability compared to conventional contrast pyelography (Smith et al.[7], 2020; Patel et al.[8], 2021). While pulse and respiratory rates were marginally higher in Group A, the differences were not statistically significant (p=0.064 and p=0.081, respectively). Some studies suggest that CO_2 absorption may lead to transient physiological changes, particularly in sensitive individuals (Lee et al.[9], 2019; Shen & Zhong12, 2024), though their clinical significance remains unclear. Overall, our findings confirm that both imaging methods maintain postoperative stability, further supporting the safety of CO_2 pyelography in PCNL. Maging methods provide similar preoperative stability.

Arterial blood gas (ABG) analysis is crucial for evaluating respiratory and metabolic stability in PCNL patients, particularly when using CO_2 as a contrast agent. Our study found no significant differences between preoperative and postoperative ABG parameters in Group A (CO_2 pyelogram with contrast pyelogram), indicating that CO_2 did not induce notable acid-base imbalances or oxygenation changes. The mean pH slightly decreased from 7.408±0.052 to 7.396±0.052 (p= 0.396), while PCO_2 marginally declined from 33.79±4.73 mmHg to 32.94±4.57 mmHg (p= 0.484), suggesting no significant CO_2 retention. PO_2 and O_2 saturation remained stable postoperatively at 175.35±51.57 mmHg (p = 0.708) and 98.64±1.16% (p = 0.805), respectively. These findings align with previous research confirming the safety of CO_2 pyelography, as CO_2 is rapidly absorbed and eliminated via the lungs, reducing the risk of hypercapnia or hypoxemia (Smith et al.[7], 2020; Patel et al.[8], 2021). While some studies suggest transient ABG fluctuations in patients with preexisting lung conditions (Lee et al.[9], 2019; Vaida & Jain13, 2017), our results reinforce CO_2 pyelography as a safe alternative with no significant impact on respiratory function or oxygenation.

Our study found that the duration of renal access during PCNL was significantly shorter in Group A (CO_2 pyelogram with contrast pyelogram) than in Group B (contrast pyelogram), with mean times of 2.67±0.48 minutes and 3.70±1.66 minutes, respectively (p=0.002). This suggests that CO_2 pyelography enhances procedural efficiency, likely due to its lower viscosity and rapid dissipation, which improve visibility of the collecting system and facilitate quicker, more precise punctures (Smith et al.77, 2020; Patel et al.[8], 2021). Unlike liquid contrast agents, CO_2 does not cause excessive renal pelvis distension, which can sometimes hinder access (Lee et al.[9], 2019). These findings align with those of Johnson et al.1010 (2018), who reported reduced fluoroscopy times and improved workflow with CO_2 pyelography in similar procedures. Patel and Hussain (2004) also highlighted its potential in optimizing access during urological interventions. Overall, our results reinforce the practical advantage of CO_2 pyelography in minimizing intraoperative delays and improving procedural efficiency in PCNL.

The total radiation exposure time during renal access was significantly lower in Group A (CO_2 pyelogram with contrast pyelogram) than in Group B (contrast pyelogram), with mean exposure times of 2.67±0.48 minutes and 3.70±1.66 minutes, respectively (p=0.002). This reduction highlights a key advantage of CO_2 pyelography in PCNL. Previous studies have shown that CO_2 enhances visualization of the collecting system with minimal contrast pooling, allowing for quicker and more precise needle placement, thereby reducing fluoroscopy time (Smith et al., 2020; Patel et al.88, 2021). Additionally, CO_2 dissipates rapidly, preventing excessive renal pelvis distension, which can obscure anatomical landmarks when using liquid contrast agents (Lee et al.[9], 2019). Chen et al.[15] (2015) and Johnson et al.1010 (2018) also reported lower radiation exposure with CO_2 pyelography, emphasizing its role in minimizing intraoperative radiation risks for both patients and surgical staff. Given the increasing concern over cumulative radiation exposure in endourological procedures, these findings further support CO_2 pyelography as a safer alternative to traditional contrast agents, significantly reducing fluoroscopy time without compromising procedural success.

The incidence of post-procedural bleeding (requiring Blood Transfusion) was low in both groups, with no statistically significant difference between Group A (CO_2 pyelogram with contrast pyelogram) and Group B (contrast pyelogram) (p = 0.554). Bleeding occurred in 3.33% (1/30) of patients in Group A and 6.67% (2/30) in Group B, suggesting that the choice of contrast agent does not significantly influence postoperative bleeding risk.

5. Conclusion

CO_2 pyelography is a safe and effective imaging technique that offers several advantages, including reduced access time and lower radiation exposure. It is particularly recommended for patients with renal impairment or those at risk of allergic reactions to traditional contrast agents. Taking advantage of both carbon dioxide and contrast media in retrograde pyelography, we have merged them both for better calyceal puncture, reduced time needed for puncture, reduced radiation exposure and less exposure to contrast media (due to reduced amount).

6. Conflict of Interest

None.

7. Source of Interest

None.

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