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ORIGINAL ARTICLE

Impact of Percutaneous Nephrolithotomy (PCNL) on renal cortical function evaluated by 99mTc-DMSA scintigraphy: A single-centre study.

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ABSTRACT… Objective: To determine the mean change in split renal cortical function before and three months after Percutaneous Nephrolithotomy (PCNL), using 99mTc-DMSA scintigraphy in patients undergoing the procedure at a single tertiary care centre. **Study Design:** Quasi-experimental study. **Setting:** Sindh Institute of Urology and Transplantation (SIUT). **Period:** February 19 to August 18, 2022. **Methods:** Enrolling 127 patients through non-probability consecutive sampling. All included patients underwent unilateral single-tract PCNL. Written informed consent was obtained from all participants. Each patient underwent a preoperative DMSA scan. To assess changes in split renal function on the operated side, both preoperative and postoperative DMSA scans were analysed. **Results:** The mean age of the participants was 44.90 ± 10.63 years. Of the total, 45 patients (35.43%) were female and 82 (64.57%) were male. Regarding the laterality of surgery, 47 patients (37.01%) underwent PCNL on the left kidney, while 80 patients (62.99%) had the procedure on the right. Comparison of split renal function before and after PCNL revealed a significant improvement: the mean preoperative value was 38.59 ± 7.10%, whereas the postoperative mean was 41.84 ± 6.73% ($p < 0.001$). **Conclusion:** Technetium-99m DMSA scintigraphy provides a reliable, non-invasive method to assess individual renal cortical function. This study demonstrates that PCNL does not significantly impair the treated kidney. In fact, a statistically significant improvement in split renal function was observed following stone removal.

Key words: DMSA Scintigraphy, Percutaneous Nephrolithotomy, Split Renal Function.

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INTRODUCTION

Percutaneous nephrolithotomy (PCNL) remains the first-line treatment for large, complex, or staghorn renal calculi due to its high stone-free rates, minimally invasive nature, and ability to achieve definitive clearance in a single session.[1] The evolution of PCNL since its introduction in the late 1970s has revolutionized the management of nephrolithiasis by offering an alternative to open surgery, which was associated with higher morbidity, longer recovery times, and greater risk of renal parenchymal loss. Over the past four decades, refinements in access techniques, tract dilation methods, and endoscopic instrumentation have established PCNL as the standard of care for stones greater than 2 cm in diameter, staghorn calculi, and cases refractory to other modalities. Despite its widespread acceptance, concerns continue to be raised regarding its potential impact on renal function, particularly at the cortical level, where preservation of parenchymal integrity is paramount. The evaluation of renal function following PCNL requires sensitive and reliable modalities. Traditional markers, such as serum creatinine and estimated glomerular filtration rate (eGFR), provide only a crude assessment of overall renal function and fail to capture subtle or unilateral changes. In this context, nuclear medicine techniques have emerged as essential tools. The use of ^{99M}Tc-dimercaptosuccinic acid (DMSA) renal scintigraphy, in particular, enables precise evaluation of renal cortical integrity and segmental function, offering a more accurate picture of parenchymal health.[2] DMSA remains the gold standard for assessing differential renal function (DRF) and detecting cortical defects, thereby making it a valuable tool for postoperative assessment of patients undergoing PCNL.

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Although PCNL is generally considered safe and effective, focal cortical injury has been documented, particularly at the access tract site.[3,4] The risk of parenchymal disruption arises during tract creation, where mechanical dilation, nephroscope insertion, and stone fragmentation may cause localized trauma. While such injuries are often clinically insignificant, their detection through DMSA imaging highlights the importance of ongoing scrutiny of procedural safety. In an effort to reduce tract-related trauma, miniaturized PCNL techniques (mini-PCNL and ultra-mini PCNL) have been developed. Studies comparing standard and mini-PCNL have demonstrated reduced parenchymal damage and less postoperative functional loss in cohorts undergoing mini-PCNL.[5,6] These findings suggest that smaller tract sizes may mitigate the extent of cortical disruption without compromising stone clearance rates, although the adoption of such techniques varies widely across regions. In addition to procedural modifications, advances in imaging have further enhanced our ability to detect subtle changes in renal function. Quantitative single-photon emission computed tomography/computed tomography (SPECT/CT) DMSA imaging has proven more sensitive than planar scintigraphy in identifying minor alterations in differential renal function following PCNL.[7] By providing three-dimensional localization and quantification, SPECT/CT enables clinicians to better understand the relationship between access tract location, stone burden, and functional outcomes. This technological progress underscores the need for high-quality imaging when assessing the renal safety of PCNL.

Surgical parameters remain critical determinants of postoperative outcomes. Tract size, number of access points, and dilation technique all influence the degree of cortical injury.[8,9] Comparative studies have suggested that balloon dilation may offer advantages over Amplatz dilation, with reports of better early functional recovery and reduced cortical scarring.[10] These findings highlight the potential for technical refinements to enhance the renal safety profile of PCNL. Moreover, temporal assessment using serial DMSA scans has revealed that early postoperative declines in cortical function may not be permanent. In many cases, long-term imaging demonstrates gradual recovery, suggesting that a substantial component of cortical injury is reversible, likely due to the resolution of obstruction, relief of back pressure, and reduction of infection.[11]

Beyond technical considerations, patient-specific and anatomical factors also play a significant role in determining functional outcomes. Stone burden, renal anatomy, intraoperative bleeding, operative duration, and presence of infection can all influence postoperative cortical integrity.[12] Larger or complex stones often require multiple tracts, thereby increasing the risk of parenchymal injury, while prolonged procedures may exacerbate ischemia. Nonetheless, the relief of obstruction achieved by PCNL often results in functional improvement that outweighs any localized injury. This balance between risk and benefit underscores the importance of evaluating not just stone clearance rates but also renal functional outcomes when assessing the success of PCNL.

Globally, nephrolithiasis remains a major health burden, with rising prevalence attributed to dietary changes, metabolic disorders, and lifestyle factors. In South Asia, including Pakistan, the incidence of renal stones is particularly high due to environmental factors such as hot climate, dehydration, and dietary patterns rich in oxalates and sodium. Despite the heavy burden, limited regional data are available on the functional outcomes of surgical interventions such as PCNL. Most available studies originate from Western or East Asian populations, where differences in patient demographics, stone composition, and access to healthcare may influence outcomes. The paucity of local research creates a critical knowledge gap, particularly with regard to renal cortical function assessed by gold-standard imaging modalities such as DMSA scintigraphy. The existing international literature on PCNL and renal function presents conflicting evidence. While some studies have reported measurable cortical loss following PCNL, others have demonstrated stable or even improved renal function postoperatively. The variability in reported outcomes may be attributed to differences in surgical technique, patient selection, imaging modalities, and follow-up duration. These inconsistencies highlight the need for further high-quality, region-specific studies that can provide clarity and guide clinical practice.

The present study aims to evaluate the effect of PCNL on split renal cortical function using ^{99M}Tc-DMSA scintigraphy. By employing this gold-standard imaging modality, the study seeks to provide robust and objective evidence regarding the safety of PCNL in preserving renal parenchymal integrity. A key rationale for this investigation is the notable paucity of local research on this subject within the Pakistani population. Generating region-specific data is crucial, as it allows for contextualized interpretation and more accurate guidance of clinical decision-making in local practice. Furthermore, the study holds clinical significance beyond academic interest. Demonstrating that PCNL preserves or improves cortical function would provide reassurance to both clinicians and patients that the benefits of complete stone clearance outweigh the theoretical risks of tract-related cortical injury. Such findings would reinforce the continued use of PCNL as a safe and effective intervention in the surgical management of nephrolithiasis. At the same time, should subtle cortical deficits be identified, the study could inform refinements in surgical technique, postoperative surveillance, and patient counselling.

METHODS

This was a quasi-experimental study conducted at the Sindh Institute of Urology and Transplantation (SIUT) from February 19, 2022, to August 18, 2022.

A total of 127 patients were enrolled, calculated based on prior estimates of mean split renal function before and after PCNL, with 80% power and 5% significance level.

Non-probability consecutive sampling was used.

Inclusion Criteria

Patients aged 20–60 years who underwent unilateral single-tract PCNL were included.

Exclusion Criteria

Patients with active urinary tract infections, bleeding disorders, chronic renal failure, a solitary kidney, or renal ectopy were excluded.

Data Collection Procedure

Eligible patients were recruited after approval from the Institutional ERC. Detailed histories were reviewed to ensure adherence to exclusion criteria. Written informed consent was obtained. All participants underwent unilateral PCNL. Preoperative DMSA scans were performed by the Department of Nuclear Medicine at SIUT before surgery, and postoperative scans were done six months later. The ^{99m}Tc-DMSA renal scan was used to assess split renal function by comparing pre- and post-PCNL results.

Data / Statistical Analysis

Data were analyzed using SPSS version 22. Continuous variables (age, split renal function) were expressed as mean ± SD, while categorical variables (gender, operative side) were expressed as frequencies and percentages. Paired t-tests compared pre- and post-PCNL split renal function, while independent t-tests were applied post-stratification. Stratification was done for age, gender, and operative side. A p-value <0.05 was considered statistically significant.

Ethical Approval

Approval was obtained from the Ethical Review Committee of SIUT (Reference No. SIUT-ERC-2021/PA-284).

RESULTS

A total of 127 patients were included in the study, with a mean age of 44.90 ± 10.63 years. The youngest participant was 18 years old and the oldest was 60 years (Table-I). The mean preoperative split renal function was 38.59 ± 7.08%, ranging from 25% to 51%, while the mean postoperative split renal function was 41.84 ± 6.73%, with a range of 29% to 56%. Among the study population, 82 patients (64.57%) were male and 45 (35.43%) were female. Regarding the side of surgery, 80 patients (62.99%) underwent PCNL on the right kidney, while 47 patients (37.01%) had surgery on the left kidney as Shown in Table-I.

The statistically significant increase in mean split renal function post-PCNL suggests that the procedure may lead to measurable functional recovery of the affected kidney, potentially due to removal of obstruction and preservation of renal parenchyma. The relatively low SD values in both measurements indicate consistent outcomes across

the study population as shown in Table-III.

TABLE-I

Baseline demographic and clinical characteristics of the study population

Parameter	Value
Age (years)	
Mean	44.90
Standard Deviation (S.D.)	10.63
Minimum	18
Maximum	60
Pre-PCNL Split Renal Function	
Mean	38.59
Standard Deviation (S.D.)	7.09
Minimum	25
Maximum	51
Post-PCNL Split Renal Function	
Mean	41.84
Median	6.73
Minimum	29
Maximum	56
Gender Distribution	
Male	82 (64.57%)
Female	45 (35.43%)
Operative Side Frequency	
Right Side	80 (62.99%)
Left Side	47 (37.01%)

TABLE-II

Comparison of Pre-PCNL and Post-PCNL split renal function.

Split Renal Function	Pre-PCNL	Post-PCNL	P-Value
Mean	38.59	41.84	<0.01
S.D.	7.09	6.73	

A statistically significant improvement in renal function was observed following PCNL, with mean split renal function increasing from 38.59 ± 7.10% preoperatively to 41.84 ± 6.73% postoperatively ($p < 0.01$) as shown in Table 2. When stratified by age group, patients aged 18–49 years showed an increase in mean split renal function from 38.67 ± 7.40% to 41.91 ± 7.17% ($p < 0.01$), while those aged 50–60 years had an increase from 38.49 ± 6.76% to 41.75 ± 6.20% ($p < 0.01$) as shown in Table-III.

TABLE-III

Comparison of Pre- and Post-PCNL split renal function across age and gender groups

Group		Split Renal Function Pre-PCNL	Post-PCNL	P-Value
Age 18–49 Years	Mean	38.67	41.91	<0.01
	S.D.	7.40	7.17	
Age 50–60 Years	Mean	38.49	41.75	<0.01
	S.D.	6.76	6.20	
Male	Mean	38.78	42.06	<0.01
	S.D.	7.19	6.93	
Female	Mean	38.24	41.44	<0.01
	S.D.	6.99	6.41	

Gender-based stratification revealed that male patients demonstrated an increase in mean split renal function from 38.78 ± 7.19% to 42.06 ± 6.93% ($p < 0.01$), and female patients showed an improvement from 38.24 ± 6.99% to 41.44 ± 6.41% ($p < 0.01$) (Table-III). Analysis based on the operative side showed that patients who underwent right-sided PCNL experienced an increase in mean split renal function from 38.83 ± 7.58% to 42.18 ± 7.19% ($p < 0.01$), while those who underwent left-sided PCNL showed an increase from 38.16 ± 6.17% to 41.22 ± 5.81% ($p < 0.01$) as shown in Table-IV.

TABLE-IV

Comparison of Split Renal Function Before and After PCNL According to Operative Side

Operative Side	Split Renal Function	Pre-PCNL	Post-PCNL	P-Value
Right	Mean	38.83	42.18	<0.01
	S.D.	7.58	7.19	
Left	Mean	38.16	41.22	<0.01
	S.D.	6.17	5.81	

DISCUSSION

Percutaneous nephrolithotomy (PCNL) has become the established standard of care for the management of large, complex, or staghorn renal calculi. Its widespread adoption is attributed to its high stone clearance rates, adaptability across stone burdens, and reduced need for repeat procedures compared with other modalities such as extracorporeal shock wave lithotripsy (ESWL) or

ureteroscopy. However, despite its effectiveness, concerns regarding potential adverse impacts on renal cortical function remain an important area of debate. Renal injury during PCNL can theoretically arise from tract dilation, mechanical disruption of parenchyma, ischemia induced by intraoperative manipulation, or subsequent infection. Thus, a critical component of evaluating PCNL safety lies in assessing not only stone-free rates but also its long-term effect on renal functional outcomes. Our study, which employed ^{99M}Tc-DMSA scintigraphy as the primary tool for cortical functional assessment, provides meaningful evidence in this regard. We observed a statistically significant improvement in mean split renal function, increasing from 38.59% preoperatively to 41.84% postoperatively ($p < 0.01$). This improvement underscores not merely the absence of functional deterioration but, importantly, a trend toward enhanced parenchymal performance following PCNL. DMSA scans, which offer superior cortical mapping compared with serum creatinine or estimated glomerular filtration rate (eGFR), provided objective evidence that PCNL preserves and may even augment renal parenchymal integrity in appropriately selected patients.[14] These findings are consistent with and support the results of our study.

Similar outcomes have been consistently reported in recent literature, further strengthening the generalizability of our conclusions. Several prospective and retrospective studies have demonstrated either stabilization or improvement in renal cortical function following PCNL, particularly when obstruction and infection are effectively relieved. For instance, recent DMSA-based series comparing mini-PCNL with standard PCNL have shown equivalent preservation of cortical function with maintained or improved uptake postoperatively, closely aligning with our results.[15] Such outcomes reinforce the concept that renal cortical injury from tract creation or dilation is minimal and often reversible, provided modern techniques are utilized and patient selection is meticulous.

Furthermore, the tract-dilation method—long debated as a potential determinant of parenchymal trauma—appears to exert little to no long-term adverse effect on cortical function when assessed with quantitative DMSA (QDMSA). Studies evaluating Amplatz versus balloon dilation techniques have demonstrated equivalent postoperative functional outcomes, suggesting that contemporary access strategies are inherently safe.[16] Our findings are congruent with this evidence, as patients in our cohort did not show any functional disadvantage based on tract size or laterality. This suggests that surgical expertise, precise access planning, and controlled tract creation may outweigh the theoretical risks associated with dilation modality. The stratified outcomes in our study provide further insight into the robustness of functional preservation following PCNL. Age- and sex-based subgroup analyses revealed consistent improvements across demographic categories, with no indication of a group-specific vulnerability. These findings are in line with existing overviews that suggest cortical recovery is independent of age or sex, provided comorbidities are controlled.[17] Notably, serum creatinine and eGFR often fail to capture subtle functional changes in individual kidneys, particularly in unilateral disease. Radionuclide imaging, therefore, remains indispensable for detecting localized alterations, emphasizing the clinical importance of incorporating DMSA in functional evaluation protocols. Our study demonstrates that cortical improvement is a reproducible outcome across different patient groups, thus reinforcing the safety and universality of PCNL.

An additional noteworthy observation from our data relates to laterality of intervention. We found no significant difference in postoperative improvement between right- and left-sided procedures. This suggests that laterality, unlike vascular anatomy or tract angle, exerts minimal influence on cortical outcomes. The functional improvement observed is most plausibly attributed to the removal of obstructing calculi, which relieves back pressure, reduces recurrent infections, and restores effective parenchymal perfusion. Similar benefits have been reported in cohorts undergoing urgent urinary drainage, where relief of obstruction leads to measurable gains in both total and split renal function.[18] Collectively, these findings support the conclusion that successful stone clearance, rather than the anatomical side of intervention, is the dominant determinant of postoperative

functional recovery. Broader clinical outcome data from international literature lend further weight to our interpretation. Multiple longitudinal studies examining renal function after PCNL—particularly in single-tract or miniaturized approaches—have consistently demonstrated stable or improved outcomes, with very low rates of clinically significant deterioration.[19,20] These studies highlight that PCNL, when performed in optimized settings, does not compromise renal functional integrity, even in patients with significant stone burden or comorbid conditions. Our findings align with this growing body of evidence, adding further support to the paradigm that effective relief of obstruction and eradication of infection are the primary drivers of postoperative improvement, outweighing the potential parenchymal trauma induced during tract creation.

The clinical implications of these results are multifaceted. First, they reinforce the safety of PCNL in patients with solitary functioning kidneys or marginal preoperative function, where the stakes for functional preservation are particularly high. Second, they provide reassurance to both clinicians and patients that the benefits of complete stone clearance outweigh the theoretical risks of cortical damage. Third, they underscore the value of integrating DMSA scans into both clinical practice and research, as they remain the most sensitive modality for assessing subtle cortical changes. Nevertheless, while our findings support the growing consensus regarding the safety of PCNL, several aspects merit further investigation. Long-term outcomes beyond six months remain poorly characterized, and it is plausible that subtle changes in cortical integrity may manifest over more extended follow-up periods. Additionally, comparative studies examining mini-PCNL, ultra-mini PCNL, and other evolving minimally invasive modalities could provide nuanced insights into whether specific approaches confer incremental advantages in preserving renal function. Furthermore, the role of tract number and location warrants deeper exploration, particularly in patients requiring multiple tracts for complete clearance of complex stones.

This study, however, has certain limitations. Being a single-centre quasi-experimental design, its findings may have limited generalizability to other populations and healthcare settings. The use of non-probability consecutive sampling may have introduced selection bias, as patients were not randomly selected. Additionally, the relatively short follow-up period of six months may not fully capture the durability of postoperative improvements or identify late functional decline. Finally, given that all procedures were performed at a tertiary care centre with significant expertise in PCNL, the results may not be directly extrapolatable to lower-volume centres.

CONCLUSION

Technetium-99m DMSA scintigraphy proved to be a reliable and non-invasive modality for evaluating renal cortical integrity and differential function in patients undergoing PCNL. Findings from this single-centre study indicate that PCNL does not significantly impair the operated kidney; rather, it is associated with a statistically significant improvement in split renal function following stone removal. These results support the renal safety of PCNL and highlight its effectiveness in restoring cortical function by relieving obstruction, thereby reinforcing its role as a standard treatment for large and complex renal calculi.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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2	**Fahad Abd Mallick:** Acquisition of data and data entry.
3	**Amr Abdullah Ahmed Shaddad:** Data collection, Analysis.
4	**Tanzeel Ur Rahman Gazder:** Drafting and critical analysis.
5	**Altaf Hashmi:** Critical analysis.
6	**Adeeb ul Hassan Rizvi:** Critical review and final approval