

Research Article

COMPENSATORY RENAL HYPERTROPHY AFTER NEPHRECTOMY: A CLINICO-FUNCTIONAL CORRELATION STUDY

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Abstract: **Introduction:** Compensatory renal hypertrophy (CRH) is an adaptive physiological response of the remaining kidney following unilateral nephrectomy, characterized by structural enlargement and functional enhancement. Understanding the relationship between morphological and functional changes is essential for predicting renal outcomes. **Objectives:** To evaluate compensatory renal hypertrophy after nephrectomy and to assess its correlation with renal functional parameters. **Methods:** This prospective observational study was conducted at a tertiary care center over a period of 18 months. A total of 60 adult patients undergoing unilateral nephrectomy were included. Renal size was assessed using ultrasonography and CT volumetry, while renal function was evaluated using serum urea and creatinine levels. Measurements were recorded preoperatively, and at 3 and 6 months postoperatively. Statistical analysis was performed using paired t-test and Pearson correlation. **Results:** The mean age of patients was 45.22 ± 16.06 years, with a slight female predominance (51.7%). Malignancy was the most common indication (40%). There was a significant improvement in serum urea (37.90 to 27.62 mg/dL) and serum creatinine (1.38 to 0.80 mg/dL) over 6 months ($p < 0.05$). The mean contralateral renal volume increased significantly from 99.80 cc preoperatively to 188.35 cc at 6 months. A positive correlation between renal hypertrophy and functional improvement was observed. **Conclusion:** Compensatory renal hypertrophy occurs rapidly after nephrectomy and is associated with significant improvement in renal function. The study demonstrates a strong clinico-functional correlation, indicating that structural enlargement of the remaining kidney generally reflects effective physiological adaptation.

Keywords: Compensatory renal hypertrophy, Nephrectomy, Renal function, Serum creatinine

INTRODUCTION

Compensatory renal hypertrophy (CRH) is a well-recognized adaptive response that occurs in the remaining kidney following unilateral nephrectomy. This physiological phenomenon involves an increase in renal size and function, enabling the solitary kidney to maintain overall homeostasis. The process is driven by a combination of cellular hypertrophy, hyperplasia, and hemodynamic alterations, including increased renal blood flow and glomerular filtration rate (GFR) in the residual kidney [1,2]. The underlying mechanisms of CRH are multifactorial and involve complex molecular pathways. Key contributors include activation of growth factors such as insulin-like growth factor-1 (IGF-1), transforming growth factor-beta (TGF- β), and epidermal growth factor (EGF), which stimulate tubular and glomerular cell growth [3]. Additionally, adaptive hyperfiltration occurs shortly after nephrectomy, characterized by increased single-nephron GFR, which plays a crucial role in maintaining total renal function but

may predispose to long-term glomerular injury [4]. Clinically, compensatory hypertrophy is observed in various scenarios, including living kidney donors, patients undergoing nephrectomy for renal tumors, trauma, or congenital anomalies such as unilateral renal agenesis. While CRH is generally considered beneficial, emerging evidence suggests that prolonged hyperfiltration and increased intraglomerular pressure may contribute to progressive renal damage, proteinuria, and eventual decline in renal function in some individuals [5]. The extent and rate of compensatory hypertrophy vary depending on several factors, including age, baseline renal function, presence of comorbidities (such as hypertension and diabetes), and the duration of follow-up. Pediatric populations often exhibit a more robust compensatory response compared to adults, likely due to greater nephron adaptability [6]. In contrast, older individuals or those with pre-existing renal impairment may demonstrate a limited adaptive capacity [7]. Radiological assessment, particularly using ultrasonography, computed tomography (CT), and

magnetic resonance imaging (MRI), plays a crucial role in evaluating renal size and structural changes post-nephrectomy. Functional assessment is typically performed using serum creatinine, estimated GFR (eGFR), and radionuclide renal scans, which help establish the clinico-functional correlation of CRH [8]. Despite extensive research, there remains variability in the reported relationship between morphological hypertrophy and functional outcomes. Some studies suggest a strong correlation between increased renal size and improved renal function, while others indicate that hypertrophy does not always equate to optimal functional compensation [8, 9]. This discrepancy highlights the need for further clinico-functional studies to better understand the adaptive mechanisms and their long-term implications.

AIMS & OBJECTIVES:

The present study aims to evaluate compensatory renal hypertrophy following nephrectomy and to correlate morphological changes with renal functional parameters.

METHODOLOGY

The present prospective observational study was carried out in the Department of General Surgery at Gandhi Medical College and Associated Hospitals, Bhopal, India, over a period of 18 months from May 2023 to October 2024. A total of 60 patients who underwent unilateral nephrectomy were included in the study. Patients with incomplete clinical data or lost to follow up were excluded.

Inclusion Criteria:

- Patients age ≥ 18 years, both genders
- Presence of a functionally adequate contralateral kidney
- Patients willing to participate and provide informed consent
- Availability for follow-up up to 6 months

Exclusion Criteria:

- Bilateral renal disease
- Pre-existing non functional kidney.
- Congenital anomalies of the kidney (e.g., solitary kidney)
- Previous renal surgery affecting the contralateral kidney

RESULTS

Majority of the participants (43.3%) were 41–60 year age group with mean age was 45.22 ± 16.06 years. Slight Female patients predominated (51.7%) was observed. Left nephrectomy was performed more (61.7%) often than right nephrectomy [Table: 1].

Table 1: Demographic profile of Study Participants (n = 60)

Variable	Frequency (n)	Percentage (%)
Age Group (years)	≤20	3 (5%)
	21–40	21 (35%)
	41–60	26 (43.3%)
	>60	10 (16.7%)
	Mean±SD	45.22±16.05

Prior to surgery, all patients underwent detailed clinical evaluation, laboratory investigations (including serum creatinine and blood urea), and radiological assessment using ultrasonography and, where indicated, CT imaging to evaluate renal morphology and baseline contralateral kidney size.

All patients underwent unilateral nephrectomy (open or laparoscopic), depending on clinical indication and surgeon expertise. Relevant operative details such as indication and side of nephrectomy were recorded.

Assessment of compensatory hypertrophy was performed using ultrasonography as the primary modality, with CT volumetry where available. Renal dimensions (length, width, thickness) were measured, and renal volume was calculated using the ellipsoid formula. Measurements were recorded at baseline (preoperative), 3 months, and 6 months postoperatively.

Renal function was evaluated using serum creatinine and blood urea levels, recorded at similar time intervals. These parameters were used to assess functional adaptation of the remaining kidney.

The primary outcome was the degree of compensatory hypertrophy (change in renal volume), while secondary outcomes included changes in renal function and their correlation with renal hypertrophy.

Patients were followed up at 3 months and 6 months postoperatively for clinical, biochemical, and radiological evaluation

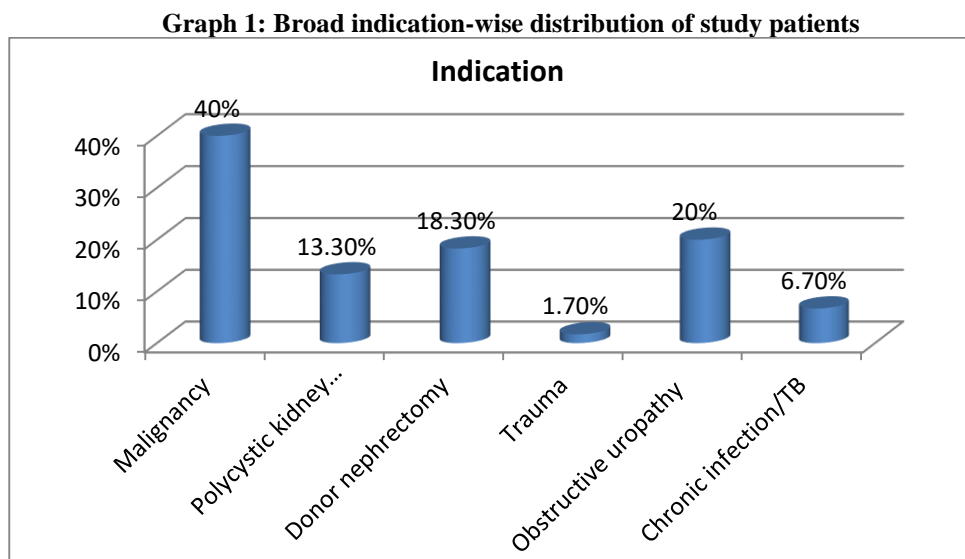
Ethical Considerations: The study was approved by the Institutional Ethics Committee (IEC)

Statistical analysis: The collected data was analysed using IBM SPSS software, ver.27.0

Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequency and percentage. Paired t-test was used to compare preoperative and postoperative values, and Pearson correlation coefficient was applied to assess the relationship between renal volume and functional parameters. A p-value < 0.05 was considered statistically significant.

Gender	Female	31	51.7%
	Male	29	48.3%
Site	Left nephrectomy	37	61.7%
	Right nephrectomy	23	38.3%

Broadly, the commonest category was malignancy (40%), followed by Obstructive uropathy (20%). Details indication was shown in graph: 1.



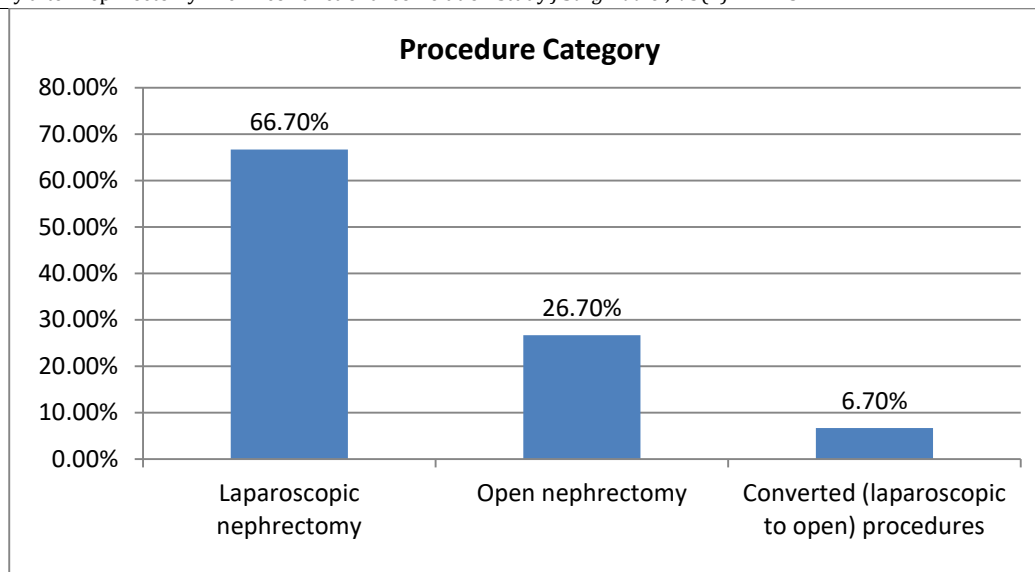
Mean serum urea levels improved from 37.90 mg/dL preoperatively to 32.43 mg/dL at 3 months and 27.62 mg/dL at 6 months. Mean serum creatinine decreased from 1.38 mg/dL to 1.10 mg/dL and further to 0.80 mg/dL. In the 60 patients with complete radiological values, mean contralateral renal volume increased from 99.80 cc preoperatively to 188.35 cc at 6 months, with a mean rise of 88.55 cc.

Table 2: Comparison of serial renal functional and radiological parameters (mean ± SD)

Parameter	Preoperat	3 months	6 months
	ive		
Serum urea (mg/dL)	37.90 ± 16.10	32.43 ± 10.50	27.62 ± 6.46
Serum creatinine (mg/dL)	1.38 ± 0.86	1.10 ± 0.41	0.80 ± 0.47
Contralateral renal volume (cc)	99.80 ± 23.42	—	188.35 ± 84.26

The majority of procedures were performed using a minimally invasive approach, with laparoscopic nephrectomy accounting for 66.7% of cases followed by Open nephrectomy (26.7%) and converted laparoscopic to open procedure were in 6.6% cases [Graph: 2].

Graph 2: Distribution of Surgical Procedures among study subjects



There is a statistically significant reduction in serum urea and serum creatinine levels at both 3 months and 6 months following nephrectomy, indicating improvement in renal function ($p < 0.05$). Additionally, a substantial increase in contralateral renal volume is observed at 6 months, reflecting compensatory renal hypertrophy. Overall, the findings demonstrate significant functional and morphological adaptation of the remaining kidney after nephrectomy [Table: 3].

Table 3: Paired comparison of serial parameters

Comparison		Mean difference	t value	p value
Pre-op vs 3 months urea	0	5.465	3.003	.0039
Pre-op vs 6 months urea	0	10.273	5.144	.213
Pre-op vs 3 months creatinine	0	0.28	2.974	.0042
Pre-op vs 6 months creatinine	0	0.572	4.641	.977
Pre-op vs 6 months renal volume	8	88.55	-8.505	.003

The recorded outcome variable ranged from 0.100 to 0.308, with a mean of 0.180 ± 0.060 . Most patients were clustered between 0.10 and 0.24 [Table: 4].

Table 4: Distribution of final outcome values

Outcome band	Frequency (N)	Percentage (%)
0.10–0.14	24	40.0
0.15–0.19	8	13.3
0.20–0.24	21	35.0
≥ 0.25	7	11.7

DISCUSSION

In this study, the majority of patients belonged to the 41–60 years age group with a slight female predominance. Similar demographic distributions have been reported in Yan Y et al [3] and Agrawal S, et al [10], where middle-aged individuals constitute the bulk of nephrectomy cases due to higher incidence of renal malignancies and obstructive pathologies. The predominance of left-sided nephrectomy observed in our study is also consistent with clinical trends, often attributed to anatomical and pathological considerations.

Malignancy emerged as the most common indication for nephrectomy, followed by obstructive uropathy. These finding aligns with Patel et al [11] and Sharma et al [12], where renal tumors remain the leading cause for nephrectomy, especially in adult populations.

A key observation in this study is the significant reduction in serum urea and creatinine levels at both 3 and 6 months postoperatively. This indicates effective functional compensation by the remaining kidney. These findings are in agreement with studies by Lee YP et al [4] and Naveen et al [13], demonstrated improved renal function following compensatory hypertrophy in renal

transplant recipients, and sustained functional adaptation after donor nephrectomy.

The marked increase in contralateral renal volume observed in our study reflects robust compensatory hypertrophy. Comparable findings have been reported by Lenihan CR et al [9] and Singh et al [14], observed a significant increase in renal size following nephrectomy, with compensatory hypertrophy occurring as early as 3 months post-surgery. The magnitude of hypertrophy further supports the concept that structural enlargement is a key component of renal adaptation.

Importantly, the study demonstrated a statistically significant correlation between morphological (renal volume) and functional (serum urea and creatinine) parameters. This supports the notion that increased renal size is generally associated with improved renal function. However, previous literature by Denic A et al [8] and Sharma et al [12] indicates that this relationship may not always be linear. This emphasized that structural hypertrophy does not invariably translate into optimal functional outcomes, particularly in older individuals or those with comorbidities.

The early improvement in renal function observed in our study contrasts with some longitudinal studies where functional recovery lags behind structural changes. Indian studies suggest that preserved baseline renal reserve and absence of comorbidities contribute to better functional outcomes in the early postoperative period [13, 15]. However, the relatively short follow-up period of 6 months in the present study may explain the absence of such adverse outcomes.

The predominance of minimally invasive surgical approaches, particularly laparoscopic nephrectomy, reflects current surgical practices. Minimally invasive techniques are associated with reduced perioperative morbidity and faster recovery, although their direct impact on compensatory hypertrophy remains unclear.

Limitations

Despite its strengths, the study has certain limitations. The sample size was relatively small, and the follow-up period was limited to 6 months, which may not capture long-term functional decline or hyperfiltration-related complications. Additionally, more sensitive measures such as estimated GFR or radionuclide scans were not utilized.

CONCLUSION

The present study confirms that compensatory renal hypertrophy is a robust and efficient adaptive response following unilateral nephrectomy. A significant increase in contralateral renal volume was observed within six months, paralleled by meaningful improvement in renal function, as evidenced by reductions in serum urea and creatinine levels. These findings underscore that the remaining kidney undergoes both structural and

functional adaptation to preserve overall renal homeostasis. Moreover, the positive correlation between renal enlargement and functional gain indicates that morphological changes are closely linked to effective physiological compensation. The early onset of these adaptations further highlights the kidney's rapid and dynamic capacity to respond, particularly in individuals with well-preserved baseline renal function.

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