Original Research Article

Study of Renal Volume and Functional Changes in Unilateral Nephrectomy –Our Institutional Experience

Mahesh Borikar[1], Bala Murali Krishna Patibandla[2*], Ch Vishwajith Reddy[3], Mallipeddi Partha Sri[4], Arvind Kumar Prabhat[5], Subbarao Chodisetti[6]

[1]Senior Resident, Department of Urology, Government Medical College and Super Speciality Hospital, Nagpur, Maharashtra, India
[2]Assistant Professor, Department of Urology, Dr Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Chinna Avutapalli, Gannavaram, Vijayawada, Andhra Pradesh, India
[3]3Rd year Urology Resident, Department of Urology, Dr Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Chinna Avutapalli, Gannavaram, Vijayawada, Andhra Pradesh, India
[4]2nd year Urology Resident, Department of Urology, Dr Pinnamaneni Siddhartha Institute of medical sciences and research foundation Chinna Avutapalli, Gannavaram, Vijayawada, Andhra Pradesh, India
[5]Professor, Department of Urology, Andhra Medical College, Visakhapatnam, Andhra Pradesh, India
[6]Professor, Department of Urology, Andhra Medical College, Visakhapatnam, Andhra Pradesh, India

Received: 11-11-2021 / Revised: 21-12-2021 / Accepted: 13-01-2022

Abstract

Introduction: A nephrectomy is the surgical removal of a kidney, performed to treat a number of kidney diseases including kidney cancer. It is also done to remove a normal healthy kidney from a living or deceased donor, which is part of a kidney transplant procedure. Both size and functions, primarily glomerular filtration rate (GFR) and renal plasma flow (RPF), increase almost immediately following unilateral nephrectomy. **Aim:** To determine short term differences in contralateral renal function and volume in unilateral nephrectomy patients in our institution. **Material and Methods:** This is a prospective study, Observational and cross-sectional study of all patients who undergo nephrectomy for renal transplantation, malignancy and other renal diseases at Tertiary Care Teaching Hospital over a period 1 year. A total of 62 patients who undergo open or laparoscopic nephrectomy have been assessed during the study period. The detailed history of all patients has been recorded. **Results:** We evaluated a total of 62 patients who underwent nephrectomy for various reasons. In all types of nephrectomy, groups post nephrectomy improvement in GFR and kidney volume to a varying extent was noted. When compared to the other two groups donor nephrectomy group is showing higher postoperative GFR with kidney volume and more improvement as compared to their preoperative values. The mean difference is shown in the table for each nephrectomy group, and for each group, it has a p-value <0.05. Similarly, for RPV improvement donor nephrectomy group shows the highest mean difference, and the diseased nephrectomy group shows the lowest mean difference. The difference in means of all nephrectomy is significant and has p-value <0.05. **Conclusion:** The DTPA-GFR and RPV of contralateral kidney increased steadily after surgery in all nephrectomised groups. Difference in functional and volumetric outcome after unilateral nephrectomy, can be arranged in decreasing order as donor nephrectomy group, radical nephrectomy group and then diseased nephrectomy group. The change in RPV and GFR of contralateral kidney after nephrectomy will help to predict compensatory response in healthy as well as co-morbid patients.

Keywords: Nephrectomy, Renal Volume, Glomerular filtration rate

Introduction

A nephrectomy is the surgical removal of a kidney, performed to treat a number of kidney diseases including kidney cancer. It is also done to remove a normal healthy kidney from a living or deceased donor, which is part of a kidney transplant procedure[1]. Nowadays, nephrectomy most commonly performed after malignancy, trauma, and transplantation. Live donor renal transplantation is the treatment of choice for patients with end-stage renal disease. Patients undergoing nephrectomy for renal malignancies increased due to incidental detection of renal masses by imaging. Nephrectomy also performed for irreversibly damaged kidney after chronic infection, obstruction, calculus disease, pyelonephritis, and dysplasia of kidneys[2].

The surgical removal of a normal kidney shows dramatic changes in the remaining kidney. Both size and functions, primarily glomerular filtration rate (GFR) and renal plasma flow (RPF), increase almost immediately following unilateral nephrectomy[3].

After nephrectomy, the remaining kidney undergoes compensatory adaptation, and its total glomerular filtration rate (GFR) increases by 70% of the preoperative value within 8 to 12 weeks[4]. GFR is generally accepted as an optimal test for the overall assessment of renal function. It was observed that although the remaining kidney does continue to function normaly, nevertheless, it undergoes self-mutilation in the form of glomerulosclerosis and interstitial injury[5].

Multiple autopsy studies indicated that kidney volume strongly correlates with the number of functioning nephrons[6]. In terms of donor nephrectomy, kidney volume directly corresponds with renal function in living donors and affects post-transplantation graft outcomes; and CT measured parenchyma strongly correlates with differential renal function on a nuclear renal scan for normal or

*Correspondence
Dr. Bala Murali Krishna Patibandla
Assistant Professor, Department of Urology, Dr Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Chinna Avutapalli, Gannavaram, Vijayawada, Andhra Pradesh, India.
E-mail: patibandlabalu@gmail.com

chronically obstructed kidneys[7]. Also, a significant correlation was identified between preoperative and postoperative kidney volume and their respective GFR after unilateral nephrectomy[8]. In addition, studies reported that preoperative kidney volume in donor patients can be a predictor of delayed renal function measured 6 months after surgery[9].

To identify factors determining the risk of renal failure after unilateral nephrectomy, it is necessary to correctly estimate the function and volume of each of the kidneys before and after surgery. In previous studies, the GFR of each kidney in binephric individuals was expressed as half of the corresponding two-kidney value[10]. However, this method does not accurately reflect the individual function of each of the kidneys because creatinine clearance determines the total GFR rather than the individual kidney function.The Tc-99m DTPA scan has been validated and accepted as a method for determining the GFR as a measure of both the overall renal function and the individual function of each of the kidneys[11].

So, we want to evaluate changes in the postoperative glomerular filtration rate (GFR) and kidney volume after nephrectomy in order to understand the relation between these two factors.

Material and Methods

This is a prospective study, Observational and cross-sectional study of all patients who undergo nephrectomy for renal transplantation, malignancy and other renal diseases at Tertiary care Teaching Hospital over a period 1 year. A total of 62 patients who undergo open or laparoscopic nephrectomy have been assessed during the study period. The detailed history of all patients has been recorded.

Inclusion Criteria

- All patients aged 18-80 yrs with RCC and urothelial tumors underwent either open or laparoscopic radical nephrectomy.
- All living kidney donors aged 18-55 yrs operated during the study period.
- All patients aged 18-80 yrs underwent either simple or subcapsular nephrectomy for various benign and infective aetiologies

Exclusion Criteria

Patients with an abnormal contralateral radiological kidney, solitary kidney or synchronous RCC, patients with metastatic or locally advanced cancer at RN (pT4/N1–2), previous surgery for RCC and pre-existing severe renal insufficiency (defined as an eGFR of <30 mL/min/1.73 m^2) were excluded. All marginal kidney donors with age>55yrs, GFR<80ml/min, hypertension and diabetes.

All patients evaluated with non-contrast computed tomography (NCCT) scan and DTPA scan pre-operatively and one month post operatively. The renal parenchymal volume can be calculated by ellipsoid formula as volume = length (average of sagittal and coronal lengths) × width × depth × π/6. While in DTPA scan the estimated GFR is calculated. Both parameters will compare using appropriate software. Selected patients undergoing RN for solitary renal masses (RCC group), donor nephrectomy for renal transplantation and appropriate type of nephrectomy for various renal diseases were matched for age and gender to the most suitable group.

The GFR of the individual kidney was determined by Tc-99m DTPA scintigraphy before and after nephrectomy. While renal volume is calculated by Non-contrast CT scan with 128 slice 72 kW CT scan machine with 5 mm cut section, before and after nephrectomy.

Quantitative scans of Tc-99m DTPA uptake in the kidneys were taken using a gamma camera-based on Gates method. The patient was injected intravenously with 75- 150 MBq (5 mCi) Tc-99m DTPA, and the Gates analysis was performed 2–3 min after the tracer was injected. Regions of interest were assigned for each kidney and perirenal semilunar background region. Perfusion and dynamic images were obtained using the Symbia E dual head gamma camera. All GFR values were corrected on the basis of depth and normalized correction.

In calculating renal volume, linear renal dimensions (length, lateral diameter, anterior-posterior diameter) were measured. Renal length was calculated from axial slices by multiplying the slice thickness by the number of slices between the superior and inferior tips of the kidneys. The slice represented the greatest cross-sectional area for width and thickness measurements. Lateral diameter was measured from the lateral extent of the kidney to the renal sinus and antero posterior diameter was measured perpendicular to the lateral diameter. Renal volume was estimated from the linear dimensions using the ellipsoid formula. Same procedure has been repeated pre-and post-nephrectomy.

The ellipsoid formula to estimate renal volume = length ×lateral diameter ×anterior- posterior diameter ×π/6.

Statistical Analysis

All the data collected analysed through Microsoft excel 2007 software. Statistical data have been analysed through SPSS software version 26**.** The pre and postoperative renal volume and GFR values were compared using a paired t-test. Categorical variables were examined using a simple chi-square analysis**.** P value <0.05 was considered statistically significant.

Results

In the study group, more than 50% of the patients were between 41-60yrs age, and in the donor nephrectomy group, 75% were in that age. The mean age of patients is 45.08 ± 7.67 yrs, 52.07 ± 12.68 yrs, and 42.22 ± 13.02 yrs in donor nephrectomy group, radical nephrectomy group, and diseased nephrectomy group respectively.

Table 1: Distribution of Age group

Age	Donor nephrectomy	Radical Nephrectomy	Diseased Nephrectomy	Total
<20	0	0	1	01
20-40	4	3	18	25
40-60	8	6	17	31
>60	0	4	1	05
				62

The majority of the patients were between 41-60 yrs age in both donor nephrectomy group and diseased nephrectomy group. But in a radical nephrectomy group, an approximately equal proportion of patients were noted in both 40-60yrs and >60 yrs age groups. No patient was present in < 20 yrs and >60 yrs age group in the donor nephrectomy group. Only 1 patient was in less than 20 yrs age in a diseased nephrectomy group. No patient of age less than 20 yrs was presented with RCC in the study.

Table 2: Distribution of gender

Gender	Donor Nephrectomy	Radical Nephrectomy	Diseased Nephrectomy	Total
Male	4	10	15	29
Female	8	3	22	33
				62

In the study population, we are seeing a slight female predominance in total. As well in both donor nephrectomy group and diseased nephrectomy

group, female predominance is prominently present

Table 3: Surgery Wise Distribution

Operative Side	Donor Nephrectomy	Radical Nephrectomy	Diseased Nephrectomy	Total
Left	7	5	20	32
Right	5	8	17	30
				62

Donor nephrectomy was done in 12 patients, and radical nephrectomy was done in 13 patients. Simple or subcapsular nephrectomy was done for the remaining 37 patients. Hence in our study, major patient load came from a diseased nephrectomy group.

Table 4: Etiological Distribution

Surgery	Etiology		No. Of Patients
Donor Nephrectomy			12
Radical Nephrectomy	Renal Malignancy	13	13
Diseased Nephrectomy	TB	2	37
	PUJO	11	
	XGPN	6	
	EPN	5	
	Pyonephrosis	11	
	Angiomyolipoma	1	
	Renal Artery Thrombosis	1	

As we see in the above table, we evaluated a total of 62 patients who underwent nephrectomy for various reasons. In those, 12 were donor nephrectomy, 13 were having renal malignancy, and 37 diseased nephrectomies. In this 37 diseased nephrectomy, we got 2 tuberculosis patients, 11 pelviureteric junction obstruction, 6 xanthogranulomatous pyelonephritis, 5 emphysematous pyelonephritis, 11 pyonephrosis, 1 angiomyolipoma, and 1 renal artery thrombosis. In our study, two unusual nephrectomy we got, i.e., renal artery thrombus formation due to trauma and angiomyolipoma.

Table 5: Mean GFR Before and After Nephrectomy

Surgery	Pre-op GFR (ml/min)	Post-op GFR (ml/min)	Mean Difference	p-value
Donor Nephrectomy	54.42±3.47	79.17±4.82	24.75(45.5%)	<0.05
Radical Nephrectomy	46.44±6.65	62.99±6.83	16.55(35.6%)	<0.05
Diseased Nephrectomy	49.04±8.63	64.98±8.69	15.94(32.5%)	<0.05

In all types of nephrectomy, groups post nephrectomy improvement in GFR and kidney volume to a varying extent was noted. When compared to the other two groups donor nephrectomy group is showing higher postoperative GFR with kidney volume and more improvement as compared to their preoperative values. Similarly, the percentage increase in GFR of each nephrectomy group is shown in the table. The mean difference is shown in the table for each nephrectomy group, and for each group, it has a p-value <0.05.

Table 6: Mean RPV Before and After Nephrectomy

Surgery	Pre-op RPV (cm^3)	Post-op RPV (cm^3)	Mean Difference (cm^3)	p-value
Donor Nephrectomy	154.69±11.63	175.80±12.86	21.11(13.64%)	<0.05
Radical Nephrectomy	154.73±15.95	174.39±18.02	19.66(12.70%)	<0.05
Diseased Nephrectomy	148.62±16.56	165.27±18.8	16.65(11.70%).	<0.05

Similarly, for RPV improvement donor nephrectomy group shows the highest mean difference, and the diseased nephrectomy group shows the lowest mean difference. The percentage increase in each group of nephrectomy is shown in the table. The difference in means of all nephrectomy is significant and has p-value <0.05.

Discussion

This present prospective study was conducted to compare the renal function and RPV outcome following nephrectomy for different indications. We evaluated the outcome by comparing the remaining kidney GFR, both pre and post-operatively, using DTPA renogram, while RPV changes measured by NCCT KUB.

In the study group, more than half of the patients were between 41-60 yrs age. The mean age of living donors was 45.08 ± 7.67 years (range – years), with the majority of donors being between 41 and 60 years old. The ratio of male to female donors was 4:8. Renal function was normal in all patients. In the year 2014, according to the Indian transplant registry mean age of the donor was 35-49 yr. Miki N et al., in a similar study of 2013, demonstrated the mean age of donor as 59.1 yr. In our study, the mean age of the donor was 45.08 ± 7.67 yr, which almost similar to the mean age described in the Indian transplant registry[12].

The mean age for diseased nephrectomy in our study is 41.9 ± 13.02 yrs with major patient load in 40-60 yrs age group. Suraj Godara et al. in his study has mean age of diseased group 48.7 ± 5.5 yrs while in Funahashi et al. study, the mean age of study population is 62.3 ± 13.3 yrs[13,14]. In our study, in diseased group patients have been included with very variable age, ranging from 19 yrs to 70 yrs.

Emamian SA et al., reported mean RPV 146 cm^3 in the left kidney while 134 cm^3 in the right in 665 adult volunteers in one study[15]. In our study, the mean RPV comes for the left side is 152.65 ± 16.09 cm^3 and that for the right side, it comes to 149.78 ± 15.43 cm^3. Our sample size for left side kidney were 33 for left, and 29 for right, so due to small sample size the difference between left and right-side volume may not be that much significant. As like above study, there is no any data found which shows the difference in GFR according to side of kidney.

In present study, the average percentage increase in the GFR of the contralateral kidney in donor nephrectomy group is 45.5% compared to radical nephrectomy group (35.6%) and disease nephrectomy group (32.5%). Z. Chen et al.[16], in 2012 in his study showed a 22% increase in GFR post 1-month nephrectomy and 23.5% post 12 months nephrectomy in donor Nephrectomy group, and both values are not significantly different at 1 and 12 months. Kim et al., in 2010 also showed that mean change in GFR was significantly greater in the

donor nephrectomy group than in the disease nephrectomy group (11.1 ± 8.5ml/min vs. 5.6 ± 7.2ml/min, p<0.05)[17].

In the study population with advanced age, reduced pre-operative GFR was noted. This change in GFR with advanced age in present study population was similar to the general population. In the general population, the GFR decreases with age and begins to fall at the age of 40. After 50 years of age, the GFR declines more rapidly. The decline in GFR between the age of 35 and 55 years is approximately 1 ml/min/year, and it accelerates to approximately 1.4 ml/min/year beyond 55 years of age.

Considering the RPV, the highest increase in mean value found in the donor group (13.64%) as compared to radical (12.70%) and diseased groups (11.70%). Prassonpoulos et al. had inferred that the compensatory reaction in the remaining kidney occurs before surgery in patients with renal cell cancer because he found unaffected kidneys were 36% larger than the corresponding normal kidney in binephric individuals 1 month before nephrectomy[18]. In Yasuhito Funahashi et al. study, the mean RPV of group including all types of nephrectomy increases by 13.3 % after 1 week and stabilised to 9% after 6 months[19].

Conclusion

The DTPA-GFR and RPV of contralateral kidney increased steadily after surgery in all nephrectomised groups. Difference in functional and volumetric outcome after unilateral nephrectomy, can be arranged in decreasing order as donor nephrectomy group, radical nephrectomy group and then diseased nephrectomy group. The compensatory change in the GFR will help in predicting variation in GFR after nephrectomy, especially in elderly patients. The change in RPV of contralateral kidney helps to predict the surgical CKD in association with GFR data. The change in RPV and GFR of contralateral kidney after nephrectomy will help to predict compensatory response in healthy as well as co-morbid patients.

References

1. Drozdzik M, Domanski L, Rozanski J, Gorecka B. Functional evaluation of the remaining kidney in patients after unilateral nephrectomy. Scand J Urol Nephrol 2003;37:159–63.
2. Artur A Antoniewicz, Sławomir Poletajew, Andrzej Boro´wka, et al. Renal function and adaptive changes in patients after radical or partial nephrectomy. Int Urol Nephrol 2012;44:745–751.
3. Saxena AB, Myers BD, Derby G, Blouch KL, Yan J, Ho B et al. Adaptive hyperfiltration in the aging kidney after contralateral nephrectomy. Am J Physiol Renal Physiol 2006;291: F629–34.
4. Bieniasz M, Domagala P, Kwiatkowski A, et al. The assessment of residual kidney function after living donor nephrectomy. Transplant Proc. 2009;41(1):91-2.
5. Poggio ED, Hila S, Stephany B et al. Donor kidney volume and outcomes following live donor kidney transplantation. Am J Transplant 2006; 6: 616– 24.
6. Hugen CM, Polcari AJ, Farooq AV, Fitzgerald MP, Holt DR, Milner JE. Size does matter: donor renal volume predicts recipient function following live donor renal transplantation. J Urol 2011; 185: 605– 9.
7. Morrisroe SN, Su RR, Bae KT *et al*. Di#erential renal function estimation using computerized tomography based renal parenchymal volume measurement. J Urol 2010; 183: 2289– 93.
8. Funahashi Y, Hattori R, Yamamoto T, Kamihira O, Sassa N, Gotoh M. Relationship between renal parenchymal volume and single kidney glomerular "Filtration rate before and after unilateral nephrectomy. Urology 2011; 77: 1404– 8
9. Jeon HG, Lee SR, Joo DJ *et al*. Predictors of kidney volume change and delayed kidney function recovery after donor nephrectomy. J Urol 2010; 184: 1057– 63
10. Miki N. Hew, Dedan Opondo, Ernesto R. Cordeiro, Karlijn A.M.I. van Donselaar. The 1-year decline in estimated glomerular filtration rate (eGFR) after radical nephrectomy in patients with renal masses and matched living kidney donors is the same ; BJU Int 2014; 113: E49–E55.
11. Chen Z, Fang J, Li G, Et Al. Qi Compensatory Changes In The Retained Kidney After Nephrectomy In A Living Related Donor. Transplantation Proceedings 2012;44: 2901– 2905.
12. Kim, Hye & Chae, Sun-Young & Baek, Sora & Moon, Dae. Factors Affecting Changes in the Glomerular Filtration Rate after Unilateral Nephrectomy in Living Kidney Donors and Patients with Renal Disease. Nuclear Medicine and Molecular Imaging. 2010;44:69-74.
13. Yoshinori Shirasaki, Tomoyasu Tsushima, Takashi Saika, Et Al. Kidney Function After Nephrectomy For Renal Cell Carcinoma. Journal Of Urology 2004;64(1):43–47.
14. Shin HS, Chung BH, Lee SE, Kim WJ, Ha HI, Yang CW: Measurement Of Kidney Volume With Multidetector Computed Tomography Scanning In Young Korean. Yonsei Med J. 2009; 50:262-5
15. Roseman DA, Hwang SJ, Oyama,Manabe N, Chuang ML, O'Donnell CJ, Manning W J, Fox CS: Clinical Associations Of Total Kidney Volume: The Framingham Heart Study. Nephrol Dial Transplant 2017;32: 1344–1350.
16. Wang X, Vrtiska TJ, Avula RT, Walters LR, Chakkera HA, Kremers WK, Lerman LO, Rule AD : Age, Kidney Function, And Risk Factors Associate Differently With Cortical And Medullary Volumes Of The Kidney. Kidney Int 2014;85: 677–685.
17. Musab S. Hommos, Richard J. Glassock And Andrew D. Rule : Structural And Functional Changes In Human Kidneys With Healthy Aging : JASN October 2017, 28 (10) 2838-2844.
18. John EO, Igbinedion BO, Akhigbe AO. Comparative Sonographic Assessment Of Renal Dimensions And Clinicobiochemical Parameters Among Diabetic And Nondiabetic Adults In Benin City, Nigeria. J Med Trop 2018;20:17-23.
19. Grewal GS, Blake GM. Reference Data For51 Cr-EDTA Measurements Of The Glomerular Filtration Rate Derived From Live Kidney Donors. Nucl Med Commun 2005; 26: 61-65.

Conflict of Interest: Nil Source of support: Nil