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Comprehensive Renal Function Evaluation in Patients Treated for Synchronous Bilateral Wilms Tumor

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Abstract

Objectives—The purpose of this study was to perform a comprehensive assessment of long-term renal function in patients treated at our institution for synchronous bilateral Wilms tumor (BWT) and to determine the optimal method for estimating glomerular filtration rate (eGFR).

Methods—Surgical approach, adjuvant therapy, and pathology reports were reviewed for patients with at least six months follow-up from definitive surgery. eGFRs, as assessed by the Schwartz

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and Chronic Kidney Disease in Children (CKiD) formulas, were compared to measured GFR (mGFR) determined by ^{99m}Tc -DTPA scanning. Urine studies, including microalbumin, β -microglobulin, and FE_{Na} were also reviewed.

Results—Forty-two patients were identified. Of 36 living patients, 28 (77.8%) had greater than 6 months follow-up, with a median overall follow-up of 5.2 years (range: 1.4-13.4). The median mGFR was 97mL/min/1.73m², while the median eGFR_{Schwartz} and eGFR_{CKiD} were 103.3mL/min/1.73m² and 79.7mL/min/1.73m², respectively, ($p=0.13$ and $p=0.75$, compared to mGFR). Eleven (39.3%) patients had at least one abnormal urine study (microalbumin >30 $\mu\text{g/g}$ creatinine, $n=3$; β -2 microglobulin >133 $\mu\text{g/g}$ creatinine, $n=9$; FE_{Na} >1%, $n=4$).

Conclusions—In our series, few patients had an abnormally low GFR. Neither method for estimating GFR gave a significantly different result from measured GFR, suggesting that the Schwartz equation is adequate, although specific urine tests may be more sensitive for detecting subtle renal dysfunction.

Keywords

renal function; bilateral Wilms tumor; nephron-sparing surgery

Wilms tumor (WT) is the most common tumor of renal origin in childhood, affecting approximately 650 children in the United States each year [1, 2], with about 5% presenting with synchronous disease in both kidneys. These patients present a management challenge: obtaining local disease control, while maintaining good renal function. Renal function has, in the past, been evaluated by estimating the glomerular filtration rate (eGFR) based on anthropometric measurements and serum chemistry results. More recently other renal function studies, such as ^{99m}Tc -diethylene triamine pentaacetic acid (^{99m}Tc -DTPA) or iohexol clearance, have proven to be more accurate [3, 4]. These studies, however, have not been compared or evaluated to study the prevalence of chronic kidney disease in patients with bilateral Wilms tumor (BWT), as others have done for patients with unilateral WT [5]. In addition, some groups have reported additional studies to assess renal dysfunction, including clearance of β -2 microglobulin, fractional excretion of sodium (FE_{Na}), glucosuria, and microalbumin:creatinine ratio [6-9], although the role of these tests for identifying renal dysfunction in this patient population is poorly defined.

Historically, patients with BWT were treated with unilateral nephrectomy of the more involved kidney and contralateral partial nephrectomy or nephron sparing surgery (NSS). Recurrence in the remnant kidney, often necessitating its removal, resulted in the requirement for renal replacement therapy and ultimately kidney transplantation, and was the most frequent cause of renal failure in these patients, as reported by Ritchey and colleagues [10]. Several groups have subsequently reported excellent oncologic outcomes when BWT patients were treated with bilateral NSS, leading to a further decrease in nephron loss. This surgical approach is particularly relevant as these patients may be exposed to nephrotoxic chemotherapeutic agents and/or direct renal radiation to treat positive margins and/or diffuse anaplasia [11-16]. Giel and colleagues previously reported the results of renal function evaluation in a small series of patients with BWT [17] and we recently reported the oncologic outcomes of a larger cohort of patients [18]. We undertook the present study to

evaluate renal function in BWT patients after NSS, with the specific goal of comparing the calculation of GFR using technetium renal clearance studies to a comprehensive panel of renal function tests, urine chemistry studies, and different equations to estimate GFR

1. PATIENTS AND METHODS

1.1. Patient Population and Exclusions

Following approval by our institutional review board, we retrospectively identified all patients presenting with synchronous BWT who received the initial surgical management of their disease at St. Jude Children's Research Hospital between 2001 and 2014. Patients with metachronous lesions were excluded. Only patients with greater than six months of follow-up from definitive surgery performed at our institution for their disease were included. Patient demographics (age, gender, race, height, and weight at last follow-up appointment) and cancer-related history (chemotherapeutic agents used, radiation used, and tumor histology) were collected. Comprehensive renal studies included serum chemistries [magnesium, phosphorus, vitamin D levels, blood urea nitrogen (BUN), cystatin C, and creatinine], and urine chemistries (sodium, protein, creatinine, microalbumin, and β -2 microglobulin). Medications at last follow-up were also reviewed for the use of anti-hypertensive agents.

1.2. Definition of renal function

The estimated GFR (eGFR) was calculated using the Schwartz equation ($eGFR_{\text{Schwartz}}$) for children based on body length and serum creatinine, where creatinine clearance = $(k \times \text{height in cm}) / \text{serum creatinine}$, in which $k = 0.55$ for children older than 18 months, and $k = 0.45$ for children younger than 18 months [19]. The Counahan-Barratt equation ($eGFR_{\text{Counahan-Barratt}}$) for children is also based on body length, where creatinine clearance = $(0.38 \times \text{height in cm}) / \text{serum creatinine}$ [20]. The Chronic Kidney Disease in Children equation ($eGFR_{\text{CKiD}}$) is based on body length, serum cystatin C, BUN, and serum creatinine, where creatinine clearance = $39.1[\text{height (m)}/\text{serum creatinine (mg/dl)}]^{0.516} \times [1.8/\text{cystatin C (mg/L)}]^{0.294} \times [30/\text{BUN (mg/dl)}]^{0.169} \times [1.099]^{\text{male}} \times [\text{height (m)}/1.4]^{0.188}$ [19]. Pre-hypertension was defined as persistent (at least two measurements three months apart) systolic or diastolic blood pressure $\geq 90^{\text{th}}$ and $<95^{\text{th}}$ percentile adjusted for age and height, while hypertension was defined as persistent systolic or diastolic blood pressure $\geq 95^{\text{th}}$ percentile or the use of anti-hypertensive medication [21]. Total renal parenchymal volumes were assessed by a senior study radiologist (M.B.M.), using an ellipsoid volume formula of $\text{length} \times \text{width} \times \text{diameter} \times 0.523$ [22], and summing the volumes for the left and right kidney. The patient age was plotted against the total renal parenchymal volume, with the trend lines adapted from nomograms of total kidney volume adopted from Leung et al. [23].

1.3. Statistical analysis

Summary statistics estimated the prevalence of patient characteristics and events within specific categories. The Wilcoxon rank sum test was used to compare continuous variables between groups and Fisher's exact test for categorical variables between groups. Wilcoxon signed rank test was used to assess the change of eGFR per volume over time.

2. RESULTS

2.1. Patient Characteristics

Forty-two patients with synchronous BWT were identified. Renal function data were available for 36 (85.7%) surviving patients. Eight (22.2%) patients with follow-up duration shorter than six months from their last surgical resection were excluded from this analysis leaving 28 patients (Figure 1). The patient demographics and histology-directed therapy are summarized in Table 1. Thirteen (46.4%) were females. Twenty-five (89.3%) were Caucasian, while three (10.7%) were African-American. Twenty-four (85.7%) were diagnosed prior to four years of age, with the median age at diagnosis being 2.4 (range: 0.3-10.8) years. Five patients had associated anomalies – Beckwith-Wiedemann Syndrome (BWS) – one (3.6%) patient; cryptorchidism – three (10.7%) patients; hemihypertrophy – one (3.6%) patient. One other patient subsequently developed a medulloblastoma as a second malignancy. No patient had Wilms tumor, aniridia, genitourinary anomalies, and mental retardation (WAGR) syndrome. Four (14.3%) patients presented with pulmonary metastatic disease; no patients had other visceral metastases.

Our institution started using a National Institute of Standards and Technology (NIST)-traceable creatinine standard in January 2005. The median pre-operative $eGFR_{\text{Schwartz}}$ of the 25 patients assessed after 2004 was 108.9 (range: 75.9-186.4) mL/min/1.73m², with six (24.0%) of these patients having hypertension at the time of diagnosis. Twenty-six (92.9%) patients underwent bilateral nephron-sparing surgery (NSS), while the other two (7.1%) underwent unilateral nephrectomy with contralateral NSS. Seven (26.9%) patients initially treated with bilateral NSS, required a repeat NSS, with one requiring a third partial nephrectomy. Local tumor staging at initial presentation is provided in Table 1. Most (60.7%) kidneys were local stage 1. Four patients received carboplatin-based therapy, while one received ifosfamide as part of the chemotherapeutic regimen. No patient in this cohort was treated with cisplatin. Fourteen (50.0%) patients received flank (n=13) or whole abdomen (n=1) radiation (ranging from 10.5-10.8 Gray).

2.2. Time to follow-up, renal function, and renal volume

The median time of follow-up was 5.2 (range: 1.4-13.6) years from the date of diagnosis and 4.2 (range: 0.6-13.1) years from the last surgical resection. Four patients had greater than eight years of follow-up from their last surgical resection. Renal function variables for all patients at last follow-up are summarized in Table 2. Nine (32.1%) were taking anti-hypertensive medications (Table 2), with two of these taking anti-hypertensive medication pre-operatively. An additional six (21.4%) patients were noted to have persistent pre-hypertension. Eight (28.6%) patients had persistent 1+ proteinuria by urinalysis. The median estimated GFR_{Schwartz} for all patients was 103.3 (range: 67.8-159.5) mL/min/1.73m² at last follow-up, while the median estimated $GFR_{\text{Counahan-Barratt}}$ was 103.5 (range: 70.6-163.4) mL/min/1.73m². The median estimated GFR_{Schwartz} at last follow-up for the 25 patients with pre-operative NIST-traceable creatinine standards was 105.6 (range: 67.8-159.5) mL/min/1.73m². For these 25 patients, there was a statistically significant change of -7.74 mL/min/1.73m² ($p=0.0394$) from pre-operative assessment to last follow-up (Table 3).

Total renal parenchymal volume was assessed for all 28 patients in the study, one of whom did not have immediate post-operative imaging, and plotted using an adapted nomogram by Leung and colleagues (Figure 2). The median calculated total renal parenchymal volume at the first post-operative imaging time point of the 27 patients was 93.7 (range: 10.0-187.6) cm³, while the volume at last follow-up was 139.0 (range: 14.9-363.5) cm³. The median volume change of +28.8 (range: -129.7-277.5) cm³ was statistically significant ($p=0.003$). Based on the adapted nomogram, 13 patients crossed the trend lines shown, ten of whom (76.9%) showed a decrease in percentile. Eleven patients had a total kidney volume greater than the 97th percentile adjusted for age in the immediate post-operative imaging, while only six of these maintained the volume greater than the 97th percentile at last follow-up.

2.3. Comprehensive renal function assessment

Twenty-five patients underwent renal function testing with ^{99m}Tc-DTPA to assess renal clearance, with a median mGFR of 97 (range: 56-155) mL/min/1.73m². Patients with cystatin C and urine electrolytes were compared to patients without these studies to identify differences between these groups. Patients with cystatin C and urine electrolytes were younger ($p=0.0014$), but were otherwise not different based on the factors identified in Table 1. The median eGFR_{Schwartz} for all 28 patients was 103.3 (range: 67.8-159.5) mL/min/1.73m², with no significant difference ($p=0.130$) when compared to the mGFR. The eGFR_{CKiD} for the 17 patients with available data was 79.7 (range: 58.3-180.7) mL/min/1.73m², with no significant difference ($p=0.753$) when compared to the mGFR for these patients. Eleven (44.0%) of these patients had a mGFR < 90 mL/min/1.73m², with one patient having a mGFR < 60 mL/min/1.73m² (56 mL/min/1.73m²). Of the 11 patients with a decreased mGFR, seven had a persistently decreased mGFR by repeat ^{99m}Tc-DTPA. Of these 25 patients, only three had persistent 1+ proteinuria by urinalysis, only one of whom had a mGFR of < 90 mL/min/1.73m² (although this was an isolated measurement and repeat is required). Three patients with persistently decreased ^{99m}Tc-DTPA < 90 mL/min/1.73m² were on anti-hypertensive medications at last follow-up.

2.4. Subgroup with cystatin C and urine studies

Seventeen patients had serum cystatin C measurements, eight of whom (47.1%) had an eGFR_{CKiD} < 75 mL/min/1.73m². Only one patient had an eGFR_{CKiD} < 60 mL/min/1.73m². Six of these eight patients also had ^{99m}Tc-DTPA values < 75 mL/min/1.73m². Repeat measurements were not available to estimate eGFR_{CKiD} to categorize these patients with as having chronic kidney disease. Sixteen of the 17 patients with the comprehensive renal function work-up had a median urine β -2 microglobulin of 154 (range: 66-662) μ g/g of creatinine, with nine (56.3%) patients having an abnormal (greater than 133 μ g/g creatinine) result. Four of the nine patients with abnormal results had ^{99m}Tc-DTPA persistently < 90 mL/min/1.73m². One of the nine patients was also found to have 1+ glucose by dipstick urinalysis. Three of these 17 patients with urine chemistry studies had an abnormally increased microalbumin to creatinine ratio (>30 μ g microalbumin per g of creatinine in urine), all three of whom had abnormal (1+ proteinuria) dipstick urinalysis and normal mGFR by ^{99m}Tc-DTPA.

2.5. Adjuvant therapy and nephrotoxicity

Fourteen patients received flank or whole abdomen radiation (n=14), carboplatin (n=4), or ifosfamide (n=1). Seven of these patients were found to have a mGFR by ^{99m}Tc -DTPA <90 mL/min/1.73m², five of which had been persistently decreased for more than three months. Two patients had persistent 1+ proteinuria by dipstick urinalysis. Nine (64.3%) patients had comprehensive urine chemistry studies, three of whom were found to have both elevated β -2 microglobulin and $\text{FE}_{\text{Na}} <1\%$. Five (35.7%) of the 14 patients who received nephrotoxic adjuvant therapy were taking single agent, anti-hypertensive therapy which controlled their blood pressure, while an additional patient was noted to be persistently pre-hypertensive.

In comparison, of the 14 patients who did not receive nephrotoxic adjuvant therapy, eight had urine chemistry studies, and 11 had mGFR by ^{99m}Tc -DTPA. Of the 8 with urine chemistry studies, 6 had elevated β -2 microglobulin, while two had an elevated microalbumin to creatinine ratio. Two patients had persistent 1+ proteinuria by urine dipstick. Of the eight patients with mGFR by ^{99m}Tc -DTPA, four had mGFR <90 mL/min/1.73m², of which only two were persistently decreased.

2.6. Patient with associated anomalies

Of the five patients with associated anomalies, one (20%) had both $\text{eGFR}_{\text{Schwartz}}$ of <90 mL/min/1.73m² and persistent 1+ proteinuria by urine dipstick. All three with cryptorchidism were taking anti-hypertensive medications at last follow-up, while only one was taking them pre-operatively.

3. DISCUSSION

This is the largest, single-institution comprehensive evaluation of renal function in patients with bilateral Wilms tumor who have undergone nephron-sparing surgery. While no patient has required renal transplantation or long-term hemodialysis, one third of patients are taking anti-hypertensive medications; only two of nine were taking them pre-operatively. Four patients were also noted to have persistent 1+ proteinuria by dipstick urinalysis, and an additional one-third of patients show other isolated findings of renal dysfunction by detailed urine analysis. While repeat measurements more than three months apart are required to diagnose these patients with chronic kidney disease, these findings suggest that these patients may have clinically relevant renal disease. Furthermore, although the follow-up time from surgery to renal function analysis is significant, these patients are all younger than 15 years of age, emphasizing the need for longer follow-up for early development of renal dysfunction which may predispose these patients to significant cardiovascular risks and an increase in mortality [24]. Additionally, the overall decrease in $\text{eGFR}_{\text{Schwartz}}$ over time from the pre-operative period to the last follow-up is significant, and may reflect a trend over time towards this dysfunction. Interestingly, the patients with longer follow-up appeared to have improved eGFR when compared to the more recent 13 patients in this study, suggesting patients' renal function may improve over time. However, total renal parenchymal volumes showed a negative correlation of total kidney volume percentile over time with some of these patients. A larger cohort assessed over longer periods of time is necessary to validate this observation.

While others have correlated measured kidney volumes with eGFR [25], Hubertus and colleagues comparing the mean kidney volumes of patients after bilateral NSS (n=10) to those of patients after unilateral NSS with contralateral nephrectomy (n=12), showed greater volumes in patients after bilateral NSS [26]. However, understanding how this volumetric assessment correlates to the estimated and measured GFR has been difficult. Some patients appeared to have maintained total kidney volume within age-adjusted percentiles potentially due to the effect of hypertrophy of kidneys to accommodate for the loss of nephrons. Lastly, some variation in measurements may have been due to post-operative changes in renal contour, and other imaging modalities may play a role in assessing kidney volumes.

While there may be more accurate ways of measuring GFR (e.g. inulin), renal clearance by ^{99m}Tc -DTPA was our standard practice in this cohort of patients. We found no significant difference between estimated GFR and ^{99m}Tc -DTPA, suggesting that, in this small cohort, estimating equations using either cystatin C or creatinine may be sufficient to assess renal function, although using other adjunct studies, such as β 2-microglobulin, may also help identify patients at risk for chronic kidney disease.

This study has several evident limitations. First, the data were retrospectively collected. Second, the comprehensive renal function work-up has not been performed for all patients as many patients have yet to follow-up since this was initiated in our clinic. Although this is a single institution experience, a larger multi-institutional cohort may further define the incidence and significance of long-term renal insufficiency in these patients. Lastly, this study also has significant follow-up; however, longer follow-up will help trend these patients' renal function over time.

In conclusion, this is the largest cohort of patients with a comprehensive renal function evaluation after nephron sparing surgery. It has been difficult to determine which studies will predict a patient's subsequent renal function adequately. Additionally, more recent modifications to the Schwartz equation and other equations utilized may show some differences in calculating renal function. Mir and colleagues recently reported a decline in function approximating 20% in the operated kidney following partial nephrectomy [27]. This decline, however, was not seen in children undergoing bilateral partial nephrectomies with the follow-up in this study. While other groups have shown that radiation therapy and certain nephrotoxic chemotherapeutic agents have deleterious effects on renal function, we were unable to show this relationship, although the number of exposed patients may have been too small to demonstrate such effects. It is possible that patients who undergo bilateral NSS conserve more nephron mass despite requiring adjuvant therapy for positive margins, resulting in better renal function with time. Importantly, this approach does not appear to be associated with worse oncologic outcomes [18]. Thus, in patients with bilateral Wilms tumor, a full comprehensive renal function analysis will help to identify patients with mild renal dysfunction, not suspected based on equations estimating GFR and dipstick urinalysis. While estimating equations may be sufficient to assess GFR, other urine chemistry studies may identify patients at risk for developing renal dysfunction. Longer follow-up will be critical in reassessing these patients' renal function over time.

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Figure 1. Consolidated Standards of Reporting Trials (CONSORT) diagram depicting the cohort of patients included in the present study.

Figure 2.

Diagram plotting total renal parenchymal volume for all patients with immediate post-operative ultrasound imaging and imaging at last follow-up. The age of the patients was plotted versus the total kidney volume, with the trend lines adapted from nomograms of total kidney volume adopted from Leung et al. [23].

Table 1

Patient and disease characteristics

Characteristics	All (N=28)	Patients with cystatin C and urine electrolytes (N=17)	Patients without cystatin C or urine electrolytes (N=11)	
Categorical variable	N (%)	N (%)	N (%)	P
Gender				
Female	13 (46.4)	8 (47.1)	5 (45.5)	1.0000
Male	15 (53.6)	9 (52.9)	6 (54.5)	
Race				
African-American	3 (10.7)	1 (5.9)	2 (18.2)	0.5433
Caucasian	25 (89.3)	16 (94.1)	9 (81.8)	
Age at diagnosis (years)				
0-1	8 (28.6)	8 (47.1)	0	0.0014
1-4	16 (57.1)	9 (52.9)	7 (63.6)	
>4	4 (14.3)	0	4 (36.7)	
Age at follow-up (years)				
Mean $\pm$ SD	8.4 $\pm$ 3.2	8.0 $\pm$ 3.5	8.9 $\pm$ 2.9	
Median (Range)	7.9 (2.4, 14.6)	7.8 (2.4, 14.6)	8.7 (5.4, 13.7)	0.7040
Duration of follow-up (years)				
Mean $\pm$ SD	5.6 $\pm$ 3.1	6.1 $\pm$ 3.4	4.9 $\pm$ 2.5	
Median (Range)	5.2 (1.4, 13.4)	6.1 (1.4, 13.4)	3.9 (2.3, 9.2)	0.4582
Associated anomalies				
Beckwith-Wiedemann syndrome	1 (3.6)	0	1 (9.1)	0.085
WAGR syndrome	0	0	0	
Cryptorchidism	3 (10.7)	1 (5.9)	2 (18.2)	
Hemihypertrophy	1 (3.6)	0	1 (9.1)	
None /other	23 (82.1)	16 (94.1)	7 (63.6)	
Surgical resection				
Bilateral NSS only	19 (67.9)	12 (70.6)	7 (63.6)	0.8350
Bilateral NSS followed by repeat NSS	7 (25.0)	5 (29.4)	2 (18.2)	
Unilateral nephrectomy with contralateral NSS	2 (7.1)	0	2 (18.2)	
Local tumor staging at initial procedure	By side (N=56)	By side (N=34)	By side (N=22)	
Initial biopsy	8 (14.3)	6 (17.6)	2 (9.1)	0.6801
Stage 1	34 (60.7)	21 (61.8)	13 (59.1)	
Stage 2	7 (12.5)	3 (8.8)	4 (18.2)	
Stage 3	7 (12.5)	4 (11.8)	3 (13.6)	
Received abdominal irradiation				
Yes	14 (50.0)	9 (52.9)	5 (45.5)	1.0000
No	14 (50.0)	8 (47.1)	6 (54.5)	

Abbreviations: WAGR – Wilms tumor, Aniridia, Genitourinary, Retardation; NSS – nephron-sparing surgery; SD – standard deviation. Bolded *p* values indicate statistically significant differences.

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Table 2

Renal function variables at last follow-up

Characteristic	All (N=28)	Patients with cystatin C and urine electrolytes (N=17)	Patients without cystatin C or urine electrolytes (N=11)	
Categorical variable	N (%)	N (%)	N (%)	<i>P</i>
1+ proteinuria by urinalysis				
Yes	8 (28.6)	4 (23.5)	4 (36.4)	0.6715
No	20 (71.4)	13 (76.5)	7 (63.6)	
Taking anti-hypertensive medication				
Yes	9 (32.1)	6 (35.3)	3 (27.3)	1.000
No	19 (67.9)	11 (64.7)	8 (72.7)	

Continuous variable	Median (range)	Median (range)	Median (range)	<i>P</i>
Serum laboratory value				
BUN	15.5 (5, 27)	16 (7, 27)	15 (5, 18)	0.3185
Serum creatinine	0.49 (0.2, 0.88)	0.54 (0.20, 0.88)	0.44 (0.31, 0.68)	0.3312
Cystatin C (normal <1.12mg/L)	N/A	1.12 (0.40, 1.46)	N/A	
Urine laboratory value				
Sodium (mmol/L)	N/A	139 (29, 246)	N/A	
Protein (normal <30 mg/dL)		10.5 (4.0, 53.0)		
Creatinine (mg/dL)		0.08 (0.02, 0.18)		
Protein/creatinine ratio (normal <45 mg/mmol)		122.8 (57.3, 766.0)		
Microalbumin (mg/dL)		<1.2 (0.50, 70.1)		
β2-microglobulin (normal <133μg/g Cr)		154 (66, 662)		
Other laboratory value				
Magnesium (mg/dL) ^κ	2.0 (1.5, 2.3)	2.0 (1.5, 2.3)	1.9 (1.7, 2.3)	0.4303
Phosphorus (mg/dL) ^κ	4.7 (3.7, 5.5)	4.8 (4.1, 5.5)	4.2 (3.7, 5.5)	0.0913
Vitamin D levels (ng/mL) [℥]	30 (18, 44)	30 (18, 44)	24 (21, 34) [*]	0.3448
Glomerular filtration rate (mL/min/1.73m²)				
(A) eGFR _{CKiD} ^{**}	N/A	79.67 (58.31, 180.70)	Not available	
(B) ^{99m} Tc-DTPA renal clearance ^α	97 (56, 155)	87 (56, 155)	107 (87, 126)	0.0388
(C) eGFR _{Schwartz}		103.27 (67.78, 159.53)		
(D) eGFR _{Counahan-Barratt}		103.45 (70.57, 163.40)		

Abbreviations: BUN – blood urea nitrogen; eGFR – estimated glomerular filtration rate; ^{99m}Tc-DTPA – technetium-99m Diethylene Triamine Pentacetic Acid

^κ Available for 26 patients.

[℥] Available for 20 patients.

^{*} Only 3 patients with Vitamin D levels value.

^{**} eGFR_{CKiD} was calculated based on p.632 of the reference paper.

^a Available for 25 patients.

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Table 3

Median eGFR_{Schwartz} (mL/min/1.73m²) for patients evaluated after 2005 with NIST-traceable creatinine standard with comparison of change of eGFR

Value	Mean	Median	Minimum	Maximum	<i>P</i>
Pre-operative	117.27	108.93	75.89	186.44	
One-week post-operative	129.17	136.40	72.30	186.40	
Last follow-up	109.90	105.56	67.78	159.53	
One-week post-operative vs. Pre-operative	11.90	2.97	-33.56	57.01	0.0017
Last follow-up vs. Pre-operative	-7.37	-7.74	-48.01	40.89	0.0394

Bolded *p* values indicate statistically significant differences.