transplantology

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A Single-Center Experience of En Bloc vs. Single Renal Transplantation on Adult Recipients †

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† This article is a revised and expanded version of a poster entitled "A Single-Center Experience of En Bloc vs. Single Renal Transplantation on Adult Recipients", which was presented at the American Society of Transplant Surgeons Winter Symposium on 11 January 2024 in Miami, FL, USA.

Abstract: Background/Objectives: While there are several debates on en bloc renal transplants and pediatric donors regarding the efficacy and concern for renal mass, multiple studies have supported the notion that transplanting pediatric en bloc kidneys produces comparable results in contrast to single kidneys from living or deceased donors. **Methods**: This case series included a retrospective analysis of a university medical center, primarily focused on comparing the post-operative outcomes between recipients of pediatric and adult en bloc kidneys, which are horseshoe kidneys, from deceased donors and recipients of single adult kidneys from living or deceased donors. **Results**: This study demonstrated that the post-operative results in recipients of pediatric en bloc kidneys consisting of serum creatinine and estimated glomerular filtration rate (eGFR) values were lower and higher, respectively, and had a comparable improvement in kidney function at post-transplant, 1-week, 1-month, 3-months, and 1-year post-op marks. **Conclusions**: Our center data and outcomes indicate that en bloc kidney transplantation from pediatric donors yields comparable results to that of single kidney transplantations from living and deceased donors.

Keywords: en bloc; pediatric; transplantation

Academic Editor: Alberto Rosati

Received: 30 December 2024
Revised: 15 February 2025
Accepted: 27 February 2025
Published: 4 March 2025

Citation: Chang, Y.-J.; Simpson, S.; Charette, M.; Ekwenna, O. A Single-Center Experience of En Bloc vs. Single Renal Transplantation on Adult Recipients. *Transplantology* **2025**, *6*, 7. https://doi.org/10.3390/transplantology6010007

1. Introduction

With the continuous advancement in surgical techniques over the past decades, renal transplantation has become the foremost treatment for patients with end-stage renal disease (ESRD). After a transplant, patients are often freed from needing dialysis, experience a drastic improvement in their quality of life, and have an increased survival. However, due to inadequate numbers of living and cadaveric donors and the increasing numbers of patients on the national waiting list, patients are waiting ever-longer for transplants. To address the increase in demand for organs, more options have been explored within the medical community, one of which includes the utilization of pediatric en bloc kidneys for a single recipient, as well as horseshoe adult kidneys. Given that specific criteria are met for each individual patient, this approach may effectively increase the number of donor kidneys available for transplantation without compromising the post-operative outcomes.

In addition to the conventional criteria necessary to be cleared for transplantation, providers may need to consider additional factors to determine whether one would be a good match for the pediatric donors to compensate for the size and body habitus. As

such, depending on the renal mass and weight of the recipient and pediatric donor, the kidneys may be transplanted as two, which we call en bloc kidney transplantation, or traditionally as single kidneys to two separate recipients. En bloc kidney transplantation to a single recipient would require the anastomosis of the donor's aorta, IVC, and ureters to the recipient's iliac artery, external iliac vein, and bladder, respectively [1]. Though pediatric donors have been infrequently considered due to technical complexities and ethical implications, multiple studies have shown that en bloc renal transplants produce comparable or even superior outcomes when compared to single renal transplants from living donors [1–3].

Though there are numerous papers published with reassuring data on single kidney transplantations from adult donors to adult recipients, that may not be the case for the topic of pediatric en bloc transplantations. Yet, we are still able to draw a conclusion from the available research data and post-operative outcomes from multiple medical centers that pediatric en bloc transplantations produce superior outcomes compared to single kidney transplantations from living or deceased donors. For instance, the serum creatinine levels in single kidney transplant (SKT) recipients from living donors were higher than those of en bloc kidney transplant (EBKT) recipients at discharge, 1-year, and 5-year post-op for the majority of the patients in one of the studies conducted [4]. In addition to these lab values, the average graft survival was also longer than that of single renal transplants, further highlighting the efficacy of pediatric en bloc transplantation. Thus, the following study further explores and analyzes whether the outcomes from this university medical center support the notion as presented by other institutions.

2. Materials and Methods

2.1. Study Design

This is a retrospective study that was carried out by obtaining data from the United Network for Organ Sharing (UNOS). Clinical data consisting of donor and recipient demographics, post-operative outcomes, and complications were collected via random selection from the years 2007 to 2023 among the pediatric en bloc, adult en bloc, and single kidney transplantations from living and deceased donors.

2.2. Data Collection and Variables

First and foremost, the list of individuals who underwent en bloc transplantations was identified. The list was then divided into pediatric en bloc recipients and adult en bloc recipients, which are horseshoe kidneys from adult donors for this study. During the years 2007 to 2023, a total of 21 en bloc transplantations were performed at this medical center. Of the 21 individuals, data from a total of 17 patients were obtained and analyzed due to challenges faced with accessing data among different modalities. Of the 17 individuals studied, 13 patients were pediatric en bloc kidney recipients and 4 patients were adult en bloc (horseshoe kidney) recipients. To compare this set of data to single kidney recipients, 22 additional patients who were recipients of single kidneys from living or deceased donors were chosen and divided via random selection among the 2528 patients who underwent kidney transplantation from 2007 to 2023 at this institution.

In addition to the types of transplantations, the demographics and characteristics of the donors (Table 1) and recipients (Table 2) were obtained. The following variables were identified: age, gender, weight, height, BMI, and type of dialysis received prior to transplantation, all of which were represented as mean values with the corresponding units. Upon reviewing the clinical records of the chosen recipients, the following data were additionally identified: primary renal diseases for transplantation (Figure 1), HLA-match, post-operative graft status, and laboratory values including serum creatinine and eGFR

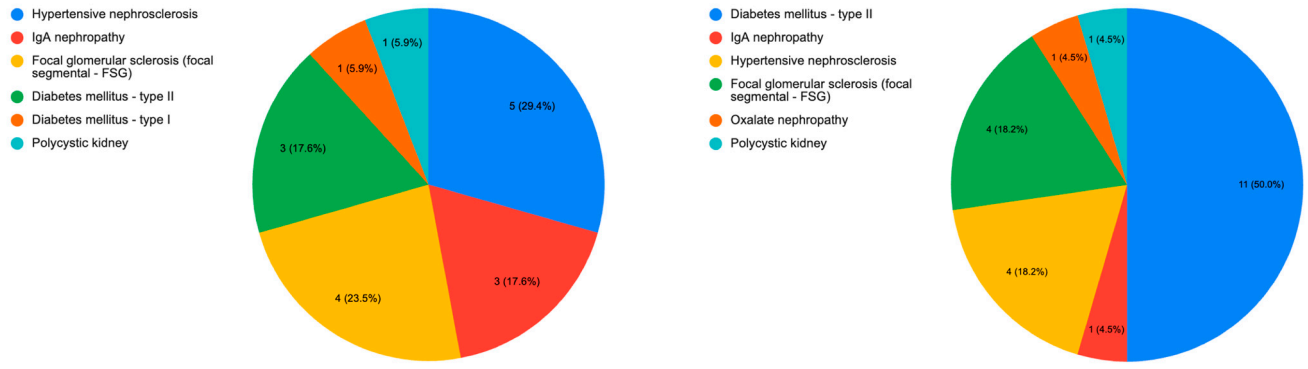
values at post-transplantation, 1-week, 1-month, 3-months, and 1-year post-transplant (Table 3). Numbers for laboratory values were represented as median values, along with the first and third interquartile ranges. Any values above 60 for eGFR values were calculated as 60 per the university medical center calculations.

Table 1. Donor demographics of en bloc kidney and single kidney transplantations.

	Pediatric En Bloc Kidney	Adult En Bloc Kidney	Single Kidney (Living Donor)	Single Kidney (Deceased Donor)	*p*-Value
Age (years), median (IQR)	2.00 (1.00–3.00)	54.00 (48.25–57.75)	46.00 (40.00–58.00)	36.00 (22.50–45.00)	<0.0001
Female, *n* (%)	2 (15.38)	1 (25.00)	6 (54.54)	2 (18.18)	0.17
Height (cm), mean ± SD	89.69 ± 16.97	178.25 ± 9.07	164.28 ± 8.02	170.73 ± 15.63	<0.0001
Weight (kg), median (IQR)	13.10 (11.20–15.70)	84.50 (67.88–97.95)	65.77 (62.15–70.53)	88.50 (79.55–105.65)	<0.0001
BMI, mean ± SD	17.85 ± 4.88	25.22 ± 7.52	25.44 ± 2.83	29.60 ± 5.67	<0.0001

Table 2. Adult recipient demographics of en bloc kidney and single kidney transplantations.

	Pediatric En Bloc Kidney	Adult En Bloc Kidney	Single Kidney (Living Donor)	Single Kidney (Deceased Donor)	*p*-Value
N (#)	13	4	11	11	
Age (years), mean ± SD	50.08 ± 15.64	60.50 ± 12.07	64.00 ± 8.15	65.27 ± 7.24	0.009
Female, *n* (%)	7 (53.85)	3 (75.00)	5 (45.45)	4 (36.36)	0.60
Race, *n* (%)					
White Black Hispanic Asian	7 (53.85) 3 (23.08) 2 (15.38) 1 (7.69)	3 (75.00) 1 (25.00) 0 (0.00) 0 (0.00)	9 (81.81) 1 (9.09) 1 (9.09) 0 (0.00)	5 (45.45) 6 (54.55) 0 (0.00) 0 (0.00)	0.30
Height (cm), mean ± SD	168.03 ± 8.48	164.47 ± 10.45	170.41 ± 12.97	170.41 ± 9.66	0.74
Weight (kg), mean ± SD	72.35 ± 16.74	66.00 ± 21.76	86.65 ± 24.03	83.34 ± 15.89	0.15
BMI (kg/m^2), mean	25.41 ± 4.15	24.11 ± 6.50	29.33 ± 5.38	28.74 ± 5.01	0.12
Delayed graft function, *n* (%)	2 (15.38)	2 (50.00)	1 (9.09)	5 (45.45)	0.13
Type of dialysis, *n* (%)					
Hemodialysis Peritoneal dialysis None	7 (53.85) 6 (46.15) 0 (0.00)	1 (25.00) 3 (75.00) 0 (0.00)	6 (54.55) 3 (27.27) 2 (18.18)	8 (72.73) 1 (9.09) 2 (18.18)	0.14



(**a**) (**b**)

Figure 1. (**a**) Primary renal diseases of pediatric en bloc kidney recipients at this center; (**b**) primary renal diseases of adult kidney recipients at this center.

Table 3. Comparison of post-operative lab values for combined en bloc kidney and single kidney transplantations on adult recipients.

	Pediatric En Bloc Kidney	Adult En Bloc Kidney	Single Kidney (Living Donor)	Single Kidney (Deceased Donor)	*p*-Value
Serum creatinine (mg/dL), median (IQR)					
Post-transplant	6.69 (5.54–8.43)	6.43 (5.03–7.24)	4.53 (4.17–6.64)	5.83 (4.15–8.37)	0.70
1-week	1.71 (1.45–3.70)	2.53 (1.18–5.17)	1.43 (1.00–1.70)	3.70 (1.51–7.19)	0.19
1-month	1.25 (1.22–1.41)	1.11 (0.61–2.50)	1.36 (1.07–1.55)	1.50 (1.14–1.77)	0.83
3-months	1.07 (0.86–1.52)	1.48 (1.22–1.55)	1.32 (1.17–1.48)	1.34 (0.90–1.50)	0.94
1-year	0.98 (0.74–1.09)	1.32 (1.11–1.45)	1.15 (0.87–1.38)	1.21 (1.04–1.37)	0.21
eGFR (mL/min/1.73 m^2), median (IQR)					
Post-transplant	8.00 (6.00–11.00)	8.00 (6.75–15.00)	10.00 (8.00–11.50)	9.00 (7.00–13.50)	0.66
1-week	33.00 (21.00–47.00)	27.50 (14.00–43.50)	48.00 (38.50–58.00)	19.00 (9.50–51.50)	0.21
1-month	49.00 (42.00–59.00)	46.00 (26.50–60.00)	45.00 (41.00–60.00)	53.00 (39.00–60.00)	0.98
3-months	60.00 (58.00–60.00)	40.00 (36.00–47.25)	50.00 (45.00–56.50)	60.00 (46.00–60.00)	0.11
1-year	60.00 (60.00)	41.50 (39.25–47.25)	50.00 (46.00–60.00)	60.00 (55.00–60.00)	0.03

2.3. Statistical Analysis

Continuous data are presented as mean ± standard deviation (SD) or median and interquartile range (IQR) based on distribution. Categorial data are presented as counts and percentages. Variance in continuous data was assessed using Bartlett's test for homogeneity, and an analysis of variance (ANOVA) or Kruskal–Wallis test was subsequently used to determine if a statistical difference existed between means or medians, respectively. All categorical data were evaluated using Fisher's exact test. Analyses were performed using R 4.2.2 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria), and p-values < 0.05 were considered statistically significant.

3. Results

3.1. Donor Demographics and Characteristics

The donor demographics and characteristics among all four groups are shown in Table 1. The median age of pediatric en bloc donors was 2 years old, with the age ranging from 0 (months-old unspecified) to 10 years old. The mean weight of the pediatric en bloc donors was 13.10 kg, with the weight ranging from 7 kg to 43.4 kg. Taking an in-depth and extensive look into the breakdown of the weights, the weight range between the ages 0 and 1 years old was 7 kg to 14.4 kg, between the ages 1 and 2 was 9.3 kg to 14.5 kg, and between the ages 2 and 4 was 14.5 kg to 17 kg.

The median age of the adult en bloc kidney donors was 54 years old, along with the median age of the single kidney living donor and single kidney deceased donor noted to be 46 years old and 36 years old, respectively. The mean weight of the adult en bloc kidney donors was 84.50 kg, whereas the mean weight of the single kidney living donor and single kidney deceased donor was 65.77 kg and 88.50 kg, respectively. As expected, pediatric en bloc donors were significantly younger and were lower in weight, height, and BMI when compared to all adult donors, p-value < 0.001. No statistically significant differences were observed when comparing only adult donors in age, height, weight, or BMI, with all p-values > 0.05. Further information about the donors including race and cause of death was unable to be accessed.

3.2. Recipient Demographics and Characteristics

The recipient demographics and characteristics among all four groups are shown in Table 2. The mean age of the pediatric en bloc kidney recipients was 50.08 years old, which was lower compared to the mean age of all other groups, namely, 60.50 years old for the

adult en bloc kidney recipients, 64 years old for the single kidney living donor recipients, and 65.27 years old for the single kidney deceased donor recipients. Furthermore, the percentage of female patients was also the highest within the pediatric en bloc kidney recipients, noted to be at 53.85%, likely due to the relatively smaller body mass and habitus as indicated by the lower mean weight of 72.35 kg compared to the other two single kidney recipient groups. It may be possible to hypothesize that the mean weight was the lowest in the adult en bloc kidney recipients, taking into consideration that the adult en bloc kidney (horseshoe kidney) may have the greatest renal mass and length.

Looking at the race of the recipients, the pediatric en bloc kidney recipients were likely to be white (53.85%), as well as the single kidney recipients from living donors. However, the single kidney recipients from deceased donors were likely to be African-American (54.55%). Patients predominantly received hemodialysis over continuous ambulatory peritoneal dialysis among all groups, with the exception of the adult en bloc kidney recipients.

Primary Disease

The most prevalent primary renal disease of pediatric en bloc kidney recipients was hypertensive nephrosclerosis, while the most common primary renal disease for single kidney recipients was diabetic nephropathy from type 2 diabetes mellitus (Figure 1).

3.3. Post-Operative Outcomes

Within the study population, kidney function was objectively measured using serum creatinine and eGFR. Our data demonstrated that the post-operative outcomes among en bloc kidney recipients, specifically pediatric en bloc kidneys, were comparable to that of single kidney recipients as shown in Table 3 and Figure 2. The median serum creatinine value of the pediatric en bloc kidney recipients was 0.98 mg/dL at the one-year mark, compared to 1.15 mg/dL and 1.21 mg/dL for the single kidney recipients from living or deceased donors, respectively. However, despite the serum creatinine values for pediatric en bloc recipients being lower at most post-operative visits when compared to adult recipients, analyses failed to demonstrate a statistically significant difference. This may be due to the limited sample size. Of note, the eGFR at one year for pediatric en bloc recipients was comparable to single kidney and living donors and significantly better than that observed in the recipients of adult en bloc kidneys (p-value 0.03).

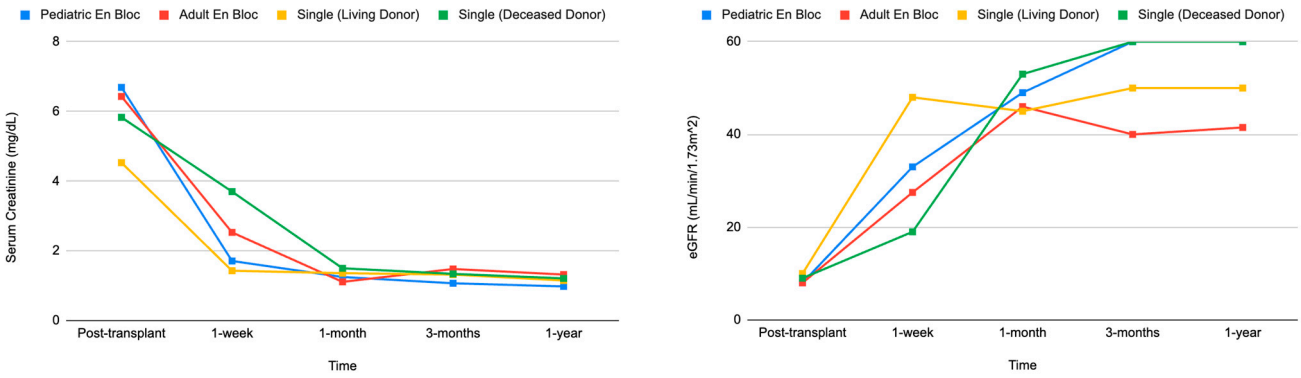


Figure 2. (**a**) Serum creatinine levels of pediatric en bloc vs. single kidney transplantation on adult recipients at the post-transplant, 1-week, 1-month, 3-months, and 1-year marks; (**b**) eGFR levels of pediatric en bloc vs. single kidney transplantation on adult recipients at the post-transplant, 1-week, 1-month, 3-months, and 1-year marks.

3.4. Post-Operative Complications and Graft Loss

Among the en bloc kidney recipients studied, there have been a total of two graft failures: one who presented with antibody-mediated rejection three years post-transplant and was subsequently transplanted and another who failed secondary to t-cell-mediated rejection four years post-transplant. Three patients who received en bloc kidneys have passed away, one from intracranial hemorrhage, another from pulmonary malignancy, and the last from dementia. At the time of their death, all three patients were reported to have had functioning grafts. There was no ureteral obstruction or injury reported in this group. The 12 remaining en bloc recipients are living and have functioning kidneys in active follow-up at our center. Among the single kidney recipients, there has been only one graft failure. The patient had a recurrent infection and was subsequently re-transplanted. Of note, one of the patients among the deceased donor recipients presented with complications on post-operative day seven, which included dehiscence and sacral decubitus ulcers, and was designated as high risk for post-operative venous thromboembolism. This patient was treated appropriately and underwent wound care with vascular surgery and was instructed to take prophylactic heparin. Four single kidney recipients have passed away, two from sepsis, one from an abdominal surgery complication, and another from pancreatic cancer. At the time of their death, all four patients were reported to have functioning grafts. There was no ureteral obstruction or injury reported in this group. The 17 remaining single kidney recipients are living and have functioning kidneys in active follow-up at our center.

4. Discussion

Our data provide satisfactory post-operative outcomes, as well as support the conclusion that pediatric en bloc kidney transplantation results in comparable graft function to single kidney recipients. Likewise, the pediatric en bloc kidney recipients presented with relatively immediate post-operative complications compared to the recipients of single kidneys (recurrence of primary renal disease) [5]. Though there was no statistically significant difference in the serum creatinine, a favorable downward trend was nonetheless observed, and a statistically significant difference in the eGFR values at the 1-year post-transplant mark between the pediatric en bloc recipients and the single kidney recipients was also noted. Likewise, the *p*-value only indicates that some of the medians are different; however, we may be able to conclude from this data that pediatric en bloc is comparable to living and deceased transplants but may not be adequately supported for living donors. A limitation of this study that may have played a role in the outcomes includes a small sample size and the high-risk end-stage renal disease patient population that this medical center operates on. Yet, we would like to highlight the significance of performing pediatric en bloc transplantations and the ability to produce such post-operative outcomes at this medical center and transplant program.

The concern remains, however, regarding ureteral complications including stenosis and leakage, thrombosis, and hyperfiltration injury, as these pediatric en bloc kidneys are still growing anatomically to reach their full and appropriate size [2]. To address the ongoing concern, we may be able to further explore what is implemented in current practice, which includes the addition of induction therapy, use of advanced antiplatelet and anticoagulation medication post-operatively, prevalence of increasingly adept surgical skills, and sophisticated imaging modalities such as interventional radiology to track the progress of each patient. With these protocols in place, some of the initial concerns regarding renal mass, surgical skills, and thrombosis may be alleviated. As with this single-center study, there was adequate growth of the kidneys and significant improvement and return of filtration with the pediatric en bloc kidneys. This growth was not only seen here but also in one of the studies carried out at a different institution, as they were able to track

the growth of the pediatric en bloc kidneys until 6-months post-transplant [1]. The question still exists, however, whether this growth was a result of pure compensatory physiological growth or a growth driven by hyperfiltration [6].

As mentioned previously, a limitation of this study consists of its small sample size and the patient population that our medical center operates on, which may, in turn, affect the outcomes of the surgical procedures. Given that hypertensive nephrosclerosis and diabetic nephropathy were the two most prevalent primary renal diseases among the four groups, it is likely that the patients had additional comorbidities that indirectly shaped the direction in which the graft function progressed. With this in consideration, it is also important to consider the socioeconomic status of the patient population at our center, as a high percentage of patients do not have access to optimal healthcare or transportation. As a result, many patients may not have been able to afford or access the proper post-operative care necessary to encourage favorable outcomes.

A few possible topics for future research may include the correlation between the age of the pediatric donor and its effect on graft survival in adult recipients if any exist and whether the stage of the anatomic growth of the pediatric donors has any cause in reducing the risk of thrombosis and prolonging graft survival. Furthermore, as we enter an era of a rise in telehealth, it may be worthwhile to study whether, in the field of transplantation as a whole, the increase in the frequency of telehealth will reduce the mortality rate and waiting time on the transplant list, as more patients may have access to faster test results and care.

Author Contributions: Conceptualization, investigation, methodology, analysis, writing—original draft preparation, Y.-J.C.; conceptualization, investigation, methodology, analysis, writing—original draft preparation, S.S.; formal analysis, writing—review and editing, M.C.; conceptualization, investigation, methodology, project administration, supervision, writing—review and editing, O.E. All authors have read and agreed to the published version of the manuscript.

Funding: There was no funding provided for this study, as it was a retrospective review.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the University of Toledo Biomedical Institutional Review Board (approval code 300350 and date of approval 4 September 2019). An amendment was submitted extending the timeframe for investigation and addition of more variables of interest, this was approved on 23 May 2024.

Informed Consent Statement: Informed consent was not obtained from the subjects prior to their participation in this research. This was a retrospective review, and a waiver of consent was requested in the application and subsequently approved by the University of Toledo Biomedical Institutional Review Board.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Acknowledgments: This work was supported by Obi Ekwenna. We would like to acknowledge the Department of Urology and Renal Transplantation as well as Obi Ekwenna, Mary Brown, Megan Charette, and Jennifer Mikulak for their direction, guidance, and mentorship on the project. We would also like to acknowledge Kunal Yadav, John Rabets, Puneet Sindhwani, Deepak Maholtra, Shobha Ratham, Dinkar Kaw, Zubia Alam, and Michael A. Rees for their supervision, guidance, and significant contributions to the study.

Conflicts of Interest: The authors declare no conflict of interest.

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