ORIGINAL ARTICLE

Paediatric kidney transplants from donors aged 1 year and under: an analysis of the Australian and New Zealand Dialysis and Transplant Registry from 1963 to 2018

Jinna Yao[1,2,3], Philip A. Clayton[4,5,6], Kate Wyburn[3,7], Harsham Choksi[3], Elena Cavazzoni[8,9], David Tovmassian[1], Howard M. H. Lau[1,11,12], Richard Allen[1,3], Lawrence Yuen[1,3], Jerome M. Laurence[3,10], Vincent W. T. Lam[1,11] & Henry C. C. Pleass[1,3]

1 National Pancreas Transplant Unit, Westmead Hospital, Sydney, NSW, Australia
2 Department of Urology, Westmead Hospital, Sydney, NSW, Australia
3 Faculty of Medicine and Health, University of Sydney Medical School, Camperdown, NSW, Australia
4 Department of Medicine, The University of Adelaide, Adelaide, SA, Australia
5 Australia and New Zealand Dialysis and Transplant (ANZDATA) Registry, South Australian Health and Medical Research Institute (SAHMRI), Adelaide, SA, Australia
6 Central and Northern Adelaide Renal and Transplantation Service, Royal Adelaide Hospital, Adelaide, SA, Australia
7 Department of Renal Medicine, Royal Prince Alfred Hospital, Sydney, NSW, Australia
8 NSW Organ and Tissue Donation Service, Sydney, NSW, Australia
9 Paediatric Intensive Care Unit, The Children's Hospital at Westmead, Sydney, NSW, Australia
10 Department of Surgery, Royal Prince Alfred Hospital, Sydney, NSW, Australia
11 Faculty of Medicine and Health Sciences, Macquarie University, Sydney, NSW, Australia
12 School of Medicine, Western Sydney University, Sydney, NSW, Australia

SUMMARY

Kidneys from very small donors have the potential to significantly expand the donor pool. We describe the collective experience of transplantation using kidneys from donors aged ≤1 year in Australian and New Zealand. The ANZDATA registry was analysed on all deceased donor kidney transplants from donors aged ≤1 year. We compared recipient characteristics and outcomes between 1963–1999 and 2000–2018. From 1963 to 1999, 16 transplants were performed [9 (56%) adults, 7 (44%) children]. Death-censored graft survival was 50% and 43% at 1 and 5 years, respectively. Patient survival was 90% and 87% at 1 and 5 years, respectively. From 2000 to 2018, 26 transplants were performed [25 (96%) adults, 1 (4%) children]. Mean creatinine was 73 μmol/l ±49.1 at 5 years. Death-censored graft survival was 85% at 1 and 5 years. Patient survival was 100% at 1 and 5 years. Thrombosis was the cause of graft loss in 12% of recipients in the first era from 1963 to 1999, and 8% of recipients in the second era from 2000 to 2018. We advocate the judicious use of these small paediatric grafts from donors ≤1 year old. Optimal selection of donor and recipients may lead to greater acceptance and success of transplantation from very young donors.

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Key words
en bloc transplant, infant donors, kidney transplant, organ procurement, paediatric donor, surgical complications

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Correspondence
Henry C. C. Pleass, National Pancreas Transplant Unit, Westmead Hospital, Sydney, NSW 2145, Australia.
Tel.: +61 2 88906821;
fax: +61 2 98937440
e-mail: henry.pleass@sydney.edu.au

Introduction

In response to the increase need for donor organs internationally, there have been changes in the demographics of accepted kidney donors. Whilst there is established evidence that transplantation with paediatric kidneys yields good outcomes [1,2], there exists a reluctance amongst centres in utilizing organs from very small paediatric donors.

Historically, smaller body weight donors are less likely to be used than larger paediatric donors due to concerns of vascular thrombosis and low nephron mass [3]. A study from the North American Paediatric Renal Trials and Collaborative Studies (NAPRTCS) registry showed higher rates of small paediatric donor graft loss due to thrombosis in paediatric recipients under 2 years old compared to those over 12 years old (9.0% vs. 3.5%; $P = 0.01$) [4]. A study by Lam *et al.* [5] showed vascular thrombosis was the most common cause of early graft loss with an incidence of 11% in en bloc transplants from donors under 5 years of age. Furthermore, there is a concern that kidneys from small paediatric donors may not provide adequate kidney function for adult recipients due to hyperfiltration-associated renal injury. However, a study by Thomusch *et al.* [6] demonstrated that paediatric transplants provide similar long-term graft function and outcomes as adult donors. Table 1 summarizes the published case series of renal transplantation from very small or young paediatric donors over the last decade.

With recent improvements in surgical techniques and immunosuppressive regimens, very small paediatric donors increasingly represent a valuable source of organs which has the potential to significantly expand the donor pool. The aim of this study was to evaluate the outcomes of using kidneys from small paediatric donors younger than 1 year of age in Australia and New Zealand.

Patients and methods

Data source and study population

We retrospectively identified 42 paediatric donors from the Australian and New Zealand Dialysis and Transplant (ANZDATA) registry between 1 January 1963 and 31 December 2018. All recipients of deceased donor kidney transplants from donors aged 1 year and under were included in this study. Demographic data including age and sex were collected. Graft and patient outcomes were compared between two eras, 1963–1999 and 2000–2018. These intervals were selected as the cut-off corresponds to the era of modern immunosuppression. This study was conducted in accordance with institutional ethical research guidelines.

Clinical data and outcome definition

All clinical and biological data were extracted from the databases. Graft function, incidence of delayed graft function (DGF) and graft loss at 1 and 5 years were collected. Cause of graft failure was also determined from the database and categorized as acute rejection, chronic allograft nephropathy, haemolytic uraemic syndrome, thrombosis, haemorrhage, cortical necrosis or death with function. Complications which did not cause graft failure were not recorded by ANZDATA. Delayed graft function was defined as requirement of at least one dialysis session within the first seven days. Graft failure was defined as return to chronic dialysis, allograft nephrectomy, re-transplantation or death.

Statistical analysis

Statistical analysis was carried out using Microsoft Excel and SPSS software (version 21, Armonk, NY, USA: IBM group). Between-group comparisons for categorical variables were made using Fishers' exact test. Patient survival and death-censored graft survival were estimated by the Kaplan–Meier method, and groups were compared using log-rank tests. Continuous variables were analysed using the unpaired *t*-tests. A P value was considered significant if <0.05.

Results

Donor and recipient characteristics

There were 42 paediatric donors ≤1 years of age (27/42; 64% males); eight (19%) were transplanted into

Table 1. Published outcomes of paediatric donors aged <5 years or <20 kg (unless specified) over the last 10 years.

Authors (country, year)	Year	*N*	Age	Graft outcome	Graft thrombosis	Ureteric complications	Comments
Kizilbash [8] (US, 2020)	1987–2017	149 EBK into adults and children	Median age 1.0 year (IQR 1.0–3.0)	• 1-year GS: EBK 80%, SCD 90% • 5-year GS: EBK 69%, SCD 68% • 10-year GS: EBK 54%, SCD 44%	• EBK – 12% • SCD – 3%Higher incidence of thrombosis during first year for EBK	Not reported	• Superior patient GS for EBK compared to remaining on wait list (HR 0.58) • Increased risk of 1-year graft loss in EBK recipients only in oldest era (1987–1997)
Su [26] (China, 2020)	2014–2018	• 56 SKT in children • 26 EBK in adults and children	Mean age 8.9 months (range 0.3–41.3)	• 1-year GS: EBK 73%, SKT 92% • 2-year GS: EBK 73%, SKT 86%	• EBK – 23% • SKT – 2%	4 (7%): 3 ureteric strictures, 1 leak • BW < 5 kg: 23% • 5 kg < BW < 10 kg: 2%	Graft GS dramatically decreased when donor <5 kg
Considine [23] (UK, 2018)	1990–2016	23 EBK, 23 SKT Adult recipients	Mean age 1.8 ± 0.97 years (range 7 months – 3 years)	• 1-year GS: EBK 100%, SKT 92% • 5-year GS: EBK 91%, SKT 79% • 10-year GS: EBK 80%, SKT 61%	0	Not reported	
Dai [27] (USA, 2018)		8 SKT into 4 children and 4 adults	Age range 37–300 days	1-year GS 100%	0	2 urine leak	• DGF in one patient • Donor CIA or EIA used as outflow tract to mitigate thrombosis
Mitrou [20] (Canada, 2018)	2001–2007	11 EBK <10 kg, 17 EBK >10 kg Adult recipients	Donor <10 kg: mean age 6.3 ± 1.6 weeks Donor >10 kg: 23.8 ± 10.4	• <10 kg group: 82% after 44 months • >10 kg group: 94% after 124 months	1 patient in <10 kg group	2 hydronephrosis	Renal function in patients who received EBK from <10 kg donors was similar to EBK >10 kg donors
Sureshkumar [16] (USA, 2018)	1990–2001	72 EBK, 75 adult LD. Adult recipients	Mean age 16.9 ± 11.2 months	1-year GS: EBK 82%, adult LD 93%-year graft GS similar between EBK and adult LD	13% (mainly from donors <12 months)	2 ureteric strictures	• DGF more frequent in EBK (26% vs. 7%, $P = 0.001$) • Transplant renal artery stenosis in 5 EBK, requiring angioplasty
Wijetunga [13] (UK, 2018)	2005–2016	15 EBK <5 kg, 15 EBK >5 kg Adult recipients	Median age 5.6 months (range 0–69)	1-year GS: EBK <5 kg: 87%, EBK >5 kg: 93%	<5 kg group: 3 >5 kg group: 1	0	DGF: <5 kg group: 23%, >5 kg group: 0
Chesnaye [11] (Germany, 2017)	1990–2013	DD: 3517 (516 DD aged 0–5 years), LD: 1169	Subgroup aged 0–5 years	5-year GS for DD aged 0–5 years: • Recipients 0–3 years: 70% • 0–5 years: 75% • 6–11 years: 81% • 12–19 years: 83%	Not reported	Not reported	• 0- to 5-year-old DD had highest risk of graft failure compared with DD aged 12–19 years, which had the lowest risk [aHR 1.69 (95% CI 1.26–2.27)] • In recipients aged 0–5 years, risk of graft failure highest in DD aged 0–5 years [compared with DD 12–19 years; aHR 2.01 (95% CI 1.11–3.67)]
Troppmann [1] (USA, 2017)	2007–2015	130 EBK Adult recipients	Median age 2.0 months (range 0.01–23.4)	• 1-year GS: DCD 89%, 91% (NS) • 5-year GS: DCD 87%, DBD 91% (NS)	• DCD 12%, DBD 16% • Graft loss due to thrombosis: DCD 5%, DBD 7%	DCD 15% DBD 12%	• DGF: DCD 25%, DBD 14% (NS)

Table 1. Continued.

Authors (country, year)	Year	*N*	Age	Graft outcome	Graft thrombosis	Ureteric complications	Comments
Yaffe [14] (USA, 2017)	1996–2013	167 (57 EBK, 110 SKT), 2350 SCD Paediatric recipients	• EBK: mean age 2.3 ± 1.5 years, • SKT: 4.6 ± 1.9 years	• 1-year GS: paediatric EBK: 86%, paediatric SKT: 90%, adult SCD: 94% • 5-year GS: paediatric EBK: 73%, paediatric SKT: 61%, adult SCD: 73%	Not reported	Not reported	• DGF: no significant difference between paediatric EBK (4%), paediatric single (9%) and adult SCD (7%). • For recipients <45 kg, paediatric EBK had worse outcomes vs adult SCDFor recipients >45 kg, similar graft GS of very small paediatric kidneys compared to adult donors
Al-Shraideh [28] (US, 2016)	2002–2015	34 EBK, 25 SKT Recipients 12–60 years	• EBK: mean age 1.4 ± 0.8 years • SKT: 3.3 ± 1.2	• EBK: 94% at 52 months f/u • SKT: 81% at 74 months f/u	• EBK: 3% • SKT: 4%	No urological complications	• DGF: EBK 12%, SKT 20% (P = NS)
Wang [29] (China, 2016)	2012–2015	6 EBK. Paediatric recipients	Mean age 4.4 ± 0.7 months	100% at median f/u of 15.5 months	1 thrombosis in 1/12 grafts	1 urine leak and obstructed ureter	• DGF: nil
Winnicki [15] (US, 2016)	2000–2013	126 EBK, 6756 SCD. Paediatric recipients	EBK: Median age 1 year (IQR 1–3 years)	1-year GS: EBK 86%, SCD 93% • 5-year GS: EBK 65%, SCD 59%	EBK 4% SCD 1%	Not reported	eGFR was significantly higher at 6 month, 1 year, 5 years for recipients of EBK compared to SCD
Gallinat [30] (Germany, 2013)	2003–2010	• 10 SKT, 1 EBK into paediatric recipients • 4 SKT, 10 EBK into adult recipients	Median age 38 months (range 3–59 months)	5-year GS: paediatric (SKT) 100%, adult (EBK) 86%	1 thrombosis after EBK in adult recipient	1 necrosis of the ureter after EBK in adult recipient	1 DGF after SKT in adult recipient
Maluf [31] (US, 2013)	2005–2010	710 SKT, 821 EBK	Mean age 2.1 ± 1.9 years	1-year GS: • EBK 80% for 8 kg, up to 91% for 20 kg • SKT 69% for 8 kg, up to 86% for 20 kg	4.4% (6.0% SKT, 3.0% EBK)	0.1%	• EBK superior 1-year GS compared to SKT
Afanetti [32] (France, 2012)	1990–2007	14 EBK. Paediatric recipients	Range 4–54 months	1-year GS: 71% 5-year GS: 64% 10-year GS: 55%	Thrombosis in 29%, leading to graft loss in 14%	Nil	• 3 of 4 thrombosis occurred from donors under 12 months old
Butani [33] (US, 2012)	2007–2011	8 EBK. Paediatric recipients	Median age 11.5 months (range 0.25–49)		1 thrombosis leading to graft loss (12.5%)	Nil	• Pulsatile perfusion used • Nil DGF
Sharma [17] (US, 2011)	2004–2010	20 EBK, 249 SCD, 215 LD. Adult recipients	Mean age 19.5 ± 10 months	5-year GS: EBK 92%, SCD 70%, LD 88%	Nil	1/20 (5%)	• DGF 1/20 (5%)

BW, body weight; CI, confidence interval; DBD, donation after brain death; DCD, donation after circulatory death; DGF, delayed graft function; EBK, en bloc kidney transplant; eGFR, estimated glomerular filatration rate; GS, graft survival; HR, hazard ratio; IQR, interquartile range; LD, live donor; SCD, standard criteria donor; SKT, single kidney transplant.

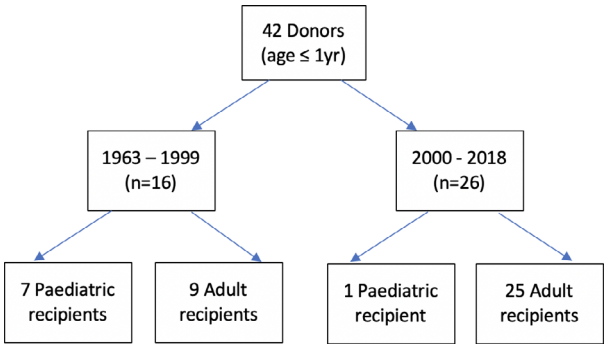

Figure 1 Patient flowchart.

paediatric recipients and 34 (81%) into adult recipients (Fig. 1). Thirty-five (83%) were transplanted en bloc, and 5 (12%) grafts were transplanted as single kidneys. Data regarding the remaining nine kidneys were missing from the database. Amongst the cohort, 4 (4/42; 10%) patients were recipients of their second transplant. Donor and recipient characteristics are shown in Table 2. Median donor weight for era 1963–1999 was 12.5 kg (IQR 10–15), and for 2000–2018 was 11 kg (IQR 10–12); *P*: 0.04.

Comparing the two eras, there were notable differences in recipient characteristics. In the earlier period, children accounted for 44% (7/16) of total recipients compared to 4% (1/26) in the later period when the vast majority of recipients were adults (25/26; 96%); $P < 0.01$. As a result, there was an increase in median recipient weight 52.5 kg [interquartile range (IQR) 27–60] to 70 kg [IQR 63–86.5]; $P < 0.01$.

Median total ischaemia time was not statistically different between the two time periods; 14.5 h [IQR 10–17.5] from 1963 to 1999 compared to 13 h [IQR 11–15] from 2000 to 2018; *P*: 0.80. There was an increase in waiting time from 13 months [IQR 5–35] in 1963–1999 to 52 months [IQR 31–68] in 2000–2018; $P < 0.01$.

Patient survival

From 1963 to 1999, patient survival was 75% and 69% at 1 and 5 years, respectively. From 2000 to 2018, patient survival was 100%; *P*: 0.70 (Fig. 2).

Graft survival

Death-censored graft survival from 1963 to 1999 was 50% and 43% at 1 and 5 years, respectively. From 2000 to 2018, death-censored graft survival was 85% at 1 and 5 years (Fig. 3).

Graft function and DGF

From 1963 to 1999, mean serum creatinine was 115 ± 59 and 1175 ± 49 µmol/l at 1 and 5 years, respectively. From 2000 to 2018, mean serum creatinine was 895 ± 17 and 735 ± 15 µmol/l at 1 and 5 years, respectively. Mean serum creatinine at 1 and 5 years was 875 ± 61 and 80 µmol/l for children and 985 ± 35 and 865 ± 3 µmol/l for adults.

Incidence of DGF in the second era from 2000 to 2018 was 15%. Data regarding DGF from the first era from 1963 to 1999 were largely missing.

Table 2. Donor and recipient characteristics.

	Child recipient (1963–1999)	Child recipient (2000–2018)	Adult recipient (1963–1999)	Adult recipient (2000–2018)
n	7	1	9	25
Donor weight, median (IQR)	14 (12, 15)	10 (10, 10)	12 (10, 15)	11 (10, 12)
Donor gender				
Female	3 (50%)	0 (0%)	4 (50%)	6 (24%)
Male	3 (50%)	1 (100%)	4 (50%)	19 (76%)
Total ischaemia, median (IQR)	14 (8, 19)	14 (14, 14)	14.5 (10, 17.5)	13 (11, 15)
Recipient age at transplant, median (IQR)	4 (1, 10)	16 (16, 16)	46 (40, 50)	45 (37, 48)
Recipient weight (kg), median (IQR)	21 (12, 27)	48 (48, 48)	59 (55, 65.5)	70 (64, 89)
Recipient gender				
Female	3 (43%)	0 (0%)	3 (33%)	9 (36%)
Male	4 (57%)	1 (100%)	6 (67%)	16 (64%)
Waiting time (years), median (IQR)	0.6 (0.2, 1.1)	0.2 (0.2, 0.2)	2.2 (1.1, 4.7)	4.6 (2.7, 5.7)
Graft number				
1	7 (100%)	1 (100%)	9 (100%)	21 (84%)
2	0 (0%)	0 (0%)	0 (0%)	4 (16%)

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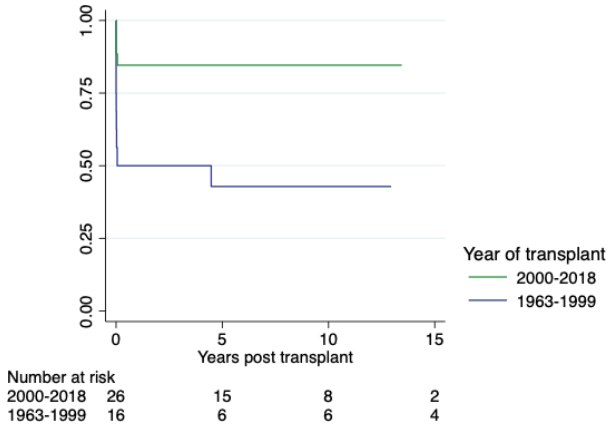

Figure 2 Patient survival by year of transplant.

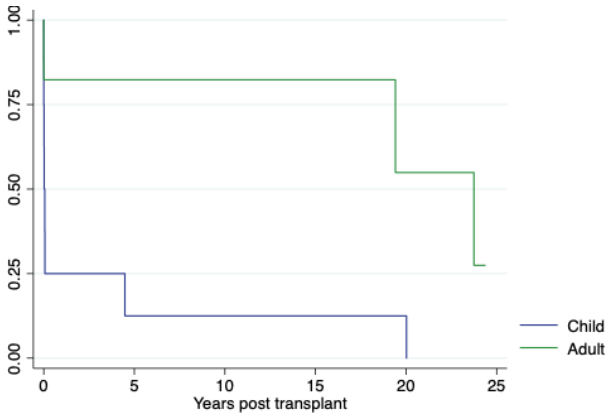

Figure 3 Death-censored graft survival by year of transplant.

Surgical complications

Causes of graft loss are listed in Table 3. Surgical complications were responsible for graft loss in 25% of recipients in the first era from 1963 to 1999, and 12% of recipients in the second era from 2000 to 2018. Paediatric recipients had a higher risk of surgical complications (38%) compared with adult recipients (12%), although the small sample size precludes any clear conclusions from this subanalysis. Thrombosis was the cause of graft loss in 12% of recipients in the first era from 1963 to 1999, and 8% of recipients in the second era from 2000 to 2018.

Discussion

This study describes the collective experience of kidney transplantation, utilizing paediatric deceased donors ≤1 year old, in Australia and New Zealand, from 1963 until 2018. Using national registry data, good graft outcomes were demonstrated in adult recipients. Historically, the poor outcomes found in the youngest donor kidneys transplanted into young recipients have been attributed to surgical complications, high rates of graft thrombosis, early rejection and hyperfiltration injury [1,7]. Consequently, there has been a reluctance to use the youngest donor kidneys for transplantation into young donors, with a considerable decline in paediatric recipients of young donor kidneys from 7/16 in 1963–1999 to 1/26 in 2000–2018 in our series.

Patient survival

Our study, albeit small, describes our growing experience using donors aged 1 year or less. There was a trend towards improved patient survival in the latter era from 2000 to 018.

Kizilbash *et al.* [8] found that recipients of paediatric en bloc transplants had superior 10 year patient (89% vs. 80%; *P*: 0.04) and graft survival (52% vs. 40%; *P*: 0.04) compared with matched nonen bloc recipients. After multivariate adjustment, en bloc transplantation was associated with superior patient survival compared to remaining on the wait list (aHR 0.58; 95% CI 0.36–0.95; *P*: 0.03).

Table 3. Causes of graft loss.

	Child recipient (1963–1999) *n* = 7	Child recipient (2000–2018) *n* = 1	Adult recipient (1963–1999) *n* = 9	Adult recipient (2000–2018) *n* = 25
Death with function	0	0	3 (33%)	4 (16%)
Acute rejection	2 (29%)	0	1 (11%)	0
Chronic allograft nephropathy	1 (14%)	0	2 (22%)	0
Haemolytic uraemic syndrome	1 (14%)	0	0	0
Thrombosis	1 (14%)	1 (100%)	1 (11%)	1 (4%)
Haemorrhage	0	0	1 (11%)	0
Cortical necrosis (not due to rejection)	1 (14%)	0	0	1 (4%)

Minimizing time spent on dialysis has benefits beyond patient survival for children. A shorter duration of dialysis has been associated with increased pretransplantation height in paediatric patients, which is in turn correlated with greater final adult height [9]. Cognitive development may also be improved with earlier transplantation, and better neurocognitive outcomes were achieved in infants who spent less time on dialysis [10].

Graft survival

Our registry data showed an improvement in graft survival in the second era from 2000 to 2018, likely related to refinement in surgical techniques and advancements in immunosuppression.

An analysis of the European Society of Paediatric Nephrology/European Renal Association-European Dialysis and Transplantation Association (ESPN/ERA-EDTA) registry demonstrated greatest risk of graft failure when kidneys from the youngest (0–5 years of age) deceased donors were transplanted into the youngest recipients (0–5 years of age) compared to older recipients (aHR 2.01, 95% CI 1.26–2.27) [11].

Despite a higher incidence of early complications, long-term graft outcomes of utilizing small paediatric kidneys are favourable. These small kidneys seem to demonstrate potential for catch up growth, attaining graft function often superior to adult standard criteria donors [12,13]. Yaffe *et al.* and Winnicki *et al.* [14,15] both demonstrated that despite marginally inferior outcomes in small paediatric kidneys at 1-year follow-up, and compared to adult standard criteria organs, this had equalized at 5 years. Additionally, Sureshkumar *et al.* [16] found that paediatric en bloc kidneys conferred long-term graft survival similar to live donor kidneys over a 25-year period after transplantation, as well as superior graft function.

Graft function

Our study demonstrated a trend towards improved renal function at one and five years in the second era from 2000 to 2018. Sharma *et al.* [17] found that after 1 year, serum creatinine levels were comparable for live donor recipients and en bloc paediatric transplants from donors <15 kg. Paediatric grafts undergo compensatory hypertrophy and continued somatic growth, and the lack of cellular senescence in these very young donors may be a major contributory factor to the observed lack of long-term GFR decline [1,18,19]. Although kidney size and volume were not evaluated in the present study, a mean serum creatinine improved from 89 $\pm$ 17 μmol/l at one year to 73 $\pm$ 15 μmol/l at 5 years, indicating the graft's adaptation to increasing size and body mass of the recipient. Pape *et al.* [18] demonstrated that paediatric grafts were able to grow within the recipient in the first 3 years after transplantation, independent of acute rejection episodes, whilst adult grafts lose their capacity after initial down-regulation when adapting to the recipient's renal function requirements. Additionally, Mitrou *et al.* [20] demonstrated in paediatric en bloc transplants from donors weighing <10 kg, all grafts underwent rapid growth, especially during the first year post-transplant. By the third week, the small grafts were no longer significantly smaller than grafts which had originated from donors >10 kg.

Surgical complications

The incidence of graft lost due to surgical complications improved in the second era from 2000 to 2018 to 12%, reflecting refinement in surgical techniques. Taher *et al.* [21] found that recipient weight <15 kg at the time of transplant was a significant risk factor for developing intra-abdominal complications. This emphasizes the importance of meticulous surgical technique in achieving good outcomes, especially when both donor and recipient are small.

Vascular thrombosis remains a main concern in paediatric kidney transplantation, especially from very small donors. The incidence of graft loss due to thrombosis improved to 8% in the second era of our study from 2000 to 2018. Our study was too underpowered for meaningful comparison between adult and paediatric recipients. Other studies demonstrate that young age of both the donor and recipient provides the greatest risk factor of thrombosis. Singh *et al.* [4] in a univariate analysis of 4394 transplants showed that graft loss due to thrombosis was significantly higher in children <2 years old, compared to older groups (9% vs. 3.5%). A study of UNOS data demonstrated a 10% rate of vascular thrombosis using donors <5 years of age compared to a 5% thrombosis risk amongst donors aged 12–17 years [22]. However, more recent studies demonstrate temporal improvement in complications rates and graft survival which may be due to the progressive refinement of surgical techniques [15,20,23]. Kizilbash *et al.* [8] demonstrated that the higher risk of graft loss due to thrombosis during the first year post-transplant amongst en bloc recipients was only seen in the earliest era of their study from 1987 to 1997. From 1998 to 2017, there was no difference in 1-year graft survival between en bloc and standard criteria donor kidney recipients.

Limitations

Our retrospective study is subject to limitations inherent in registry data, such as recall bias and patient selection bias. Given the long timeframe of retrospective analysis, not all donor kidneys were accounted for as there was missing data from the earlier days of the ANZDATA registry. Our small sample size also limits interpretation of subgroup data. Secondly, only surgical complications which led to graft loss were recorded in the ANZDATA registry. As such, data pertaining to important urological complications such as ureteric leaks and ureteric strictures were not able to be retrieved. Urological complications lead to substantial morbidity. In the same way that vascular anastomosis poses a challenge to the transplant surgeon, the small calibre of ureters from very small paediatric donors also increases the risk of urological complications [24,25]. Thirdly, the distribution of paediatric and adult recipients amongst the two time periods is skewed. As such, direct comparison of outcomes in the paediatric versus adult cohorts is confounded by the development in modern immunosuppression and improvements in surgical technique. Finally, our analysis included many, but not all of the factors which may confer risks during the perioperative period, such as implantation technique, anastomosis time, anatomical differences, immunosuppression regimen and surgeon experience. Given the technical challenges of transplanting small paediatric grafts, surgeon experience may play a pivotal role in graft outcomes. The study nevertheless exhibits real-world data demonstrating favourable graft survival in the current era when very small paediatric grafts are transplanted into adult recipients.

Conclusions

Paediatric kidneys are excellent quality organs and have the potential to expand the donor pool. We advocate the judicious use of these small paediatric grafts from donors ≤1 year old. Surgical complications remain a major impediment to the widespread use of these small paediatric kidneys. Meticulous surgical technique and careful monitoring of clinical course, especially in the early postoperative period, are the key to good long-term graft outcomes. Selection of recipients, in particular with regard to the age of the recipient, is an important factor in avoiding surgical complications such as vascular thrombosis. Prospective data collection of detailed donor and recipient characteristics and complications may inform the use of these inherently small donors. We encourage strategies to reduce discard of this precious resource as well as techniques to reduce early graft loss.

Authorship

JY: participated in the performance of the research, data analysis and writing of the manuscript. PAC: participated in the performance of the research, data analysis and writing of the manuscript. KW: participated in the performance of the research and writing of the manuscript. HC: participated in the performance of the research and data analysis. EC: participated in the performance of the research. DT: participated in the performance of the research and writing of the manuscript. HL: participated in the performance of the research and writing of the manuscript. RA: participated in the performance of the research and writing of the manuscript. LY: participated in the performance of the research and writing of the manuscript. VWTL: participated in the performance of the research and writing of the manuscript. HCCP: participated in the performance of the research, data analysis, writing of the manuscript, and supervision of the study.

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Conflicts of interest

The authors have declared no conflicts of interest.

REFERENCES

1. Troppmann C, Santhanakrishnan C, Fananapazir G, *et al.* Pediatric en bloc kidney transplantation from very small (<=10kg donation after circulatory death (versus brain death) donors: single-center matched pair analysis of 130 transplants. *Am J Transplant* 2018; **18**: 2811.
2. Foss A, Line P, Brabrand K, *et al.* A prospective study on size and function of paediatric kidneys (<10 years) transplanted to adults. *Nephrol Dial Transplant* 2007; **22**: 1738.
3. Maluf D, Carrico R, Rosendale J, *et al.* Optimizing recovery and utilization of

deceased donor kidneys from small, pediatric donors. *Am J Transplant* 2013; **13**: 2703.
4. Singh A, Stablein D, Tejani A. Risk factors for vascular thrombosis in pediatric renal transplantation: a special report of the North American Pediatric Renal Transplant Cooperative Study. *Transplantation* 1997; **63**: 1263.
5. Lam V, Laurence J, Robertson P, *et al.* En bloc paediatric kidney transplant: is this the best use of a scarce resource? *ANZ J Surg* 2007; **79**: 27.
6. Thomusch O, Tittlebach-Helmrich D, Meyer S, *et al.* Twenty-year graft survival and graft function analysis by a matched pair study between paediatric en bloc kidney and deceased adult donors grafts. *Transplantation* 2009; **88**: 920.
7. Dion M, Rowe N, Shum J, *et al.* Donation after cardiac death pediatric en bloc renal transplantation. *J Urol* 2015; **193**: 281.
8. Kizilbash S, Evans MD, Chinnakotla S, *et al.* Survival benefit of en bloc transplantation of small pediatric kidneys in children. *Transplantation* 2020. https://doi.org/10.1097/TP.0000000000003158.
9. Jung HW, Kim HY, Lee YA, *et al.* Factors affeecting growth and final adult height after pediatric renal transpalntation. *Transplant Proc* 2013; **45**: 108.
10. Johnson RJ, Warady BA. Long-term neurocognitive outcomes of patients with end-stage renal disease during infancy. *Pediatr Nephrol* 2013; **28**: 1283.
11. Chesnaye NC, van Stralen KJ, Bonthuis M, *et al.* The association of donor and recipient age with graft survival in paediatric renal transplant recipients in a European Society fo Paediatric Nephrology/European Renal Association-European Dialysis and Transplantation Association Registry study. *Nephrol Dial Transplant* 2017; **32**: 1949.
12. Bhayana S, Kuo YF, Madan P, *et al.* Pediatric en bloc kidney transplantation to adult recipients: more than suboptimal? *Transplantation* 2010; **90**: 248.
13. Wijetunga I, Ecuyer C, Martinez-Lopez S. Renal transplant from infant and neonatal donors is a feasible option for the treatment of end-stage renal disease but is associated with increased early graft loss. *Am J Transplant* 2018; **18**: 2679.
14. Yaffe HC, Friedmann P, Kayler LK. Very small pediatric donor kidney transplantation in pediatric recipients. *Paediatr Transplant* 2017). **21**, e12924. https://doi.org/10.1111/petr.12924.
15. Winnicki E, Dharmar M, Tancredi D, *et al.* Comparable survival of en bloc versus standard donor kidney transplants in children. *J Pediatr* 2016; **173**: 169.
16. Sureshkumar KK, Habbach A, Tang A, Chopra B. Long-term outcomes of pediatric en bloc compared to living donor kidney transplantation: a single-center experience with 25 years follow-up. *Transplantation* 2018; **102**: e245.
17. Sharma A, Ramanathan R, Behnke M, *et al.* Single pediatric kidney transplantation in adult recipients: comparable outcomes with standard criteria deceased donor kidney transplantation. *Transplantation* 2013; **95**: 1354.
18. Pape L, Hoppe J, Becker T, *et al.* Superior long-term graft function and better growth of grafts in children receiving kidneys from paediatric compared with adult donors. *Nephrol Dial Transplant* 2006; **21**: 2596.
19. de Santis Feltran L, Nogueira PCK, Silva FAB, *et al.* A one year prospective comparison of kidney growth and function in children recipients of grafts from children and adults. *Transplantation* 2010; **90**: 777.
20. Mitrou N, Aquil S, Dion M, *et al.* Transplantation of pediatric renal allografts from donors less than 10kg. *Am J Transplant* 2018; **18**: 2689.
21. Taher A, Zhu B, Ma S, *et al.* Intra-abdominal complications after pediatric kidney transplantation: incidence and risk factors. *Transplantation* 2019; **103**: 1234.
22. Bresnahan BA, McBride MA, Cherikh WS, *et al.* Risk factors for renal allograft survival from pediatric cadaver donors: an analysis of United Network for Organ Sharing data. *Transplantation* 2001; **72**: 256.
23. Considine SW, Davis NF, McLoughlin LC, *et al.* Long-term outcomes of en-bloc renal transplantation from paediatric donors into adult recipients. *Surgeon* 2019; **17**: 1.
24. Berger PM, Diamond JR. Ureteral obstruction as a complication of renal transplantation: a review. *J Nephrol* 1998; **11**: 20.
25. Shoskes DA, Hanbury D, Cranston D, *et al.* Urological complications in 1000 consecutive renal transplant recipients. *J Urol* 1995; **153**: 18.
26. Su X, Shang W, Liu L, *et al.* Transplantation of a single kidney from paediatric donors less than 10kg to children with poor access to transplantation: a two-year outcome analysis. *BMC Nephrol* 2020; **21**: 250.
27. Dai H, Peng L, Peng F, *et al.* A novel technique for en bloc kidney transplantation from infant donors with extremely low body weight by using the distal abdominal aorta as an outflow tract. *Am J Transplant* 2018; **18**: 2200.
28. Al-Shraideh Y, Farooq U, El-Hennawy H, *et al.* Single vs dual (en bloc) kidney transplants from donors 5 years of age: a single center experience. *World J Transplant* 2016; **6**: 239.
29. Wang H, Li J, Liu L, *et al.* En bloc kidney transplantation from infant donors younger than 10 months into paediatric recipients. *Paediatr Transplant* 2017; **21**: e12845.
30. Gallinat A, Sotiopoulos G, Witzke O, *et al.* Kidney grafts from donors 5 yr of age: single kidney transplantation for paediatric recipients or en bloc transplantation for adults? *Paediatr Transplant* 2013; **17**: 179.
31. Maluf DG, Carrico RJ, Rosendale JD, *et al.* Optimizing recovery, utilization and transplantation outcomes for kidneys from small, 20kg, paediatric donors. *Am J Transplant* 2013; **13**: 2703.
32. Afanetti M, Niaudet P, Niel O, *et al.* Paediatric en bloc kidney transplantation into paediatric recipients: the French experience. *Paediatr Transplant* 2012; **16**: 183.
33. Butani L, Troppmann C, Perez RV. Outcomes of children receiving en boc renal transplants from small paediatric donors. *Paediatr Transplant* 2013; **17**: 55.