ORIGINAL ARTICLE

The impact of changing practice on improved outcomes of paediatric renal transplantation in the United Kingdom: a 25 years review

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SUMMARY

This review reports the outcomes of paediatric renal transplantation in the United Kingdom over the last 25 years. UK Transplant Registry data on 3236 paediatric renal transplants performed between 1 January 1992 and 31 December 2016 were analysed. Significant improvements in human leucocyte antigen (HLA) matching have been achieved; 84% of recipients received 000 or favourable (0 DR and 0 or 1 B) mismatched kidneys in 2016 compared with 27% in 1992. The median waiting time has increased from 126 days in 1999 to 351 days in 2016. Tacrolimus replaced ciclosporin in most immunosuppressive regimens after 2002. Renal transplant outcome has improved significantly, mainly because of a reduction in early graft loss. One-year donation after brain death renal allograft survival for those transplanted from 2012 to 2016 was 98%, compared with 72% for those transplanted from 1987 to 1991. Renal allograft survival for first kidney only transplants at 1, 5, 10, 20 and 25 years were 89%, 79%, 65%, 42% and 33% respectively. Superior survival with living donor was maintained throughout the study period with 25-year graft survival at 33% compared with 31% from deceased donor ($P < 0.0001$). Changes in immunosuppression regimens, improvements in HLA matching and a reduction of cold ischaemia time may in part explain the improvements in graft survival.

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Key words
human leucocyte antigen, immunosuppression, kidney, paediatric transplantation, renal, survival

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Introduction

Renal transplantation is the treatment of choice for children with end-stage kidney disease (ESKD) [1] giving better survival rates and quality of life compared with dialysis. The rate of paediatric renal transplant has remained steady over the last two decades with, approximately 130 paediatric kidney transplants being performed annually in the UK.

This review reports the outcomes of UK paediatric renal transplantation over the last 25 years. It describes the changes in clinical practice and organ allocation that may have contributed to improved post-transplant outcomes. There have been three different national kidney allocation schemes (NKAS) from deceased donors after brain death (DBD) during the 25-year review period, implemented in 1989, 1998 and most recently in 2006. Each of these schemes has changed

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the way in which kidneys are allocated to paediatric recipients.

Allocation schemes

The 1989 scheme mandated national sharing of one kidney from each DBD donor for a 'beneficial' matched adult or paediatric recipient. A 'beneficial' match between donor and recipient was defined as either no mismatches at HLA-A, HLA-B and HLA-DR (000 mismatches) or one mismatch for antigens either at the HLA-A or HLA-B loci, but no mismatch at the HLA-DR locus (100 or 010 mismatches). Paediatric recipients were prioritised for all paediatric donor kidneys.

In 1998 scheme, both kidneys from a DBD donor were allocated nationally for 000 mismatched adults and 000 mismatched and well-matched paediatric recipients to maximize the benefits from human leucocyte antigen (HLA) matching and ensure priority for highly sensitized and paediatric recipients. A well-matched kidney was defined as a maximum of one mismatch at HLA-A and HLA-B and no mismatch at HLA-DR (100, 010 and 110 mismatches). Kidneys for which no well-matched recipients were identified were retained and allocated by the local transplant centre according to locally agreed criteria.

The 2006 NKAS is the currently running scheme and gives absolute priority to all 000 (HLA-A, B, DR) mismatched and well-matched paediatric recipients for DBD donor kidneys. Paediatric recipients receive priority over adults at each level of matching. The importance of well-matched grafts was recognised for paediatric recipients, and a novel form of scoring was introduced linking HLA match and age to ensure that young recipients are prioritised for well-matched grafts. HLA mismatch was grouped as four new levels to represent the increasing risk of transplant failure associated with inferior HLA matching. These levels are:

1. Level 1 – [000 HLA-A,B,DR mismatch]
2. Level 2 – [0 DR + 0/1 B mismatch]
3. Level 3 – [0 DR + 2 B mismatch] or [1 DR + 0/1 B mismatch]
4. Level 4 – [1 DR + 2 B mismatch] or [2 DR mismatch].

In addition, equity of access was built in to the allocation algorithm benefiting long-waiting recipients by overcoming disadvantage posed by poor match grade. Also, paediatric recipients were no longer prioritised for paediatric donor kidneys but had increased access to adult donor kidneys up to the age of 50 years.

Materials and methods

Study cohort

In this study, a paediatric recipient or donor is defined as less than 18 years of age at the time of transplantation. There are currently 10 UK paediatric kidney transplant centres with a small number of paediatric recipients (16–17 years) being transplanted in adult centres. All centres provide mandatory data to the UK Transplant Registry (UKTR). Data were obtained from the registry on 3236 paediatric renal transplants from deceased and living donors performed over the 25 years between 1 January 1992 and 31 December 2015. An additional 476 transplants performed between 1 January 1987 and 31 December 1991 were included in the survival analysis to enable 25-year outcomes to be reported. Excluded are 73 multi-organ transplants, 63 liver and kidney transplants, five kidney and pancreas transplants and one heart and kidney transplant. A new data collection form was introduced in 1999 to capture additional information at the time of transplant. This included cold ischaemia time (CIT) and recipient dialysis status at the time of transplant.

Statistical methods

Trends in recipient, donor and transplant characteristics over the last 25 years are summarized. Kaplan–Meier estimates were used to compare long-term renal allograft and patient survival and comparisons between year groups were made using the log rank test. Renal allograft survival was defined as time from transplant to graft failure, censoring for death with a functioning graft. Patient survival was defined as time from transplant to patient death. A multivariate Cox proportional hazards model was developed to identify factors associated with improvements in graft survival. The effect of the year/era of transplant on outcomes was also included in the sub analysis including the factors that affected such outcomes.

Results

Donors

During the study period, only kidneys from deceased DBD donors aged between 5 and 50 years were allocated to paediatric recipients. Over the last 25 years, the numbers of such donors have fallen resulting in fewer DBD donor transplants; in 1992 there were 576 DBD donors aged 5–50 years but only 344 in 2016 (Fig. 1).

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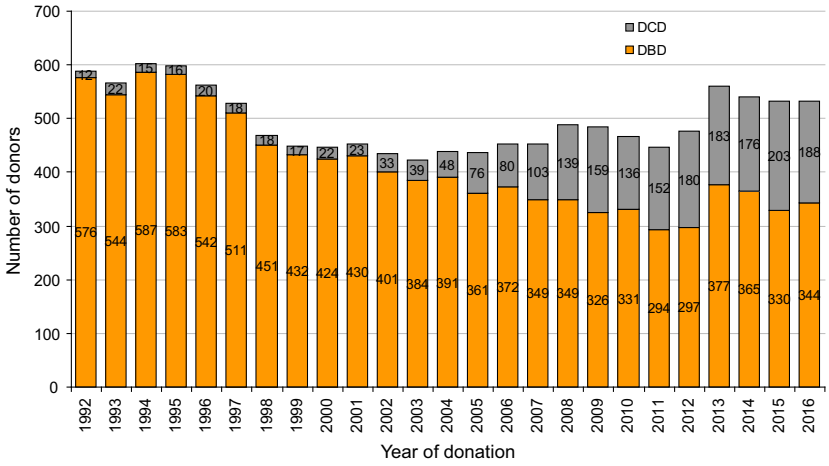

Figure 1 Deceased donors in the UK aged between 5 and 50 years, 1992–2011.

In recent years, there has been an increase in the number of donors after circulatory death (DCD) within this age range.

Between 1 January 1992 and 31 December 2016, there were 3236 paediatric renal transplants, 2081 from deceased donors (1736 donors) and 1155 from living donors. Donor characteristics are summarised in Table 1. The median age of deceased donors has increased steadily from 10 years in 1992 to 17 years in 1998, 34 years in 2006 and 36 years in 2016 (Fig. 2). This reflects both the general trend of increasing donor age, changing practice and changes in allocation policy in 1998 and 2006. The median age of living donors has remained constant at 40 years. Of the 1155 living donors, 1033 (89%) were parental (53% paternal, 47% maternal), 79 (7%) were siblings or other relatives and 43 (4%) were unrelated donors.

The cause of death for deceased donors was trauma in 35%, however this decreased from 56% in 1992 to just 5% in 2016. The majority of deceased and living donors were white and this has not changed over the review period. Cytomegalovirus (CMV) positive donors were also constant at 45% and 39% for living and deceased donors respectively.

Table 1. Demographics of donors used for paediatric kidney transplantation in the UK, 1992–2016.

	Deceased		Living	
	N	%	*N*	%
Donors	1736		1155	
Donor type				
Brain death	1696	98		
Circulatory death	40	2		
Living – related			1112	96
Living – unrelated			43	4
Donor ethnicity				
White	1169	96	799	84
Asian (Indo-Asian)	22	2	89	9
Black	12	1	23	2
Other	18	1	41	4
Not reported	515	–	203	–
Donor cause of death				
Trauma	603	35		
Intracranial haemorrhage	740	43		
Other	393	23		
Donor CMV				
Negative	1050	61	488	55
Positive	664	39	393	45
Not reported	22	–	274	–
Median donor age (IQ range)	22 (14–40)		40 (34–45)	

Transplants

Over the last 25 years, transplant activity has been stable with an average of 130 transplants each year. Of 3236 transplanted recipients, 1155 (36%) received a living donor renal transplant (LDRT). The proportion of LDRT increased from 11% in 1992 to 28% in 2016. This increase has been offset by a reduction in deceased donor renal transplants (DDRT). Only 43 of the 2081 DDRT were from DCD donors. Over the last 10 years, the number on the waiting list has reduced with 118 patients waiting in 2007 falling to 79 patients in 2016 (Fig. 3).

Patient characteristics for DDRT and LDRT are shown in Table 2. In both groups, the majority of transplants are performed in recipients aged 12–17 years at the time of transplant (54% and 48% respectively). The median age of recipients has remained relatively constant during the study, although in recent years a greater proportion of older paediatric recipients receive DDRT whilst a greater proportion of younger recipients receive LDRT.

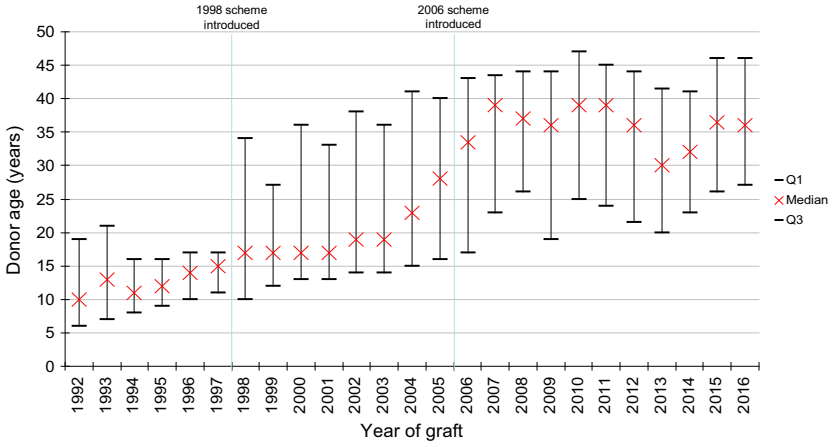

Figure 2 Deceased donor age for paediatric kidney only transplants, 1992–2011.

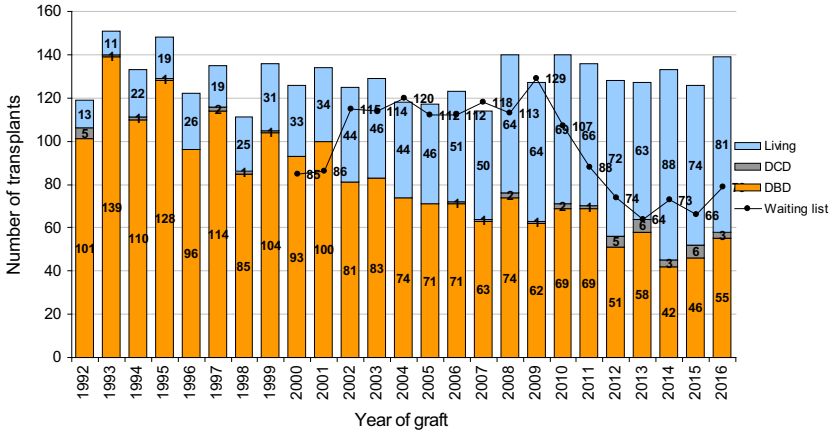

Figure 3 Deceased and living donor paediatric kidney only transplants and number on the waiting list, 1992–2011.

The number of ethnic minority recipients of DDRT increased from 13% in the early 1990s to 40% more recently. The proportion of LDRT performed in ethnic minority recipients has increased from 10% in 1992 to 17% in 2016. There has been no change in the recipients' gender over the review period for both DDRT and LDRT with approximately 60% being male.

Primary renal disease was not reported for approximately 30% of all recipients. Of those with reported renal disease, the most common causes of kidney failure were congenital renal dysplasia (22%), pyelonephritis (15%) and glomerulonephritis (13%). Information is limited because of variation in recording; the newer terminology of congenital abnormalities of the kidneys and urinary tract (CAKUT) was introduced after the data collection forms were created.

All DDRT were performed between identical or compatible blood groups. Since 2006, 28 blood group incompatible LDRT have been performed. Prior to 1999, dialysis status at time of transplant was not recorded; since then pre-emptive transplant rates for both DDRT and LDRT have remained relatively constant at 21% and 38% respectively.

Approximately 4% of transplants were performed in recipients with a calculated HLA antibody reaction frequency (cRF) of at least 85%. These are designated as highly sensitised recipients and prioritised for zero HLA-mismatched kidney transplants in the NKAS. There has been an increase in the number of sensitised recipients over the last 25 years and at least some of this may be because of advances in the way antibodies are detected.

Human leucocyte antigen matching is an important consideration in paediatric kidney transplantation as the majority of recipients will require a repeat graft in later life. Figure 4 shows the trend in HLA matching during the study. The proportion of well-matched transplants has improved significantly over time. In 1992, 27% of recipients received level 1 or 2 mismatched transplants, increasing to 84% in 2016. Better HLA matching has been achieved as a result of increased access to adult donor kidneys through the NKAS and a reduction in the use of poorly matched paediatric donor kidneys for paediatric recipients.

Ten per cent of recipients had re-transplants including 1% receiving third or subsequent transplants. Of the

Table 2. Recipient demographic characteristics for paediatric kidney only transplants, 1992–2016.

	Deceased donor		Living donor	
	N	%	*N*	%
Recipient age (years)				
0–5	356	17	284	25
6–11	597	29	321	28
12–17	1128	54	550	48
Ethnicity				
White	1434	76	920	83
Asian (Indo-Asian)	342	18	105	9
Black	62	3	24	2
Other	37	2	63	6
Not reported	206	–	43	–
Recipient gender				
Male	1232	59	723	63
Female	849	41	432	37
Primary renal disease				
Congenital renal dysplasia	314	20	211	26
Pyelonephritis	267	17	100	12
Glomerulonephritis	223	14	92	11
Other	778	49	423	51
Not reported	499	–	329	–
ABO match				
Identical	1856	89	894	78
Compatible	224	11	218	19
Incompatible	0	0	28	2
Not reported	1	–	15	–
Pre-emptive				
Yes	266	21	375	38
No	986	79	623	62
Not reported	829	–	157	–
Calculated reaction frequency*				
0–10	1470	71	799	69
11–30	92	4	32	3
31–60	263	13	134	12
61–84	181	9	143	12
85+	75	4	47	4
Graft number				
1	1819	87	1093	95
2	231	11	57	5
3 or more	31	1	5	<1

*A recipient's calculated hla antibody reaction frequency (cRF) is determined by comparing the unacceptable HLA specificities reported for the recipient with the HLA types of 10 000 donors on the national database. The % of blood group identical, HLA compatible donors determines the recipient's cRF.

re-transplants, 81% were DDRT and 19% LDRT. As expected, these recipients waited longer on the deceased donor waiting list, had higher levels of cRF and received less well-matched grafts.

As a trade-off to improve HLA matching, the median waiting time to DDRT has more than doubled from 126 days in 1999 to 351 days in 2016 (Fig. 5a). This compares favourably to adult recipient wait time of 1153 days in 2016.

Steps have been taken both on a local and national level to minimise CIT (Fig. 5b). Despite an increase in organ sharing, median CIT has fallen since 1999 from 18.8 h (IQ range 17–22) to 13.6 h (IQ range 10–16) in 2016.

Immunosuppressive drug therapy at 3 months post-transplant has changed during the study (Fig. 6). Prior to 2002, corticosteroids, azathioprine and ciclosporin were used for the majority of recipients. Subsequently, tacrolimus increasingly replaced ciclosporin, and more recently mycophenolate mofetil has replaced azathioprine in most immunosuppression regimens.

Patient and renal allograft survival

Long-term survival in paediatric recipients for first kidney only transplants between 1 January 1987 and 31 December 2016 is shown in Table 3. Renal allograft and patient survival estimates are given at 1, 5, 10, 20 and 25 years post-transplant. Overall, 25 years renal allograft survival is 33% and is significantly better following LDRT compared with DDRT, 33% (95% CI 18–41) and 31% (95% CI 27–35; $P < 0.0001$) respectively. Twenty-five year patient survival were 79% and 86% in DDRT and LDRT, respectively, no statistical difference between the two groups.

The main causes of allograft failure were rejection (42%) and vascular thrombosis (20%). The registry data did not distinguish between late acute rejection and chronic allograft nephropathy. Comparing the time periods 1992–1996 with 2011–2016, the proportion of recipients with graft loss from rejection fell from 41% to 38%, and graft failure from vascular thrombosis fell from 23% to 11%.

Figure 7a shows long-term survival after first kidney only transplant from DBD donors between 1 January 1987 and 31 December 2016 by recipient age at the time of transplant. Survival estimates are shown for each age group analysed at 1, 5, 10, 15, 20 and 25 years post-transplant. There is a significant difference in graft survival across the age groups at 1-year post-transplant. Recipients under the age of 6 years have lower 1-year renal allograft survival than recipients aged 6 years and over ($P < 0.0001$); 79% (95% CI 75–83) compared to 88% (95% CI 85–90) respectively. This difference is maintained up to 10 years after which (up to 25 years) the graft survival rates are similar in all age groups. Recipients under the age of 6 years maintained a small

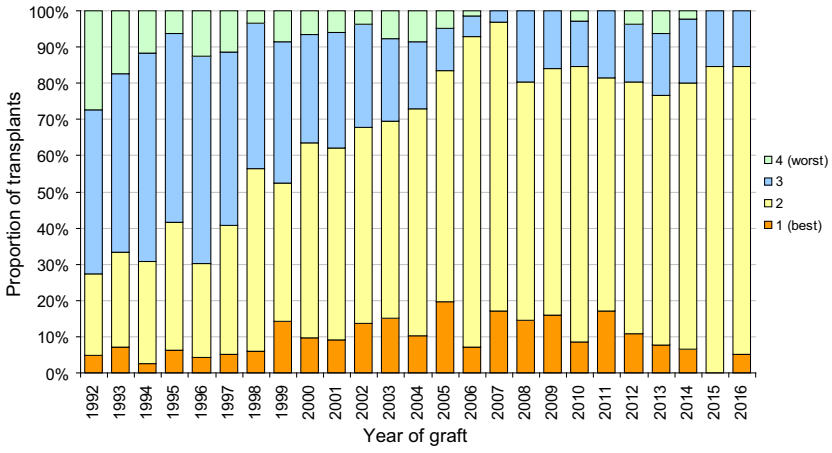

Figure 4 HLA mismatch levels of deceased paediatric kidney only transplant patients, 1992–2011.

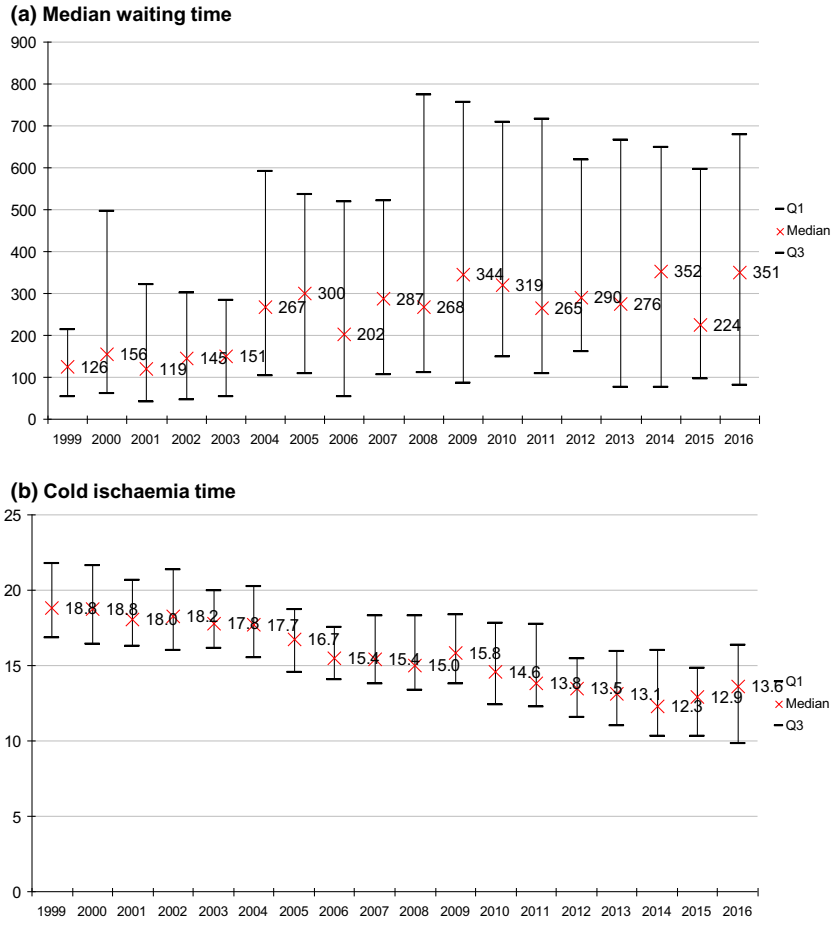

Figure 5 Deceased donor paediatric kidney only transplant patients, 1999–2011; (a) median waiting time, (b) cold ischaemia time.

but significantly inferior patient survival throughout the study period.

Long-term renal allograft survival in paediatric recipients for first DDRT and LDRT is shown in Fig. 7b. Renal allograft survival estimates are shown for each time period analysed. There has been a significant improvement in 1-year renal allograft survival over time following DDRT; 98% (95% CI 94–99) for those transplanted in 2012–2016 compared to 72% (95% CI 68–76) in 1987–1991 ($P < 0.0001$). There has also been a significant improvement in graft survival over time following LDRT; 98% (95% CI 96–99) in 2012–2016 compared to 92% (95% CI 78–97) in 1987–1991 ($P = 0.03$). There has also been a significant improvement in

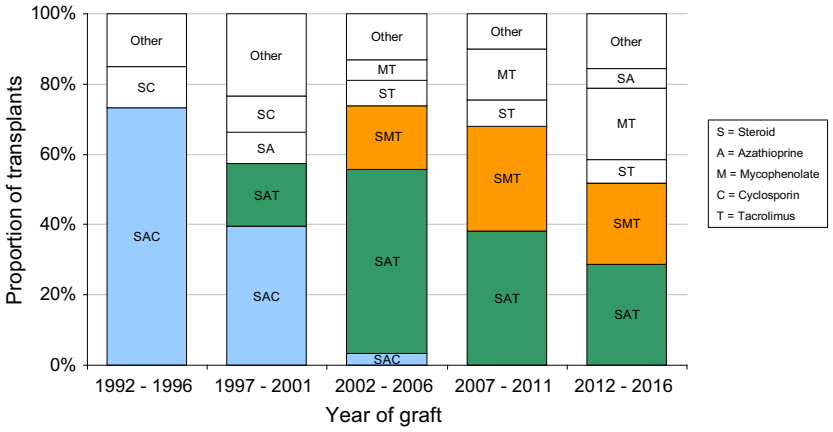

Figure 6 Reported immunosuppression after deceased paediatric kidney only transplant at 3 month, 1992–2011.

Table 3. Graft and patient survival following first paediatric renal transplant, 1987–2016.

	% Survival (95% confidence interval)				
	1 year	5 year	10 year	20 year	25 year
All renal transplants					
Allograft survival	89 (88–91)	79 (77–80)	65 (63–67)	42 (39–45)	33 (29–37)
Patient survival	99 (98–99)	97 (96–97)	93 (92–94)	84 (81–85)	80 (77–82)
Deceased donor renal transplants (DDRT)					
Allograft survival	86 (85–88)	75 (73–76)	61 (59–63)	40 (37–43)	31 (27–35)
Patient survival	99 (98–99)	96 (95–97)	92 (91–93)	83 (80–85)	79 (75–81)
Living donor renal transplants (LDRT)					
Allograft survival	96 (95–97)	89 (86–91)	74 (70–78)	49 (41–57)	33 (18–49)
Patient survival	99 (98–99)	98 (96–98)	94 (92–96)	86 (79–91)	86 (79–91)

patient survival over time following DDRT; 99% (95% CI 97–100) in 2012–2016 compared to 98% (95% CI 96–99) in 1987–1991 ($P = 0.04$). There were no statistically significant differences in patient survival over time following LDRT (Fig. 8).

Figure 7c shows long-term renal allograft survival by the year of transplant for both first DDRT and LDRT excluding failures within the first year. There is now only a borderline significant difference in survival following DDRT over the time periods meaning that most of the improvements in this group have been because of a reduction in early graft loss. The survival from LDRT has continued to improve over time following LDRT.

Long-term allograft and patient survival for first parental LDRT are shown in Fig. 7d by donor sex (paternal/maternal). There is no significant difference in short-term allograft survival between paternal and maternal donors (1-year survival 96% and 95% respectively; $P = 0.7$). However, there is a significant difference in longer term allograft outcomes between the two groups, although the number of transplants reaching 25-year survival is small [10-year allograft survival 81% paternal (76–86), 69% maternal (62–75; $P = 0.003$); 25-year allograft survival 39% paternal (17–61), 29% maternal (9–53; $P = 0.002$)]. There is no difference in patient survival between paternal & maternal donors.

Discussions

We report long-term outcomes of paediatric renal transplants in the UK with a 25-year patient survival of 86% and 79% after first LDRT and DDRT respectively, the latter being mainly DBD transplants. The 25-year renal allograft survival was significantly better at 33% for LDRT and 31% for DDRT. During this time, renal allograft outcome has improved across both donor types and our data suggest that in part the improvement in DDRT is related to changes in immunosuppression, improved HLA matching and a reduction in CIT. Improved matching has come at the expense of increased waiting time and increasing deceased donor age.

NHS Blood and Transplant organ allocation systems are under constant review and analysis of each system

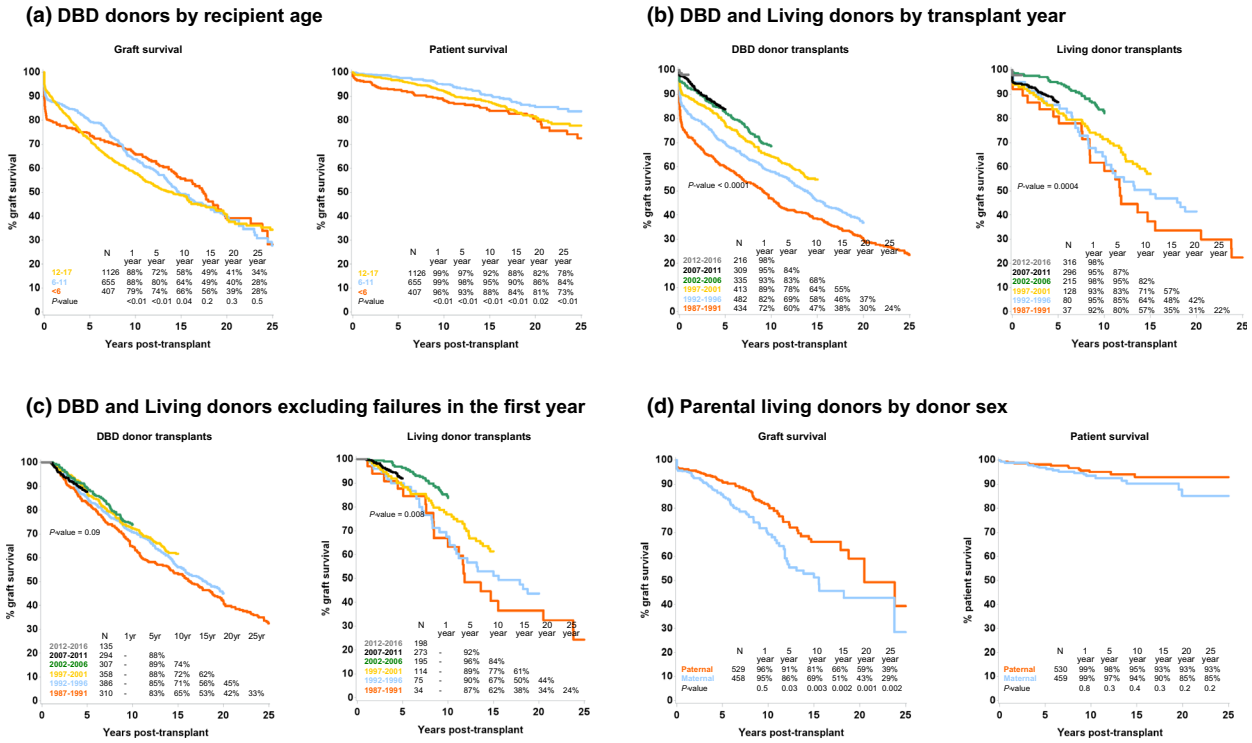

Figure 7 Long-term survival after first paediatric kidney only transplant, 1987–2011; (a) donors after brain death (DBD) donors by recipient age, (b) DBD and living donors by transplant year, (c) DBD and Living donors by transplant year, excluding failures in the first year, (d) Parental living donors by donor sex.

has informed the development of the subsequent algorithm [2–5]. Postlethwaite *et al.* [6] published data on the outcome of paediatric renal transplants performed between 1986 and 1995 and found in multi-factorial modelling that donor and recipient age and HLA matching affected outcome as did CIT. Following this, only donors aged 5–50 years were used and preference was given to placing well-matched kidneys to paediatric recipients.

Over the last 25 years, the number of deceased DBD donors has fallen partly as a result of seat belt and drink-driving campaigns and laws and a change in the logistics of managing adult donors with head injuries. Over the same time period, there has been an increase in the number of living donors and DCD donors. DCD donor kidneys have not been used extensively in paediatric recipients but in adult recipients show comparable outcomes to DBD kidneys [7,8]. Plans are in place to

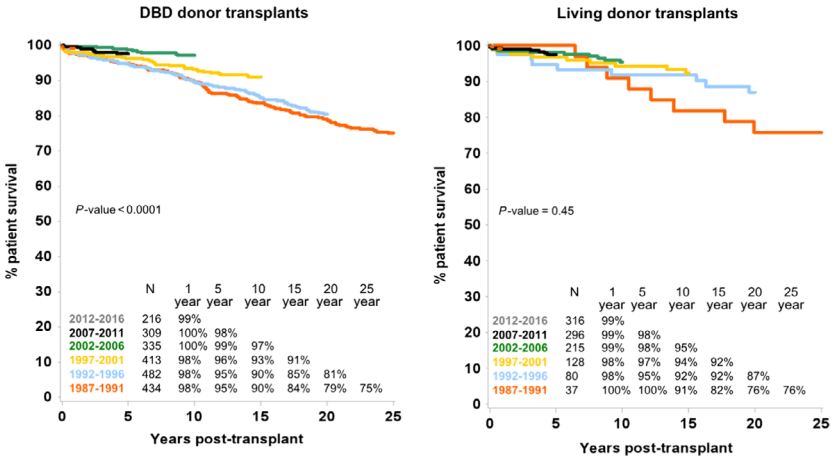

Figure 8 Patient survival over the years following first paediatric only kidney transplant.

make these kidneys more widely available to paediatric recipients.

Overall, LDRT outcomes were better than DDRT and this advantage was maintained throughout the study period. LDRT also enabled pre-emptive transplantation. The medium and long-term outcomes of pre-emptive renal transplants were better than those who spent a period on the waiting list. This is well recognised and reported in literature [9]. The majority of pre-emptive transplants were LDRT thus explaining in part, the improved outcome.

The improved outcomes with LDRT over DDRT (33% vs. 31% 25-year survival) are quantitatively less than that seen in adult practice. Similarly, the half-life for LDRT and DDRT were 15 and 14 years respectively. This may be explained by younger standard criteria donors and a better HLA matching than in adult practice.

Expanding the donor age allows for better matching but older donor age itself is a recognised risk factor for renal allograft failure [10]. Renal function declines with advancing age and transplantation of reduced nephron numbers may reduce the longevity of the graft. This effect is seen both in deceased [11] and living donation [12]. For this reason, the upper age of deceased donor for paediatric recipient is currently set at 50 years. Reducing the maximum acceptable donor age would result in fewer available organs and with potentially less favourable matching. These effects were offset by the increase in wait time.

For children who are easy to match, it is recommended that they are listed initially for a well-matched kidney, either a level 1 match (000 mismatch) or a level 2 match (0DR or 0/1B mismatch). Using this approach, the proportion of recipients receiving a well-matched kidney increased from 27% in 1992 to 84% in 2016. It is hoped that this will have both a beneficial effect on graft outcome and reduce the risks of sensitisation and make it easier to receive a second or subsequent graft. Poor HLA matching and sensitization are recognised risk factors for antibody-mediated rejection and a reduced renal allograft survival [13,14].

Using only a restricted range of DBD donors and an improved HLA matching in paediatric transplantation comes at the cost of increasing the median wait time during the study period from 126 days in 1999 to 351 days in 2016. For children on dialysis this may represent a time of poor growth, missed education and restricted activities and increased morbidity. Increased waiting time can be offset by timely listing for transplantation.

Patient and renal allograft survival has improved over the last two decades; 1-year graft survival has increased from 72% (1987–1991) to 98% (2012–2016) mostly because of a reduction in early graft loss. This is likely to be from improvements in surgical techniques, prevention of thrombosis, reduction of CIT and prevention of acute rejection. Postlethwaite *et al.* [6] described inferior graft outcome from paediatric donors aged less than 5 years. Such findings are recently confirmed in a study by Dave *et al.* [15]. The poor outcome was largely attributed to increased surgical complications from such practice and importantly graft thrombosis. There were few instances of small paediatric kidneys being used in young recipients in this cohort. Kidneys from donors less than 5 years are used in some centres and are often transplanted en bloc into adult recipients. There have been reports of the use of en bloc kidneys in paediatric and adolescent recipients [16,17] and with improving surgical techniques we expect to see increasing use of paediatric en bloc kidneys in paediatric recipients.

Figure 5b demonstrates the reduction in CIT which has been seen despite an increase in organ exchange to allow better matching. This reduction in CIT has been achieved through a variety of efforts including: pre-emptive allocation of kidneys, better access to operating theatre and virtual cross-match. Pre-emptive allocation allows for the recipient to be admitted early and optimised (e.g. dialysis prior to transplant). The use of virtual cross-match in nonsensitised recipients has enabled transplant to proceed without the wait for a conventional cross-match and achieving a significant reduction of CIT.

Our study, with 25-year paediatric renal transplant outcome data on 471 grafts, is one of the largest studies to report long-term outcome data. This compares favourably to published long-term outcome from national and regional registries. The published studies on the outcome of paediatric renal transplants are summarised in Table 4 [18–29].

Most of these studies on the outcome of paediatric renal transplantation with the exception of two studies from the US [18,19], one from the Australia and New Zealand registry data [20] and one from Iran [25] report outcome from smaller cohort of patients and only one study reported 25-year outcome [24]. Most studies have reported the outcome of the paediatric group as a whole. One study Harmon *et al.* [19] reports outcome stratified by age and showing worse outcome at the two extremes of paediatric age group (5-year graft survival of 73% in 1–5 years, 77% in 6–10 years

Table 4. Published data on outcome for paediatric renal transplantation.

Authors	Published year	Number of transplant	Age group	Country region	Graft survival years	Overall %	LDRT %	DDRT %
Mumford *et al.*	–	3236	All	UK	25	33	35	33
					20	42	49	40
					10	65	74*	61
					5	79	89	75
Feld *et al.* [18]	1997	4329	All	USA	6	–	73	56
Harmon *et al.* [19]	2005	7500†	1–5	USA	5	–	–	73
			6–10	USA	5	–	–	77
			10–18	USA	5	–	–	62
McDonald and Craig [20]	2004	1634	All	ANZ	10	79	–	–
					20	66	–	–
Groothoff *et al.* [21]	2004	397	All	Netherland	10	45	75	43
					20	30	29	49
Tangeraas *et al.* [22]	2008	251	All	Norway	10	69	–	–
					20	45	–	–
Abe *et al.* [23]	2011	52	All	Japan	20	48	48	–
Offner *et al.* [24]	1999	150	All	Hannover	10	–	48	41
					20	–	–	31
					25	–	–	31
Otukesh *et al.* [25]	2011	907	All	Iran	10	59	59‡	–
					15	45	45‡	–
Van Damme-Lombaerts *et al.* [26]	2001	100	All	Belgium	10	56	69	52
Englund *et al.* [27]	2003	53	All	Sweden	10	66	72	42
Mehrabi *et al.* [28]	2004	354	All	Heidelberg	10	–	75	–
Vats *et al.* [29]	2002	290	All	USA	5	–	88	75
					10	–	75	46

*57% in earlier cohort and 82% in the recent cohort.

†Estimated number, 50% deceased donor.

‡Majority LDRT (95.2%).

and 62% in 11–18 years groups). Many of these studies have also compared outcome between LDRT and DDRT all showing better survival with LDRT. Such advantage of LDRT over DDRT is small and insignificant in some studies compared to that in adult transplantation particularly over long term. This is supported by our data and other recently published studies. Whilst the improved outcome for LDRT is mainly attributed to better matching and a shorter cold ischaemia time, in paediatric deceased donor transplantation, a better HLA matching, younger donor age and a lower rate of cerebrovascular death may explain the smaller gap in the outcomes of DDRT and LDRT in paediatric renal transplant.

Our study reporting long-term outcome of UK paediatric transplants is one of the largest to date to report 25-year outcome data. The study has limitations associated with registry data, particularly when drawing time-to-event type of conclusions. Overall results are comparable to published data, and we have seen improvement in outcome during the study period. Better HLA matching, changes in immunosuppression and a reduction in CIT may have contributed to the improved outcome. Refinement in surgical technique during this period may also have helped reduce early graft loss. The study also demonstrates that large-scale policy intervention can deliver improved long-term outcome in paediatric renal transplant.

Authorship

Lisa Mumford, Heather Maxwell, Stephen Marks, Niaz Ahmed and Jane Tizard all contributed to the study conception, design and drafting of the paper. Lisa Mumford performed the analysis. All authors have had final approval of the submitted paper.

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Conflicts of interest

The authors of this manuscript have no conflicts of interest to disclose.

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