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Original Articles

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Expanding the criteria of renal kidneys for transplantation: use of donors with acute renal failure

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Abstract

Background. Increased numbers of patients waiting for renal transplantation have led to widening selection criteria for grafts. Thus, we have evaluated the outcome of transplanted kidneys procured in the presence of acute renal failure (ARF).

Methods. Transplant patients (n = 52) with a kidney procured with ARF were studied. Clinical data from donors and recipients, serum creatinine (SCr), creatinine clearance [estimated glomerular filtration rate (eGFR)], cold ischaemia duration, time to urine flow recovery or renal function recovery, and the number of haemodialysis sessions, were collected retrospectively.

Results. Mean donor age was 45.7 ± 12.7 years, and the mean SCr at the time of harvesting was 276.3 ± 104.2 μmol/l. Recipients' mean age was 51.1 ± 12.1 years. After transplantation, recovery of renal function was observed after 7.6 ± 7.1 days, and required 1.9 ± 3.0 haemodialysis sessions. SCr was 124.6 ± 49.5 μmol/l, and eGFR was 56.2 ± 19.8 ml/min at last follow-up. eGFR was significantly lower if the donor's death was due to stroke or cerebral haemorrhage (CH), or if the donors had previous cardiovascular disease (CVD) ($P < 0.02$). Patients with eGFR of <50 ml/min (n = 23) had donors who were older, and whose cause of death was more frequently related to CVD factors or to CH/stroke ($P < 0.03$). There were no significant differences between the two groups regarding age of recipient, gender of the donor or recipient, cold ischaemia time, occurrence of cardiac arrest, collapse or acute rejection. Linear regression analysis indicated that donor age and occurrence of acute rejection were independent factors associated with eGFR.

Conclusions. ARF before organ procurement does not have a negative effect on subsequent renal function. However, old age, CVD risk factors or CH, and late renal function recovery after transplantation are correlated with subsequent lower renal function. Thus, renal grafts with ARF can be used for renal transplantations.

Keywords: acute renal failure; graft survival; renal transplantation

Introduction

Patient survival and quality of life are improved after kidney transplantation compared to long-term dialysis [1–4]. However, the growing number of patients treated for chronic renal failure and the limited number of renal grafts have increased waiting times for renal transplantation in many countries. In addition, constant changes in road safety, particularly improvements to car safety, have reduced the number of traumatic deaths, which mostly involve young people. Therefore, several strategies have been developed to enhance graft access, including the use of living donors, the use of explanted criteria donors (ECD), dual adult kidney transplantations and recently, non-heart-beating donors (NHBD). Although these various strategies are not ideal, they appear to be associated with good outcomes. For example, kidney transplantation from ECDs appears to provide a better outcome for patients than maintaining dialysis, though graft survival remains lower than that observed for standard criteria donors (SCDs) [5–9]. However, because the number of patients with terminal nephropathy is increasing, there are insufficient numbers of donors to reduce the waiting time for patients with chronic renal failure.

Another possible deceased source includes donors with acute renal failure (ARF) at the time of organ procurement. Usually, these kidneys are excluded due to the elevated risk of developing a primary non-functioning kidney (PNF). Although the evolution of acute tubular necrosis (ATN) under stable conditions is well known, with recovery of renal function within a few weeks, the outcome of kidneys procured with ARF is unknown. Kidneys with ARF encounter multiple successive traumas including one original during the initial trauma

Table 1. Donor and recipients data

Donors	
Age (years)	45.7 ± 12.7 (17–67)
Gender (male:female ratio)	4.2
Weight (kg)	73.6 ± 7.8
Occurrence of heart arrest (%)	50
Occurrence of collapse (%)	69
Cardiovascular cause of death[a] (%)	46
Serum creatinine at harvest (μmol/l)	276.3 ± 104.2 (183–698)
eGFR at harvest (ml/min)	30.4 ± 8.3 (13.9–55.0)
Recipients	
Age (years)	51.1 ± 12.1 (26–76)
Gender (male:female ratio)	1.9
Weight (kg)	65.9 ± 14.6
PRA (%)	NA
HLA mismatch	3.2 ± 1.3
Transplantation	
Cold ischaemia time (hours)	19.6 ± 6.4 (10–38)
Time for diuresis to recover (days)	2.4 ± 2.9 (0–13)
Time for renal function to recover (days)	7.6 ± 7.1 (0–30)
Need for haemodialysis (%, mean number of sessions)	51.0%—1.9 ± 3.0 (0–12)
Primary non-functioning grafts (%)[b]	0
Early graft loss (%)[c]	1
Acute rejections (%)	27
Follow-up (months)	36.1 ± 21.3
Serum creatinine at last visit (μmol/l)	124.6 ± 49.5 (65–404)
eGFR at last visit (ml/min)	56.2 ± 19.7 (16.4–101.0)

Values are expressed as mean ± standard deviations; in parenthesis shows range. NA not available.
[a]Cardiovascular cause of death: ischaemic or haemorrhagic cerebral stroke, myocardial infarction and initial cardiac arrest of unknown origin.
[b]Primary non-functioning graft is defined by the persistent need for dialysis at 3 months.
[c]Early graft loss is defined by dialysis resumption or de-transplantation within 1 year.

or in the intensive care unit during donor resuscitation, and secondarily during harvesting. The second trauma affects the kidney that is already undergoing a repair process. Plus, the ability of the remaining cells or stem cells involved in the repair process to support the ischaemia/reperfusion process is not known. Are these cells able to overcome the second trauma with the same capability, or are they more sensitive due to increased risk from a primary non-functioning kidney? Therefore, we performed a retrospective study to evaluate graft function and graft survival in a cohort of kidney transplant patients with a kidney that had suffered ARF prior to procurement.

Materials and methods

Donors

We reviewed all patients who had undergone deceased donor kidney transplantation at our hospitals (Le Kremlin Bicêtre and Toulouse) between 1998 and 2005. Transplants procured from donors with acute renal failure were retrospectively analysed. Criteria for inclusion were: (i) lack of history of chronic renal failure or abnormal kidney size or morphology; (ii) significant increase in serum creatinine during the resuscitation period (>50%), or high serum creatinine (>250 μmol/l) with normal-sized kidneys following cardiac arrest or a prolonged collapse; and (iii) renal insufficiency not resolved with volaemic expansion or haemodynamic stabilization. Collapse was defined as a sustained systolic blood pressure (BP) of <80 mm Hg or a mean BP of <60 mm Hg. Donors with evidence of chronic kidney disease (kidney size <110 mm, or a history of elevated serum creatinine several months before) or pre-renal acute renal failure (sodium to potassium ratio in urine <1) were excluded. Needle core renal biopsies were performed in some donors to exclude severe chronic lesions, but these biopsies were not systematic. Four patients were anuric at the time of organ procurement. Those donors who still had diuresis had proteinuria that was <0.5 g/l.

Choice of recipient

Kidneys were allocated to recipients following standard criteria, including age and human leucocyte antigen (HLA) matching, waiting time on dialysis and negative cross-matching. All of the patients were treated by dialysis, and none of them have been pre-emptively transplanted.

Data collection and analyses

Data were collected retrospectively using a computerized database, and the analyses are presented as means [± standard deviation (SD)] or medians (ranges).

The following data were collected: donor's: age, gender, body weight, cause of death, occurrence of shock or cardiac arrest, lowest and highest creatinine; recipient's: age, gender, body weight, initial nephropathy, immunosuppressive regimen, panel-reactive antibodies (PRA); transplantation characteristics: cold ischaemia time (CIT), HLA matching, time for urine levels to normalize or renal function recovery (serum creatinine <250 μmol/l), need for post-transplantation haemodialysis, serum creatinine levels and estimated glomerular filtration rate (eGFR) according to the Cockcroft and Gault formula [10]).

Delayed graft function (DGF) was defined as the need for haemodialysis after transplantation. The number of dialysis sessions and the duration of dialysis dependency (days) after transplantation were recorded. Rejection episodes were assessed using the usual clinical and biochemical parameters and were confirmed by a needle core biopsy in all cases. A PNF was defined as the absence of a decrease in serum creatinine level, which resulted in persistent dialysis after 3 months.

Statistical analyses

Statistical analyses were performed using JMP software (Statistical Discovery Software, SAS Institute Inc., Cary, NC, USA, version 5.01). Student's *t*-test was used to compare continuous variables, and chi-square analysis was used to compare categorical demographic variables and outcome differences between patient groups. Linear regression analysis or multivariable linear regression was performed to correlate continuous variables.

Results

During the period of analysis, 1448 patients underwent kidney transplantation at our hospitals. Fifty-two patients (3.9%) received a kidney from a donor with ARF (which occurred during resuscitation prior to procurement) and were retrospectively eligible for this study. The donors' data are summarized in Table 1: they were mainly male (42 male:10 female), and were between 17 and 67 years old (mean age 45.7 ± 12.7 years: eight men were >60 years old). Forty-one donors (78.8%) experienced cardiac arrest and/or collapse.

Their causes of death were divided into several categories. The main cause was a cardiovascular event, including myocardial infarction and initial heart arrests of unknown origin, as well as CH or stroke; these occurred in 23 patients (46%). Other causes of donor death were suicide (n = 16), traffic accidents (n = 7) and pulmonary embolisms (n = 2).

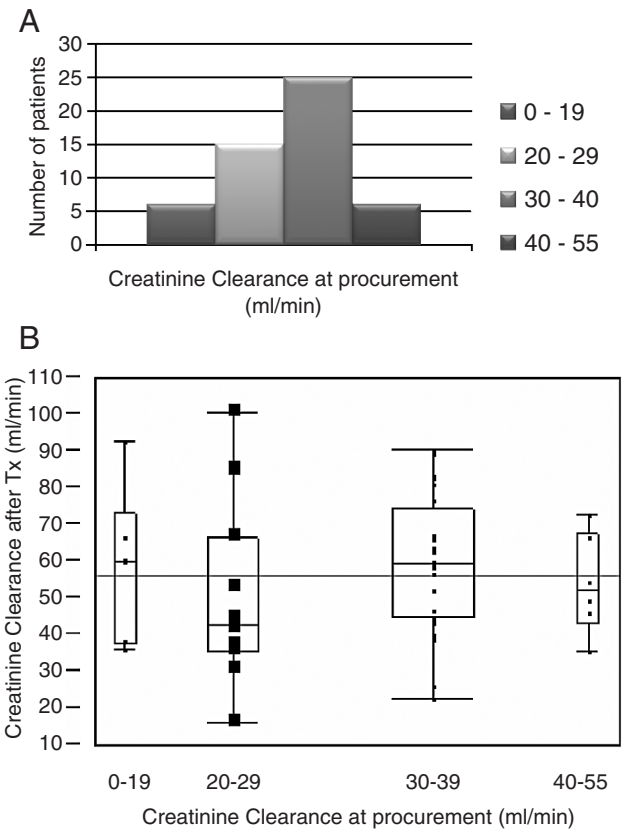

Fig. 1. Distribution of creatinine clearance at procurement (**A**) and its association with creatinine clearance after transplantation (Tx) (**B**).

Two donors died from thrombotic microangiopathy (TMA). The first was a 45-year-old pregnant woman with eclampsia, whose needle core renal biopsy performed 3 weeks after the initial ARF excluded important renal lesions of TMA. The second donor was a 58-year-old man suffering from TMA due to *Escherichia coli* prostatitis, with prominent cerebral damage: his first kidney biopsy showed glomerular capillary thrombi, which had mostly disappeared on a pre-implantation biopsy. The causes of death remained unknown in two other patients.

Overall, serum creatinine at procurement was 276.3 ± 104.2 μmol/l (range 183–698 μmol/l), and eGFR was 30.4 ± 8.3 ml/min (range 13.9–55.0 ml/min). The distribution of eGFR at procurement was classified accordingly to quartiles (Figure 1A). The most important proportion of eGFR at procurement was between 20 and 29 ml/min (Figure 1A). Pre-implantation needle core renal biopsies were performed for five donors and showed acute tubular necrosis. There was no correlation with biopsy realization and the level of eGFR impairment.

Recipients were mostly male (34 males/18 females). Their data are summarized in Table 1.

They were 51.1 ± 12.1 years old. Their causal nephropathies were chronic glomerulopathy (n = 20) corresponding to immunoglobulin A (IgA) nephropathy (n = 10), focal segmental glomerulonephritis (n = 3), membranous glomerulonephritis (n = 2), membrano-proliferative glomerulonephritis (n = 2), diabetic glomerulosclerosis (n = 2) and anti-neutrophil cytoplasmic antibody (ANCA)-associated vasculitis (n = 1). Thirteen patients had hereditary nephropathy including polycystic kidney disease (n = 11), Alport disease (n = 1) and nephronophthisis (n = 1). Five patients had malformative uropathy, four had interstitial chronic nephropathy and three had nephroangiosclerosis (n = 3); the origin of nephropathy was undetermined in seven cases (n = 7).

Immunosuppressive regimens for patients consisted of corticosteroids, calcineurin inhibitors (total of 42 patients: cyclosporine n = 21, tacrolimus n = 21), mycophenolate mofetil (n = 44), sirolimus (n = 8) and azathioprin (n = 2). Four patients were enrolled in therapeutic protocols and received FTY720 (n = 2) or Belatacept (n = 2). Some patients received an induction treatment consisting of anti-thymocyte globulins (n = 20) or basiliximab (n = 18).

After transplantation, patients were followed up for a mean time of 36.1 ± 21.3 months. No patients died during this period. Graft survival at 1 year was 98%, and none of the patients had a PNF kidney. Only one patient lost his graft 8 months later due to humoral acute rejection. Cold ischaemia time was 19.6 ± 6.4 hours (range 10 to 38 hours; Table 1). Mean times of diuresis and renal function recovery following transplantation were 2.4 ± 2.9 days (range 0–13 days) and 7.6 ± 7.1 days (range 0–23 days), respectively. Fifty-one percent of patients experienced DGF and needed 1.9 ± 3.0 haemodialysis sessions after transplantation. Twenty-seven percent of patients experienced an acute rejection, but had a good recovery after specific therapy. Only one patient had a graft loss due to acute humoral rejection at 8 months after transplantation. His renal function before this acute rejection had been good and stable.

The mean serum creatinine value at the end of follow-up was 124.6 ± 49.5 μmol/l (range 65–404 μmol/l), and the mean eGFR was 56.2 ± 19.8 ml/min (range 16.4–101.0 ml/min). This was not associated with the duration of DGF, or with the eGFR of the donors, or with the presence or not of diuresis. The mean eGFR after transplantation was not associated with renal function at procurement (Figure 1B). It was not associated with the gender, the size or the weight of the donor. In addition and because the total number of nephron may vary between male and women, we compared the renal outcomes depending on the different gender combinations. Whereas the eGFR tend to be slightly lower in female donors to male recipients, there is no statistical difference (Figure 2). In contrast, it was correlated with the donor's age (r^2 = 0.67; P < 0.003), with the cause of death of the donor (eGFR was 49.2 ± 4.1 ml/min in transplant patients with a kidney from a donor with CV or CH/stroke history *vs*. 61.7 ± 3.7 ml/min for other patients; P < 0.026), and with the occurrence of an acute rejection (without acute rejection 59.5 ± 3.2 ml/min *vs.* 46.7 ± 5.1 ml/min for those with one or more acute rejections; p < 0.04). It also tended to be associated with the induction therapy used (P = 0.053) (Figure 3). Mean eGFR was higher in the group receiving anti-thymocyte globulin (ATG) (64.1 ± 4.2 ml/min) than in the group receiving anti-IL2R (47.5 ± 4.5 ml/min) or the group that received no induction therapy (54.5 ± 5.5 ml/min) (Figure 4). All factors associated with a significant outcome for eGFR were submitted to linear regression analysis. Only

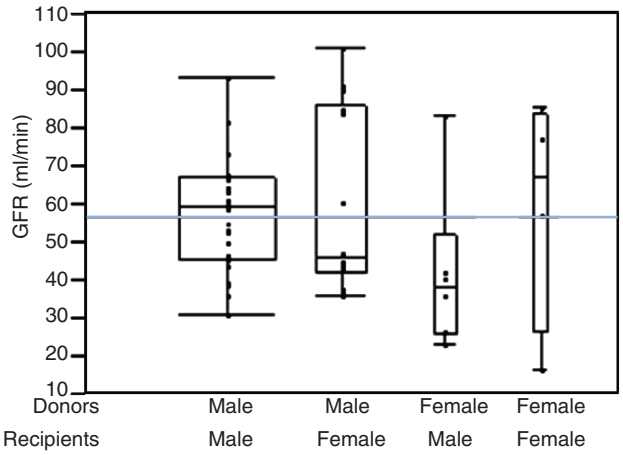

Fig. 2. Estimated GFR after transplantation in accordance with the different gender combinations.

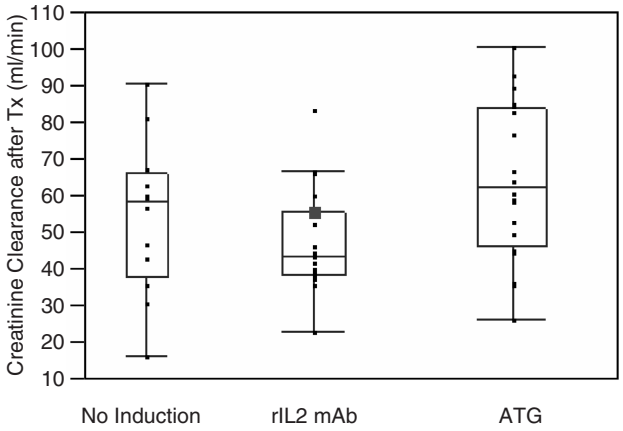

Fig. 3. Association between the induction therapies used and creatinine clearance after transplantation (Tx).

donor age and the occurrence of acute rejection were associated with eGFR after transplantation (Table 2).

Based on the evolution of renal function at Month 3, we classified the patients into two groups. One group was defined as having 'lower renal function' if eGFR after Month 3 post-transplantation was <50 ml/min. The second group was defined as having 'satisfactory renal function' if eGFR after Month 3 post-transplantation was >50 ml/min (Table 3). Twenty-three patients had low eGFR, and 29 had satisfactory eGFR (>50 ml/min). There were no significant differences between the donors' gender, whether they had a cardiac arrest or collapse, eGFR at procurement (31.1 ± 8.4 μmol/l *vs*. 29.8 ± 8.3, $P = 0.57$) or cold ischaemia time (20.7 ± 6.7 hours *vs*. 18.7 ± 6.1, $P = 0.27$). Patients with lower renal function received kidneys from older donors (50.7 ± 12.3 *vs*. 41.8 ± 11.8 years for patients with satisfactory renal function, $P < 0.01$), and the cause of donor death was more likely to be a CVD or CH/stroke (63.1% *vs*. 32.1%, $P = 0.026$). Despite an equivalent time for urine recovery, patients with lower renal function had a longer DGF (10.0 ± 8.8 days *vs*. 5.8 ± 5.0, $P < 0.04$), and a greater need for haemodialysis after transplantation (3.2 ± 3.9 *vs*. 0.86 ± 1.5, $P < 0.004$; Figure 1). The need for two or more haemodialysis sessions after transplantation was associated with worse renal function ($P < 0.01$). However, the incidence of DGF remained statistically non-significant (68% *vs*. 31%, $P = 0.1$). Patients with satisfactory renal function mostly had donors with higher serum creatinine values at harvest [301.0 ± 120.4 μmol/l (range 193–698) *vs*. 245.1 ± 70.0 (range 183–420), $P = 0.053$].

Discussion

Accepting organs from ECDs, based on their increasing age, history of hypertension, cerebrovascular death or higher baseline creatinine, according to United Network for Organ Sharing (UNOS) criteria [5] or NHBD, is a way of responding to the growing need for kidney transplants, although it still remains insufficient [6–8,11]. However, donors with ARF may constitute another possibility to increase the number of grafts available, as numerous donors experience hypovolaemia, shock or myoglobinuria-associated ARF before their kidneys are procured. At our two centres, 1448 patients underwent kidney transplantation from 1998 to 2005. Among these, 52 received kidneys from donors with ARF that occurred before organ procurement and was attributable to prior cardiac arrest or collapse. These donors must be differentiated from ECDs reported in other studies as they were younger [6–8], and had a lower frequency of cardiovascular risk factors (46%) than other ECDs [6–8]. However, the renal function at procurement of patients in other reported studies was lower as ARF was not frequently reported for ECDs [6,7]. Although biopsies were not systematically performed, ARF mostly corresponded to acute tubular necrosis, which occurred during hypoperfusion of the kidney. In our study, none of the selected patients had biological markers for prerenal failure (urinary sodium/potassium ratio <1), and most cases were considered to have acute tubular necrosis, with the exception of a few patients with a history of microangiopathy. However, no cases of myoglobinuria-associated ARF were included, despite them being reported to have a good outcome [12].

Recently, the use of NHBDs has been considered for transplantation, although their kidneys may support a more prolonged injury. However, for selected donors, based on their age, the use of a perfusion machine and in some cases, a renal biopsy, the outcome of renal transplantation can be good despite the high frequency of delayed graft function incidences and the slight increase in PNF kidneys. In cases of ARF that have occurred before or during organ procurement, it is unclear whether the remaining living cells that were not killed during initial traumas (which include ischaemia prior or during hospitalization of the donor and related to medications or haemodynamic instability, but already involved in the recovery process), may also survive to additional traumas of procurement, reperfusion and initial immunological injury and still maintain their capability to participate in the repair process. Our data and the data of others suggest that cells from transplanted kidneys procured from donors with ARF can survive ischaemia/reperfusion-associated events. No PNF

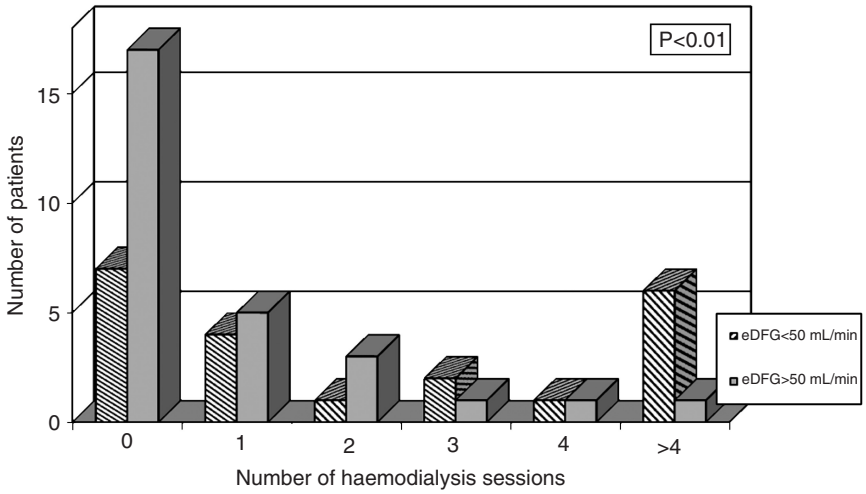

Fig. 4. Need for haemodialysis after transplantation related to renal function.

Table 2. Analysis of multivariable factors associated with post-transplant eGFR

	eGFR (ml/min ± SE)	*P*-value	*n*
Donor gender		0.21	
Male	58 ± 3		34
Female	48.7 ± 6.2		18
Donor age		0.0047	
>50	49.1 ± 3.4		29
<50	65.5 ± 3.9		23
Cause of death		0.026	
CVD or CH	49.2 ± 4.1		32
Others	61.7 ± 3.7		20
Induction therapy		0.053	
None	54.5 ± 5.4		14
Basiliximab	47.5 ± 4.45		18
ATG	64.1 ± 4.2		20
Acute rejection		0.038	
No	59.5 ± 3.2		35
Yes	46.7 ± 5.1		14

ATG anti-thymocyte globulin; CVD cardiovascular disease; CH cerebral haemorrhage and stroke.

kidneys have been reported. Although few studies have reported an increased frequency of DGF in patients receiving a kidney with evidence of ARF, other studies report a similar frequency of DGF in patients who received a kidney from a standard donor [13]. Interestingly, all these studies have confirmed a similar outcome in terms of graft survival and renal function for patients receiving a kidney from a standard criteria donor compared to those receiving a kidney with evidence of ARF [12–15]. These observations have led to the proposal of identifying a third group of donors with standard criteria but who also have impaired renal function and named 'impaired standard-criteria donors' (iSCDs [12]). Based on these criteria, which include age, absence of known chronic renal failure, and history of diabetes or hypertension, the outcome of iSCD is acceptable, and does not affect renal function during follow-up [9,16–18].

Boom *et al*. [9] have shown that, in a series of 734 deceased renal transplant patients, DGF was associated with worse renal function but not with lower kidney survival at 1 year post-transplant. Similarly, we observed that the duration of DGF was also associated with lower renal function (10.0 ± 8.8 days *vs*. 5.8 ± 5.0, $P < 0.04$), and was correlated with a greater need for haemodialysis (i.e. 3.2 ± 3.9 sessions *vs*. 0.86 ± 1.5, respectively, $P < 0.004$). However, the level of renal impairment and the evolution of the renal function (improving or worsening) at the organ procurement were not associated with a different long-term outcome [14].

To identify factors that are associated with a worse outcome (graft survival, renal function), we separated patients with 'satisfactory renal function' (eGFR >50 ml/min) from those with 'lower renal function' (eGFR <50 ml/min). Predictive factors for worse renal function were the donor's age and the cardiovascular cause of death as compared to trauma and/or anoxia. As expected, the donor's age is associated with lower renal function as it is linked to a higher frequency of atherosclerosis and cardiovascular risk factors, but it may also be associated with reduced capacity of tissue regeneration [19]. Therefore, the use of kidney from older donors or from ECD with ARF should be considered with caution. These results are consistent with the results of Anil Kumar *et al*. [8], who showed that, in a selected population of younger donors and kidneys selected according to rheological parameters, pre-procured ARF was associated with a good outcome, with long-term renal function similar to transplant patients with SCD and was better than those with ECD. Similarly, we have observed that patients receiving a transplant with ECD, at 1-year transplant, had a lower creatinine clearance (42.2 ± 16.4 ml/min; $n = 72$), and that those recipients whose donors were classified standard criteria had slightly improved renal function (64 ± 28 ml/min; $n = 72$) compared to iSCDs (56.2 ± 19.8 ml/min).

According to the United States Renal Data System (USRDS [18]) and reported studies [6,11,20–22], the incidence of acute rejection in deceased kidneys was between 10% and 25% in 1998–01. In our patients, it occurred more frequently, in 14 cases (27%), and was higher than that observed by Anil Kumar *et al*. or by Sohrabi *et al*. for patients receiving a kidney from a donor with low severity

Table 3. Renal function comparisons at Month 3

	<50 ml/min	≥50 ml/min	*P*-value
Donor's age (years)	50.7 ± 12.3	41.8 ± 11.8	<0.01
Donor's gender (ratio male:female)	2.8	6.3	0.26
Cardiovascular cause of death (%)	63.1%	32.1%	0.03
Occurrence of heart arrest (%)	48	52	0.78
Occurrence of collapse (%)	65	72	0.58
SCr at procurement (μmol/l)	245.1 ± 70.0	301.0 ± 120.4	0.05
EGFR at procurement (ml/min)	31.1 ± 8.4	29.8 ± 8.3	0.57
Cold-ischaemia time (hours)	20.7 ± 6.7	18.7 ± 6.1	0.27
Recipient's age (years)	53.2 ± 14.1	49.4 ± 10.2	0.27
Recipient's gender (ratio male:female)	1.6	2.2	0.54
Delayed graft function (%)	61	38	0.10
Time for diuresis to recover (days)	3.0 ± 3.4	2.0 ± 2.4	0.27
Time for renal function to recover (days)	10.0 ± 8.8	5.8 ± 5.0	<0.04
Need for haemodialysis (number of sessions)	3.2 ± 3.9	0.86 ± 1.5	<0.004
Acute rejections (%)	36	21	0.24
Total	23	29	

of cardiac arrest [8,15]. Acute rejection was not associated with the type of induction used (data not shown). It is difficult to compare our rejection rate to those observed in other series due to the diversity of immune backgrounds and immunosuppressive regimens prescribed. Intense prior ischaemic injury, followed by reperfusion, generates free radicals, which damage endothelial cells that then over-express adhesion molecules and chemokines. This is responsible for leukocyte chemoattraction [25], which may favour allo-immunization [26]. Therefore and as reported in the literature, DGF may constitute a risk factor for acute rejection [23,24].

Conclusions

Among the strategies developed to expand the donor pool, accepting iSCDs, which have been classically discarded, may be of great interest as the occurrence of ARF in the donor is associated with a good renal outcome and satisfactory renal function. However, anamnesis of ATN should be carefully collected to improve donor selection, to avoid kidneys undergoing chronic renal failure (CRF), to determine a history of severe hypertension or diabetes and to select donors younger than 60 years. However, it needs to be confirmed whether histology of the procured kidney and the rheological parameters from machine perfusion may help select these patients. Overall, we conclude that ARFs are suitable for kidney transplantation.

Conflict of interest statement. None declared.

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Simultaneous evaluation of renal morphology and function in live kidney donors using dynamic magnetic resonance imaging

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Abstract

Background. Evaluation of potential kidney donors requires the assessment of both kidney anatomy and function. In this prospective study, we sought to expand the diagnostic yield of magnetic resonance (MR) by adding functional measurements of glomerular filtration rate (GFR) and split renal function.

Methods. Between 2007 and 2009, all potential kidney donors presenting to our facility underwent a comprehensive single-stop MR study that included an assessment of anatomy, angiography and functional measurements. GFR was measured after a bolus injection of gadobutrol (4 ml, ~0.05 mmol/kg) and calculated from the washout of the signal intensity obtained over the liver. Split renal function was calculated from the increase of signal intensity over the renal cortex. Values were compared to renal scintigraphy with ^{99m}Tc-DTPA from the same day.

Results. The MR investigation was successfully performed in 21 participants. The GFR derived from MR (MR-GFR) correlated well ($r = 0.84$) with the GFR derived from scintigraphy (DTPA-GFR). The mean value of the paired differences was 4 ± 13 [SD] ml/min/1.73 m^2 and was not significantly different from zero. The ratio between right and left kidney function was similar with both techniques (1.01 ± 0.17 with MR and 1.06 ± 0.12 with scintigraphy, $P = 0.20$).

Conclusions. We demonstrate an MR-based approach to comprehensively evaluate both kidney anatomy and function in a single investigation, thereby facilitating the evaluation of potential kidney donors.

Keywords: donor evaluation; GFR; kidney transplantation; MR; scintigraphy

Introduction

The evaluation of potential kidney donors requires the assessment of kidney morphology and vascularization, as well as kidney function as indicated by the glomerular filtration rate (GFR) [1,2]. Currently, the anatomy of the kidneys is analysed using abdominal ultrasound or CT scans, whereas assessment of the renal vasculature is mainly performed non-invasively using computer tomography (CT) or magnetic resonance (MR) angiography [3,4]. Measurement of the GFR requires separate studies. The best GFR values are obtained from single-shot plasma disappearance curves after the injection of a filtration marker and repeated, timed blood sample collections. Creatinine clearance is less accurate and subject to collection error.