Transplant International

Transplant International ISSN 0934-0874

ORIGINAL ARTICLE

The deceased donor score system in kidney transplants from deceased donors after cardiac death

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Keywords
donation after cardiac death, donor score, ischemia-reperfusion injury.

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Received: 26 March 2009
Revision requested: 11 May 2009
Accepted: 2 August 2009

doi:10.1111/j.1432-2277.2009.00951.x

Summary

A clinical score to identify kidneys from donors after cardiac death (DCD) with a high risk of dysfunction following transplantation could be a useful tool to guide the introduction of new algorithms for the preservation of these organs and improve their outcome after transplantation. We investigated whether the deceased donor score (DDS) system could identify DCD kidneys with higher risk of early post-transplant dysfunction. The DDS was validated in a cohort of 168 kidney transplants from donors after brain death (DBD) and then applied to a cohort of 56 kidney transplants from DCD. In the DBD cohort, the DDS grade predicted the incidence of delayed graft function (DGF) and levels of serum creatinine at 3 and 12 months post-transplant. Similarly, in the DCD cohort, the DDS grade correlated with DGF and also predicted the levels of serum creatinine at 3 and 12 months. Interestingly, the DDS identified a subgroup of marginal DCD kidneys in which minimization of cold ischemia time produced better early clinical outcome. These results highlight the impact of early interventions on clinical outcome of marginal DCD kidneys and open the possibility of using the DDS to identify those kidneys that may benefit most from therapeutic interventions before transplantation.

Introduction

The survival benefit and improved quality of life on receiving a kidney transplant after remaining on the waiting list have been supported by analyses of large transplant registries all over the world [1–3]. Unfortunately, the number of patients on the waiting lists and the number of deaths that occur while awaiting transplantation are increasing constantly. In the UK, an increased use of organs from donors after cardiac death (DCD) has been recommended as a strategy to increase the transplant rate [4,5]. When carefully selected, kidneys from DCD achieve long-term graft survival similar to that of conventional donors after brain death (DBD). However, the higher incidence of delayed graft function (DGF) associated with DCD kidneys [6] is still a major problem and novel strategies to diminish the occurrence of this complication and enable the reliable use of these organs are required.

The quality of the transplanted organ is one of the most crucial factors in determining post-transplant graft function and survival in kidney transplantation. The use of clinical data to assess the quality of the transplanted organ and its intrinsic risk of post-transplant dysfunction has been explored by different clinical scoring systems [7–11]. The US Renal Database System (USRDS) proposed by Irish *et al.* [7], the deceased donor score system (DDS) constructed by Nyberg *et al.* from data of the Scientific Renal Transplant Registry (SRTS) [8,9], and the Expanded Criteria Donors (ECD) defined by the United Network for Organ Sharing (UNOS) [10] have been validated in over 20,000 kidney recipients reported to the USRDS, SRTS, and UNOS, respectively, and confirmed by subsequent studies around the world [11–13].

However, only the ECD and the DDS calculate the risks by using donor clinical data already available before transplantation. The DDS has been shown to be a better tool to detect marginal organs and correlate donor clinical information with early graft function and survival than the ECD [8,9]. However, these findings have not been confirmed in DCD kidney transplantation. Although the physiopathology and biological and clinical behavior of kidneys from DCD differ significantly from those from conventional DBD, the DDS may identify marginal kidneys from DCD and provide the opportunity to introduce early therapeutic strategies to protect these kidneys from additional ischemic and preservation injury. However, whether the DDS can be used to identify kidneys from DCD with high risk of post-transplant dysfunction is still unclear. To address this question, the DDS was validated in our center in a cohort of 168 transplants with kidneys from conventional DBD and then used to evaluate a cohort of 56 transplants performed with kidneys from DCD.

Patients and methods

A total of 224 deceased donor (DD) kidney transplants were performed between March 1st, 2002, and December 31st, 2005, at the Oxford Transplant Centre (OTC). A total of 168 transplants (75%) were performed with kidneys from DBD and 56 (25%) with kidneys from DCD. Recipient data and clinical outcomes of the entire cohort were obtained retrospectively from the OTC prospective transplant database and further confirmed by review of the clinical files.

DDS calculation

Donor data were obtained from the UK Transplant Donor Form and the DDS was calculated according to the procedure described by Nyberg *et al.* [9] (Table 1). Briefly, the DDS is based on 5 donor clinical variables: age, history and duration of hypertension, cerebrovascular disease as cause of death, final creatinine clearance, and number of HLA mismatches. The clinical variables are categorized and in the scoring system, points are assigned to each category, according to the influence on allograft function and survival: Donor age (0–25 points), history and duration of hypertension (0–5), cause of death (0–3), final creatinine clearance (0–3), and number of HLA mismatches (0–3). The final total score (0–39 points) is then used to evaluate the quality and to classify the donor organ as follows: Kidneys in DDS grade A (0–9 points) and grade B (10–19 points) are considered as optimal organs and those in DDS grade C (20–29 points) and grade D (30–39 points) as marginal organs (Table 1).

Clinical analyses

Clinical end-points of the analysis were the incidence of immediate graft function (IGF), primary non-function (PNF), delayed graft function (DGF) and acute rejection (AR), the length of hospitalization, levels of serum creatinine, and graft and patient survival rates. PNF was defined as a graft that did not achieve sufficient function to maintain the patient without regular dialysis from the time of transplantation. DGF was defined as the need for dialysis during the first week after transplantation, excluding those episodes of dialysis secondary to fluid overload or hyperkalemia during the first 24 h post-transplant. The indications for postoperative dialysis in the entire cohort were hyperkalemia (>6.6 mmol/l or <6.5 with ECG changes), fluid overload, and uncontrollable acidosis. Biopsy-proven acute rejection (AR) was assessed retrospectively using histologic reports (Banff-97 criteria). In the survival analysis, renal transplant survival and patient survival were defined as time from transplantation to the date when a patient returned to regular dialysis or died, respectively. Death with a functioning transplant was censored at the date of the patient's death.

DDS score and post-transplant clinical outcome

The DDS was calculated for each kidney in both cohorts (DBD and DCD) and used to stratify the organs into four surrogate grades of organ quality (DDS grades A to D). Subsequently, univariate and multivariate analyses were performed to identify the relationship between DDS grades and clinical outcome in each cohort. In these analyses, linear regression models were fitted to each continuous variable, while logistic regression models were used for binary variables. Serum creatinine data were logarithmically transformed in the DCD cohort. Statistical analysis was performed using the SPSS.14 statistical package (SPSS inc, Chicago, IL, USA). T-test, Fisher's exact test, and parametric and nonparametric Pearson's correlation were used to compare continuous or categorical variables as appropriate, and graft and patient survival rates were calculated using the Kaplan–Meier method. Two-tailed *P*-values <0.05 were considered to indicate statistical significance.

Results

DDS and clinical outcomes of kidneys from DBD

Donor, recipient, and pre-implantation data are shown in Table 2. In this cohort of 168 recipients, 98 (58%) received an optimal kidney and 70 (42%) received a marginal organ. Recipient age was significantly different across DDS grades A to D (41 vs. 47 vs. 51 vs. 61 years,

Table 1. Deceased donor score system (DDS).

Clinical data	Category/points						Total
Scoring chart							
Donor age (years)	<30	30–39	40–49	50–59	60–69	>70	
	0	5	10	15	20	25	0–25
Donor history of Hypertension [No/Yes:years]	NO	Yes: <5	Yes: 5–10	Yes: >10			
	0	2	3	4			0–4
Donor final creatinine clearance*	>100	75–99	50–74	<50			
	0	2	3	4			0–4
Donor number of HLA mismatches	0	1–2	3–4	5–6			
	0	1	2	3			0–3
Donor cause of death = Cerebrovascular disease	No	Yes					
	0	3					0–3
Total score							0–39

DDS grade	Total score	Tolerance to ischemia	Risk of DGF†	Graft survival
Kidney quality and clinical outcome				
Grade A	0–9	Good	Low	Excellent
Grade B	10–19	Slightly Reduced	Intermediate	Good
Grade C	20–29	Reduced	High	Intermediate
Grade D	30–39	Reduced	High	Low

*Creatinine clearance according Crockcroft–Gault, ml/min, †DGF, Delayed graft function. Modified from Nyberg *et al.* [8].

Table 2. Demographic characteristics, pre-implantation data, and clinical outcome of transplants with kidneys from donors after brain death according to their DDS grades.

	Grade A (n = 48)	Grade B (n = 50)	Grade C (n = 62)	Grade D (n = 8)	P-value
Donor data					
Age (years)*	26.5 ± 2 [12.5]	45 ± 1 [7]	57 ± 0.5 [5]	65 ± 2 [6.5]	<0.001
Cerebrovascular disease†	11(23)	34 (68)	53 (85.5)	8 (100)	<0.001
History of Hypertension†	2(4)	12 (24)	27 (43)	7 (87.5)	<0.001
Creatinine Clearance‡	116 ± 7 [48]	99 ± 4.5 [32]	83.5 ± 3.5 [27.5]	70 ± 5 [14]	<0.001
Number of HLA MM† 0:1–2:3–4:5–6 (%)	7:21:20:0 (15:44:41:0)	11:24:15:0 (22:48:30:0)	1:21:33:1 (2:37:59:2)	2:1:5:0 (25:13:62:0)	0.764
Recipient data					
Age (years)	41.5 ± 2 [13]	47 ± 2 [13]	51 ± 1.5 [12]	61 ± 3 [9]	<0.001
Gender: female/male†	13/35(27/73)	20/30(40/60)	23/39(37/39)	2/6 (25/75)	NS
Days on waiting list (SD)*	344 ± 43 [297]*	547 ± 73 [521]*	409 ± 43 [344]	345 ± 98 [276]*	0.02
First transplant†	39(81)	38 (76)	51 (82)	6 (75)	NS
Pre-transplant Ab†	23(47)	28 (56)	25 (46)	5 (62)	NS
Highly sensitized†	2(6)	6(12)	7(11)	0 (0)	NS
Pre-implantation data					
Cold ischemia time (min)*	1075 ± 51[355]	1043 ± 57 (405)	979 ± 60 (264)	1221 ± 90 [256]	NS
Anastomosis time (min)*	49 ± 2 (13.5)	45 ± 2.5 (17)	47 ± 1.5 (11.5)	57.5 ± 7 [19]	NS
Static cold storage†	48 (100)	45 (100)	62 (100)	8 (100)	NS
Clinical outcome					
Primary non-function†	2 (4)	1 (2)	0 (0)	1 (12)	NS
Immediate graft function†	37 (77)	31 (62)	34 (55)	2 (25)	0.03
Delayed graft function†	9 (19)	18 (36)	28 (45)	5 (62)	0.001
3 months serum creatinine§	125 ± 8.5 [59]	137 ± 7.5 [52]	175..5 ± 11 [79]	153 ± 28 [79]	0.002
12 months serum creatinine§	118 ± 9 [61]	138 ± 8.5 [60]	145 ± 11[85]	160 ± 53 [150]	0.01
3 months graft survival†	45 (92)	47 (94)	58 (94)	7 (88)	NS
12 months graft survival†	42 (88)	47 (94)	55 (88)	6 (75)	NS

*Values are mean ± SE [SD], †Values are number (%), ‡Creatinine clearance according Crockcroft–Gault in ml/min; HLA MM, HLA mismatches; Ab, Antibodies; Highly sensitized = Panel reactive antibodies (PRA) >85%; §Serum creatinine in μmol/l.

$P = 0.001$) and a linear correlation between donor age and recipient age was identified ($P = 0.002$). This is a reflection of the incorporation of donor and recipient matching into the national kidney allocation algorithm in the UK [14–16]. Waiting time was longer in transplants from DDS grade B kidneys than in grades A, C, and D (547 vs. 344, 409, and 345 days, respectively, $P = 0.020$). There was no difference in cold ischemia time between optimal (Grades A and B) and marginal kidneys (Grades C and D), but marginal kidneys in DDS grade D had longer cold ischemia times (CIT) than marginal kidneys in DDS grade C (1221 m vs. 979 m, $P = 0.034$). The incidence of PNF was similar in all groups (4%, 2%, 0%, and 12%, $P = 0.687$). Kidneys in the DDS grade A showed a significantly higher incidence of IGF and lower incidence of DGF than those in DDS grades B, C, and D (77% vs. 62%, 55%, and 25%, $P \leq 0.030$ and 19% vs.36%, 45%, and 62%, $P = 0.001$, respectively). Similarly, levels of serum creatinine at 3 and 12 months were lower in kidneys in DDS grade A than that of kidneys in DDS grades B, C, and D (125 vs. 137, 175, and 153 μmol/l, $P = 0.002$ and 118 vs. 138, 145, and 160 μmol/l, $P = 0.001$, respectively) (Fig. 1).

Assessment of the relationship between the DDS and allograft function and survival

With the aim of clarifying the relationship between donor clinical data available at the moment of retrieval and post-transplant PNF, IGF, DGF, levels of serum creatinine, and graft and patient survival in the cohort of DBD, the level of correlation between the DDS grades and these parameters was investigated using parametric and nonparametric Pearson's correlation test. In addition, the ability of the DDS grades to predict the development of the later clinical responses was evaluated by univariate and multivariate analyses. The DDS grade correlated and predicted the incidence of IGF, DGF, and levels of serum creatinine at 3 and 12 months ($P < 0.020$) (Table 3). In this cohort, the DDS grade D was associated with significantly higher incidence of graft loss than DDS grades A, B, and C (75% vs. 88%, 94%, and 88%, respectively, $P = 0.040$) However, the DDS grade was not able to predict post-transplant graft and patient survival in the multivariate analysis.

DDS and clinical outcome of kidneys from DCD

Donor, recipient, and pre-implantation data are shown in Table 4. In this cohort of 56 recipients, 45 (80%) received an optimal kidney (DDS grades A and B) and 11 (20%) received a marginal organ. All the marginal organs were in the DDS grade C and there were no kidneys in the DDS grade D. In contrast to that observed in the DBD cohort, recipient age was similar across DDS grades A to C (49 vs. 49 vs. 53, P = NS) and there was no correlation between donor and recipient age. These kidneys are allocated locally and the small size of the local pool of recipients makes age matching difficult. Waiting time, transplant number, presence of pre-transplant HLA antibodies, and level of sensitization were similar in all DDS groups. However, recipients of DDS grade B kidneys were better HLA matched with their donors than recipients in DDS grades A and C ($P = 0.020$). There was no difference in warm ischemia time, preservation technique, and implantation time between the DDS grades. However, kidneys in DDS grade C had significantly shorter CIT than those in DDS grades A and B (998 m vs. 1200 m and 1179 m, respectively, $P = 0.03$). Recipients of DCD kidneys were treated with induction and triple maintenance immunosuppressive therapy. In cases wherein alemtuzumab was the induction agent, maintenance therapy was initiated with tacrolimus and mycophenolate mophetil, and further reduced to sirolimus monotherapy after 6 months. The distribution of induction and maintenance immunosuppressive regimes was similar in all DDS groups and is shown in Table 4.

There was no PNF in the DCD cohort. Kidneys in the DDS grade A group had a lower incidence of DGF than kidneys in DDS grades B and C (58% vs. 79% and 64%, respectively, $P = 0.040$). Similarly, levels of serum creatinine at 3 and 12 months were significantly lower in kidneys in DDS grade A than that of those in DDS grades B and C (130 ± 9.2 μmol/l vs. 198 ± 29 μmol/l and 179 ± 11 μmol/l, $P = 0.01$, and 110 ± 10 μmol/l vs. 155 ± 35 μmol/l and 134 ± 22 μmol/l, $P = 0.040$) (Fig. 1). Additionally, there was a lower 1 year graft survival of kidneys in DDS grade C than that of those in DDS grades A and B. However, this difference did not reach significance (89% vs. 96% and 94%, respectively). Unexpectedly, there was a lower incidence of DGF (64% vs.79%) and levels of serum creatinine at 3 and 12 months (179 ± 11 vs. 198 ± 29 and 134 ± 22 vs. 155 ± 35 μmol/l, respectively) in the DDS grade C than that in the DDS grade B, but these differences did not reach statistical significance (Fig. 1).

Assessment of the relationship between the DDS and allograft function and survival

As in the DBD cohort, the relationship between donor data and post-transplant outcome was investigated in the cohort of kidney transplants from DCD. The level of correlation was investigated using parametric and nonparametric Pearson's correlation test, and univariate and multivariate analyses were performed to evaluate the ability of the DDS to predict post-transplant outcomes with

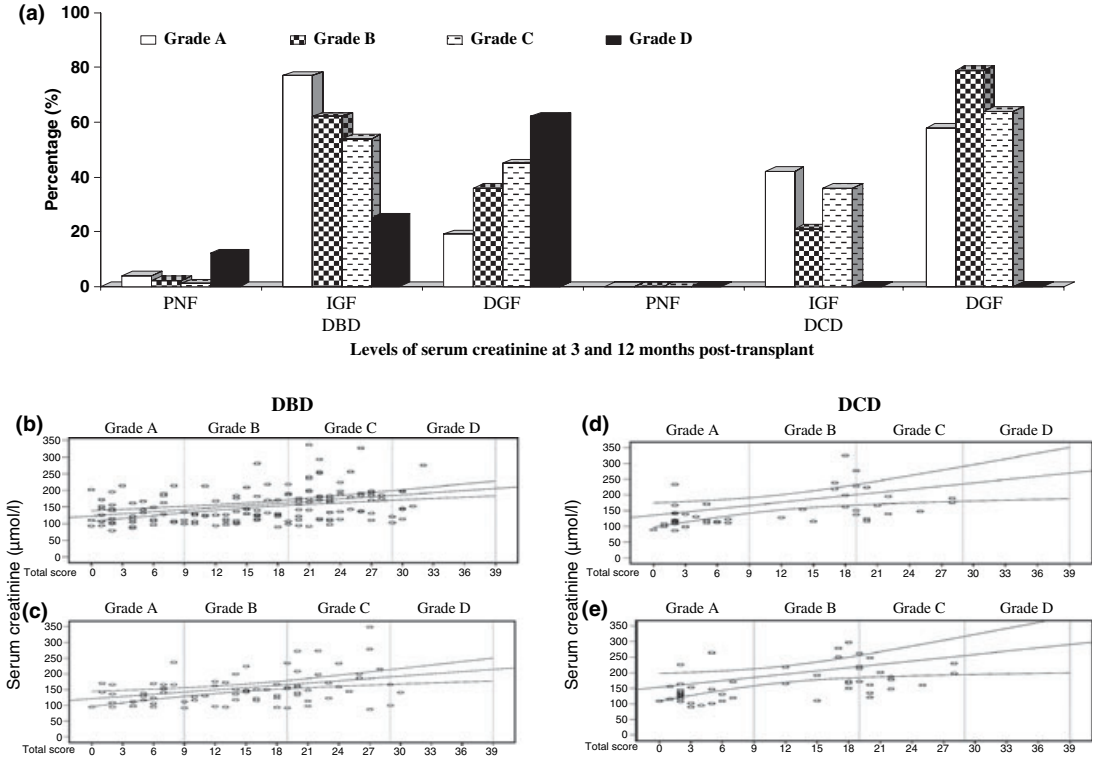

Figure 1 Correlation between DDS grades and post-transplant graft function in donors after brain death and donors after cardiac death. Panel a shows the correlation between DDS grades (A–D) and primary non-function, immediate graft function, and delayed graft function in the cohort of deceased donors after brain death (DBD) and the cohort of donors after cardiac death (DCD). Panel b and Panel c show the correlation between DDS grades (A–D) and levels of serum creatinine at 3 and 12 months in DBD, respectively, and Panel d and e–c show the correlation between the latter variables in DCD.

clinical data available before organ retrieval. There was a significant correlation between the DDS grade and the incidence of DGF across the entire DCD cohort ($P = 0.020$). However, the DDS grade was not able to predict accurately the incidence of DGF in the univariate and multivariate analyses ($P = 0.056$). In contrast, the DDS grade correlated well and predicted the levels of serum creatinine at 3 and 12 months post-transplantation in the multivariate analyses ($P < 0.05$ and $P < 0.005$, respectively) (Table 3). In this cohort of recipients of kidneys from DCD, the DDS grade C was associated with lower graft survival than that of those in DDS grades A and B (89% vs. 96% and 94%, respectively). However, the correlation did not reach statistical significance and the DDS grade was not able to predict 1 year graft survival in the multivariate analysis.

Discussion and conclusions

Donor organ quality has been recognized as one of the most crucial factors affecting graft function and survival in kidney transplantation. Some publications evaluating potential donor risk factors for allograft dysfunction and loss in kidney transplantation have highlighted the importance of the organ characteristics independent of the transplant recipient in determining allograft function and survival [17–21]. The DDS has been tested and validated in different cohorts of adult recipients of kidneys from DBD and compared with other systems designed to predict the post-transplant likelihood of DGF with encouraging results [8,9]. However, the estimation of the intrinsic ability of the DDS to predict whether DGF will definitely occur has produced conflicting results [11–13]. Some limitations of the DDS, such as over-representation of donor age and the inaccuracy of the calculation of creatinine clearance before organ retrieval, might explain the apparent inconsistencies. The DDS gives a high weight to donor age, and this has been found to be extremely useful when the investigated cohort includes young and older donors. However, when only older donors are studied, this donor variable becomes dominant and over-representation of the donor age in the final score is a significant risk. Similarly, the calculated creatinine clearance can be a very useful mea-

Table 3. Correlation between DDS and post-transplant clinical outcomes.

	Correlation*		Prediction†		
DDS Grade	Pearson's	Sig. (two-tailed)	Coeff.	SE	Sig. (two-tailed)
Donors after brain death					
DDS grade	1				
Immediate graft function	0.234	0.002	0.128	0.045	0.002
Delayed graft function	0.248	0.001	0.134	0.040	0.001
Serum creatinine at 3 months	0.224	0.004	0.123	0.028	0.001
Serum creatinine at 12 months	0.220	0.005	0.114	0.032	0.002
Donors after cardiac death					
DDS grade	1				
Immediate graft function	0.214	0.020	0.072	0.085	0.402
Delayed graft function	0.214	0.020	0.072	0.085	0.402
Serum creatinine at 3 months	0.200	0.050	0.213	0.073	0.005‡
Serum creatinine at 12 months	0.208	0.050	0.211	0.086	0.007‡

*Pearson's correlation is significant at the 0.05 level (two-tailed); †Multivariate tests (anova); ‡Model fitted to the logarithm of creatinine at 3 and 12 months.

sure in predicting early and long-term kidney function following transplantation, especially, when it is measured under stable conditions. Nevertheless, stable conditions before organ retrieval are often not possible and significant fluctuations in the levels of serum creatinine between the time of admission and the time of organ retrieval may occur, especially in donation after cardiac death. However, although the DDS is not perfect, there are significant advantages to a scoring system that utilizes multiple donor characteristics already available at the moment of organ retrieval rather than relying on a single and isolated estimate, such as donor age or creatinine clearance.

We have validated the predictive ability of the DDS score in a cohort of DBD transplants performed at our center and then applied the score to evaluate a cohort of DCD. In the DBD cohort, the DDS grade correlates with the incidence of IGF, DGF, and the levels of serum creatinine at 3 and 12 months post-transplant and is able to predict the occurrence of these clinical end-points in the univariate and multivariate analyses. To our knowledge, the predictive ability of the DDS has not been previously evaluated in DCD kidney transplantation. The assessment of the DDS in the DCD cohort shows that the DDS grade correlates and predicts the levels of serum creatinine at 3 and 12 months post-transplantation in the multivariate analysis. The level of correlation between the DDS grade and DGF across the entire cohort was statistically significant ($P =< 0.05$). However, the DDS was not able to *predict* the development of this clinical event in the multivariate analysis, probably because of the unexpected lower incidence of DGF in DDS grade C kidneys transplanted with shorter CIT and the small size of this DCD cohort.

It is well known that the physiopathology and the biological and clinical behavior of kidneys from DCD differ significantly from those from DBD. However, the same principle of 'quality assessment' before transplantation and the impact of donor organ quality on post-transplant clinical outcome could also apply to kidneys retrieved from DCD. Moreover, careful assessment of organ quality very early in the transplantation process may allow the introduction of novel strategies to manipulate the conditions in which warm ischemia, organ retrieval, and preservation before transplantation will occur. A recent retrospective review of 14,125 transplants with kidneys from deceased donors published by Selck *et al.* [22] found that organ yield and post-transplant clinical outcome depend significantly on intrinsic donor characteristics and donor management interventions. In this large retrospective study, donor clinical data such as donor age, cause of death, history of hypertension, diabetes, myocardial infarction, and body mass index, and specific donor clinical interventions such as steroid, diuretics, and oxygen administration were significantly associated with better organ yield and post-transplant allograft function. Based on these results, the authors conclude that increasing the yield and function of organs from DD may occur if the quality of organs is assessed and improved before organ retrieval, preservation, and transplantation.

In the UK, as in many other countries, treatment of the potential donor for the sole purpose of organ donation is not allowed, but treatment of the donor organ after retrieval by manipulation of CIT, preservation solutions, and techniques is widely accepted. Cumulative evidence underscores the potential benefit of two attractive early therapeutic interventions on the outcome of kidneys from DCD: Minimization of CIT and preservation by hypothermic pulsatile perfusion (HPP). Retrospective evidence suggests that the outcome of kidney transplants from DCD may be superior when CIT is kept

Table 4. Donor and recipient characteristics and pre-implantation data between DDS grades in kidneys from donors after cardiac death (DCD).

	Grade A *n* = 26 (100%)	Grade B *n* = 19 (100%)	Grade C *n* = 11 (100%)	*P*-values
Donor data				
Age (years)*	25.3 ± 1.5 [7.8]	50 ± 1.5 [6.7]	57.7 ± 0.9 [3]	0.00
Cerebrovascular disease†	2 (8)	8 (42)	11 (100)	0.000
History of hypertension†	0 (0%)	3 (16)	5 (45)	0.000
Creatinine clearance (ml/min/)‡	104.5 ± 9.6 [49.2]	106 ± 3.7 [16.5]	103 ± 3.4 [21.8]	NS
Number of HLA MM† 0:1–2:3–4:5–6 (%)	1:9:15:1 (4:34:58:4)	0:15:9:0 (0:84:16:0)	0:2:8:0 (0:18:82:0)	0.02
Recipient data				
Age (years)*	48.8 ± 2.4 [12.6]	49 ± 2.8 [12.5]	53.3 ± 4.3 [14.1]	NS
Days on waiting list*	551 ± 117 [597]	559 ± 92 [400]	793 ± 90 [630]	NS
First transplant†	23 (88)	19 (100)	9 (82)	NS
Pre-transplant antibodies†	2 (8)	4 (16)	2 (68)	NS
Highly sensitized†	2(8)	0(0)	(0)	NS
Pre-implantation data				
Warm ischemia time (min)*	19.6 ± 1.1[5.6]	18.6 ± 1.7[7.4]	19.4 ± 1.5 [5.2]	NS
Cold ischemia time (min)*	1200 ± 66 [336]	1179 ± 40 (302)	998 ± 58 (264)*	0.03*
Anastomosis time (min)*	49.9 ± 4 (18.5)	49.5 ± 4 (18.3)	53.7 ± 2.2 (7.3)	NS
Static cold storage†	13 (50)	11 (58)	7 (64)	NS
Pulsatile perfusion†	13 (50)	8 (42)	4 (36)	NS
Induction therapy†				
Anti-thymocyte globulin¶	14 (55)	11 (58)	4 (36)	NS
Basiliximab**	4 (15)	4 (21)	3 (28)	NS
Alemtuzumab††	8 (30)	4 (21)	4 (36)	NS
Maintenance therapy†				
Cyclosporine A	2 (7)	0 (0)	0 (0)	NS
Tacrolimus/Sirolimus	24/5 (93/19)	19/5 (100/26)	11/2 (100/18)	NS
Mycophenolate Mophetil	26 (100)	19 (100)	11 (100)	NS
Prednisolone	18 (69)	16 (84)	7 (63)	NS
Clinical outcome				
Primary non-function†	0 (0)	0(0)	0(0)	NS
Immediate graft function†	11 (42)	4 (21)	4 (36)	0.02
Delayed graft function†	15 (58)	15 (79)	7 (64)	0.02
3 months Serum creatinine§	130 ± 9.2 [47]	198 ± 29 [126]	179 ± 11 [39]	0.001
12 months Serum creatinine	110 ± 10 [50]	155 ± 35 [153]	134 ± 22 [74]	0.002
3 months graft survival	25 (96)	19 (100)	10 (90)	NS
12 months graft survival	25 (96)	18 (94)	9 (89)	NS
1 year Patient survival	25 (96)	18 (94)	9 (89)	NS

*Values are mean ± SE [SD], †Values are number (%), ‡Creatinine clearance according Crockcroft–Gault in ml/min; HLA MM, HLA mismatches; Ab, Antibodies; Highly sensitized = Panel reactive antibodies (PRA) > 85%; §Serum creatinine in μmol/l. ¶Anti-thymocyte Globulin ATG®, Fresenius, multiple doses of 1.5 mg/kg, **Alemtuzumab (Campath-1H®, Berlex, Montville, NJ, USA), two doses of 30 mg, ††Basiliximab (Simulect® Novartis Pharma, Numberg, Switzerland), two doses of 40 mg.

under 14 h. Sudhindran *et al.* in the UK and Doshi *et al.* in the USA reported that when DCD kidneys are transplanted with less than 14 h of CIT, the incidence of DGF decreased by 20% and 1- and 5-year graft survival was similar to that obtained from kidneys from conventional DBD transplanted contemporaneously [23,24]. Moreover, Locke *et al.* [25] showed that when CIT was limited to less than 12 h, the incidence of DGF in DCD kidneys was reduced by 15% and approached that of DBD. Similarly, clinical introduction of preservation by HPP has also been associated with a significant improvement in graft function and survival of kidneys from DD, especially kidneys subjected to longer CIT and those coming from extended criteria DBD and DCD [26,27]. We recently showed that introduction of HPP significantly reduces both incidence of DGF and length of hospitalization as well as allows better graft function in a homogenous cohort of DCD kidneys subjected to more than 14 h of CIT [28]. These encouraging results are in line with those coming from a retrospective analysis of large DCD kidney registries [24–27,29] and with early results of the DCD arm of the randomized clinical trial of machine perfusion

conducted by Eurotransplant. In this trial, DCD kidneys preserved by HPP achieved significantly lower incidence of DGF and higher graft survival than DCD kidneys preserved by static cold storage [30].

In summary, the results of our study suggest that the use of the deceased donor scoring system in DCD kidney transplantation may offer the opportunity to assess organ quality using intrinsic donor characteristics already available before organ retrieval. In addition, this score could identify marginal kidneys from DCD, which may benefit from early therapeutic strategies before transplantation, such as minimization of cold ischemic times and preservation by hypothermic pulsatile perfusion.

Authorship

JJP-M, PJF and SVF: designed the study, analyzed the data, and wrote the paper. MV-M: was involved in the data analysis.

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