View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Erasmus University Digital Repository

European Surgical Research

Eur Surg Res

DOI: 10.1159/000501602
Received: March 29, 2019
Accepted: June 16, 2019
Published online: September 3, 2019

© 2019 The Author(s)
Published by S. Karger AG, Basel
www.karger.com/esr

Karger Open access

This article is licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND) (http://www.karger.com/Services/OpenAccessLicense). Usage and distribution for commercial purposes as well as any distribution of modified material requires written permission.

Research Article

Systematic Surgical Assessment of Deceased-Donor Kidneys as a Predictor of Short-Term Transplant Outcomes

Elise L. Tierie[a] Joke I. Roodnat[b] Frank J.M.F. Dor[a, c]

[a]Division of Transplant Surgery, Department of Surgery, Erasmus MC, Rotterdam, The Netherlands; [b]Division of Nephrology, Department of Internal Medicine, Erasmus MC, Rotterdam, The Netherlands; [c]Imperial College Renal and Transplant Centre, Department of Surgery and Cancer, Imperial College, London, UK

Keywords

Organ retrieval · Deceased donor kidney transplantation · Surgical expertise · Organ assessment · Graft function

Abstract

Background: Short-term kidney graft dysfunction is correlated with complications and it is associated with a decreased long-term survival; therefore, a scoring system to predict short-term renal transplant outcomes is warranted. ***Aim:*** The aim of this study is to quantify the impression of the organ procurement surgeon in correlation with the following kidney transplant outcomes: immediate graft function (IGF), delayed graft function (DGF), and primary nonfunction (PNF). Results are compared to factors associated with the 1-year outcome. ***Methods:*** A regional prospective pilot study was performed using deceased-donor organ assessment forms to be filled out by procurement surgeons after procurement. Data were gathered on kidney temperature, perfusion, anatomy, atherosclerosis, and overall quality. ***Results:*** Included were 90 donors who donated 178 kidneys, 166 of which were transplanted. Variables that were significantly more prevalent in the DGF-or-PNF group (n = 65) are: large kidney size (length, p = 0.008; width, p = 0.036), poor perfusion quality (p = 0.037), lower diuresis (p = 0.039), fewer hypotensive episodes (p = 0.003), and donation-after-circulatory-death donors (p = 0.017). Multivariable analysis showed that perfusion quality and kidney width significantly predicted the short-term outcome. However multivariable analysis of long-term outcomes showed that the first measured donor creatinine, kidney donor risk index, IGF vs. DGF+PNG, and kidney length predicted outcomes. ***Conclusions:*** Results show that short-term

Elise Tierie
Erasmus Medical Center, Room 524a
s-Gravendijkwal 23
NL–3015 CE Rotterdam (The Netherlands)
E-Mail e.tierie@adrz.nl

graft function and 1-year graft function indeed are influenced by different variables. DGF and PNF occur more frequently in kidneys with poor perfusion and in larger kidneys. A plausible explanation for this is that these kidneys might be insufficiently washed out, or even congested, which may predispose to DGF. These kidneys would probably benefit most from reconditioning strategies, such as machine perfusion. A scoring system including these variables might aid in decision-making towards allocation and potential reconditioning strategies.

© 2019 The Author(s)
Published by S. Karger AG, Basel

Introduction

Currently there are various methods, i.e., the deceased-donor score, the donor risk score, and the kidney donor risk index (KDRI), for pretransplant quality assessment of donor organs. These methods consist of donor, recipient, and donation procedure characteristics [1, 2]. Apart from renal artery plaque in the deceased-donor score, none of these assessments includes surgical and anatomical variables available during procurement (procurement surgeon's assessment of an organ).

Although eventually long-term graft survival is the aim, short-term dysfunction is associated with morbidity and mortality associated with the presence of a nonfunctioning graft in an immunosuppressed patient. DGF is associated with a reduced graft survival [3–7], although some studies have found an unimpaired long-term graft survival [4, 6]. DGF is also associated with increased comorbidity and mortality in the direct postoperative phase and with increased costs [4, 7]. After a deceased-donor kidney transplantation, 21–52% of recipients have delayed graft function (DGF) and 48–69% have immediate graft function (IGF) [5, 6, 8]. A small percentage (0.6–8%) of transplanted kidneys will never function [9].

This study attempts to quantify the surgeon's subjective detailed impression of organ quality and to correlate this to the following transplant outcomes: IGF, DGF, and primary nonfunction (PNF). A scoring system to predict short-term renal transplant outcomes incorporating these surgical details might aid in decision-making towards acceptance and potential reconditioning strategies.

Materials and Methods

Between 2014 and 2016, we performed a prospective regional pilot study in which procurement surgeons were asked to participate. A detailed organ assessment form (scoring system) was developed to be filled out by the procurement surgeons immediately after kidney procurement. The parameters are based on the aspects of a kidney upon inspection by the procurement surgeon and could be observed or measured during retrieval. The organ assessment form was set up by a procurement surgeon and a nephrologist and modified after consultation with other procurement surgeons. The form was tested by all regional organ procurement surgeons for feasibility and accuracy.

This study included all kidneys from deceased donors that were retrieved by the organ procurement team of the Erasmus MC, University Medical Center, Rotterdam, The Netherlands, during the period studied. There was no selection process for inclusion. During the procurement procedure, all kidneys included were scored based on the scoring system (Table 1). Variable scorings were intended to be independent of donor age.

Forms were assigned and collected centrally by nurses from the regional procurement team.

The temperatures at explantation and at packaging were measured with an infrared thermometer in a standardized manner. The maximum length and width of the kidney were measured with a flexible ruler. Cold ischemic time was defined as the time between the start of cold perfusion in the donor and the start of the warm ischemia time in the recipient.

Table 1. Donor organ assessment variables

Variable	Type	Unit	Scoring system
Temperature at extraction	scale	°C	
Temperature at packaging	scale	°C	
Quality perfusion	scale	n/a	extent of decoloration of the parenchyma (1 = poor, 10 = excellent) 1 2 3 4 5 6 7 8 9 10
Aspect perfusate	scale	n/a	aspect perfusate after procurement on the bench (1 = bloody, 10 = clear) 1 2 3 4 5 6 7 8 9 10
Quality parenchyma	scale	n/a	quality of the parenchyma (independently of factors such as age) (1 = poor, 10 = excellent) 1 2 3 4 5 6 7 8 9 10
Parenchymal abnormalities	nominal	n/a	cysts (yes/no), size, number scarring (yes/no) parenchymal tears (yes/no) other abnormalities (yes/no)
Atherosclerosis of the origo of the renal artery	scale	n/a	extent of atherosclerosis of the origo of the renal artery (not in relation to age) (1 = none, 10 = extensive) 1 2 3 4 5 6 7 8 9 10
Atherosclerosis of the renal artery	scale	n/a	extent of atherosclerosis of the renal artery >0.5 cm distal from the origo (1 = none, 10 = extensive) 1 2 3 4 5 6 7 8 9 10
Atherosclerosis of the aorta	scale	n/a	(not in relation to age) (1 = none, 10 = extensive) 1 2 3 4 5 6 7 8 9 10
Plasticity of the renal artery	scale	n/a	plasticity of the renal artery >0.5 cm distal from the origo (by palpation) (1 = rigid, 10 = very flexible) 1 2 3 4 5 6 7 8 9 10
Degree of stenosis in the origin renal artery		%	degree of stenosis of the origo of the renal artery 1. <50% 2. 50–75% 3. >75%
Artery and vein abnormalities	nominal	n/a	
Overall quality of the left kidney	scale	n/a	overall quality of the left kidney (1 = very poor, 10 = excellent) 1 2 3 4 5 6 7 8 9 10
Overall quality of the right kidney	scale	n/a	overall quality of the right kidney (1 = very poor, 10 = excellent) 1 2 3 4 5 6 7 8 9 10
Kidney length	scale	cm	
Kidney width	scale	cm	

The first warm ischemic time was defined as the time between circulatory arrest in the donor and the start of the cold perfusion, which is only applicable to donation after circulatory death (DCD). The second warm ischemic time was defined as the time from the moment the kidney was taken from ice until recirculation in the recipient (anastomosis time). This is applicable to both donation after brain death (DBD) and DCD.

From each donor, anonymous data were retrieved from the Eurotransplant database. This data included: age, BMI, weight of the donor, length of the donor, sex, cause of death, DBD versus DCD, cardiac arrest, hypotensive episodes, CMV IgG status, smoking, creatinine values, alcohol abuse, hypertension, and diabetes mellitus. Furthermore, the KDRI score was calculated as a means of comparison [10].

For follow-up, data on the anonymous recipients were collected from European transplant centers based on the recipient number. Age, sex, cold and warm ischemic times, maximum PRA, creatinine at 3 months and at 1 year, graft survival, patient survival, and graft function were added to the database. The measured creatinine was recalculated to the estimated glomerular filtration rate (eGFR) with the Cockcroft-Gault formula as a method to assess graft function [11]. Graft function was scored as IGF, DGF, or primary PNF. DGF was defined as the need for hemodialysis in the first week after transplantation. IGF was compared to either DGF or PNF.

A second analysis was performed studying 1-year graft function. Patients with a 1-year eGFR >50 mL/min/1.73 m^2 were compared to patients with graft failure, PNF, and/or an eGFR <50 mL/min/1.73 m^2. This cut-off point was chosen so that 2 comparable groups could be obtained.

In this study the aim is to predict short-term outcomes, and therefore patients with IGF are compared to patients with DGF and PNF. All analyses were performed using Statistical Package for the Social Sciences 21.0.0.1 (IBM Corporation, USA). Two-sided $p < 0.05$ were considered statistically significant. The tests used to evaluate differences between populations were: a 2-tailed independent samples t test, a χ^2 test, and the Mann-Whitney U test.

Results

In this study, 90 donors donated 178 kidneys, 166 of which were transplanted at 24 different European transplant centres across The Netherlands, Belgium, Germany, Hungary, and Austria.

Table 2 shows the descriptive statistics of donor, recipient, procurement, and follow-up variables. In total, 10 different procurement surgeons filled out the organ assessment forms.

Twelve kidneys, from 9 different donors, were declined based on presumed bad quality. Those rejected kidneys were significantly more often from a donor of an older age (65 ± 13 vs. 54 ± 14 years; $p = 0.031$) and a lower BMI (22 ± 4 vs. 25 ± 5; $p = 0.026$). The quality of the parenchyma was worse (7.5 vs. 8.3; $p = 0.014$) and there was significantly more atherosclerosis in the aorta (6.5 ± 2.6 vs. 4 ± 2.5; $p = 0.002$), in the renal artery origo (5.2 ± 2 vs. 3.1 ± 2.2; $p = 0.004$), and in the renal artery (4.8 ± 3.2 vs. 2 ± 1.6; $p < 0.001$).

There were 92 kidneys with IGF, 57 with DGF, and 8 with PNF. In Table 3, the variables were analyzed for prevalence of graft function (IGF vs. DGF or PNF). In this analysis, low diuresis in the donor and having a DCD donor were significantly more frequent in patients with DGF or PNF. A period of hypotension occurred significantly more often in the population with IGF (Table 3). The length and width of the kidney were significantly greater in the DGF-or-PNF group than in the IGF group. In addition, the quality of the perfusion as assessed by the procurement surgeon was significantly better in IGF group than in the DGF-or-PNF group. Finally, there was no significant difference in KDPI/KDRI score between the DGF-or-PNF group and the IGF group.

In the univariate binary logistic regression analysis, the only variables with a significant influence on IGF versus DGF-or-PNF grafts were: donor weight ($p = 0.050$), donor BMI ($p = 0.048$), DCD or DBD donor ($p = 0.028$), hypotensive episodes ($p = 0.004$), quality of perfusion ($p = 0.032$), kidney length ($p = 0.010$), and kidney width ($p = 0.041$).

Table 2. General characteristics and variables of the donors and recipients

	Unit	*n*	Mean (range)	SD	Percentage
Donors (n = 90)					
Age	years	90	55 (6–77)	14.5	
BMI		90	25 (14–48)	5	
Weight	kg	90	76 (24–140)	20	
Height	cm	90	173 (121–202)	11	
Gender	% female	50			55.6
DCD vs. DBD		50			55.6
Cardiac arrest	%	33			36.7
Hypotensive episode	%	20			22.2
Smoking	%	57			63.3
Pack years	years		14 (0–60)	16	
Creatinine (first measurement)	μmol/L		75 (36–138)	23	
Creatinine (lowest value)	μmol/L		62 (33–128)	19	
Diuresis	mL/h		160 (15–490)	107	
Diuresis (last h)	mL/h		140 (3–540)	110	
Diabetes mellitus	%	6			6.7
Alcohol abuse	%	9			10
Hypertension	%	20			22.2
CMV IgG+	%	45			50
Recipients					
Age	years	83	55 (3–79)		
Gender	% female	57			31.7
Maximum PRA	%		14 (0–98)	26	
Procurement variables					
Cold ischemic time	min		781 (93–2,134)	268	
Warm ischemic time 1	min		9 (0–21)	7.6	
Warm ischemic time 2	min		23 (14–96)	13.5	
Temperature at explantation	°C		20.1 (12.5–27.6)	3.1	
Temperature at packaging	°C		15 (3.5–22.5)		
Kidney length	cm		11.4 (8–16)	1.4	
Kidney width	cm		5.9 (4–9)	0.9	
Follow-up					
Creatinine at 3 months	μmol/L		155 (48–579)	71.5	
Creatinine at 1 year	μmol/L		142 (47–317)	48.9	
Graft survival after 1 year	%				89
Patient survival after 1 year	%				94
Donor assessment score					
KDRI		90	1.34 (0.61–2.39)	0.41	
KDPI	%	90	70 (3–100)	24.6	

In the multivariable analysis, the only variables with a significant influence on IGF versus DGF or PNF were quality of perfusion (p = 0.003, Exp[B] = 2.211; 95% CI 1.310–3.733) and kidney width (p = 0.010, Exp[B] = 0.530, 95% CI 0.327–0.860). A worse decoloration of the kidney was associated with decreased chances of IGF. With an increased kidney width, the chances for IGF diminished. All other variables in Table 2 lacked influence on short-term graft function in multivariable analysis.

A second analysis of the 1-year graft function was performed (Table 3*)*. A 1-year eGFR >50 (n = 67) was compared to graft failure, PNF, and/or an eGFR <50 (n = 57). In comparison to the population with an eGFR >50, the population with graft failure, PNF, and/or an eGFR

Table 3. Analysis of variables in the IGF and DGF-or-PNF groups and analysis of the 1-year graft function

	IGF (*n* = 92)	DGF (*n* = 57) or PNF (*n* = 8)	2-sided *p* value	1-year eGFR>50 (*n* = 67)	Graft failure, PNF, or eGFR <50 (*n* = 57)	2-sided *p* value
Donor variables						
Age	53±16	56±11	0.229	50±14	61±8	0.000
BMI	25±5	26±5	0.054	26±5	24±4	0.000
Female sex	55	54	0.486	46	72	0.003
Weight	75±17	81±22	0.060	84±20	67±14	0.000
Height	173±10	174±12	0.602	177±1	169±8	0.000
Smoking	62	60	0.479	75	51	0.009
Pack years	13±15	13.3±16	0.931	16±14	12±16	0.205
Creatinine (first measure)	75±23	73±21	0.559	79±25	68±17	0.007
Creatinine (lowest value)	60±19	64±18	0.272	60±20	61±18	0.673
Diuresis (first measure)	177±117	140±91	0.039	172±116	145±84	0.151
Diuresis (last h)	152±118	132±106	0.298	162±128	125±86	0.082
Diabetes mellitus	5	9	0.528	5	9	0.470
Alcohol abuse	9	11	0.784	12	9	0.770
Hypertension	18	29	0.127	18	33	0.062
CMV IgG+	45	62	0.051	52	49	0.857
DBD	52	34	0.034	46	37	0.362
Cardiac arrest	39	31	0.313	37	37	1.000
Hypotensive episode	29	10	0.003	22	19	0.825
Cause of death (CVA)	58	42	0.872	40	54	0.117
KDRI	1.3±0.4	1.4±0.4	0.390	1.1±0.3	1.5±0.4	0.000
KDPI	0.7±0.3	0.7±0.2	0.146	0.6±0.2	0.8±0.2	0.000
Recipient variables						
Age	56±13	55±14	0.741	55±12	57±14	0.274
Female sex	35	32	0.864	34	33	0.907
% PRA maximum	11±21	17±31	0.158	12±23	8±21	0.330
Procurement variables						
Cold ischemic period	753±240	806±298	0.244	767±295	765±247	0.976
Warm ischemic period 1 (DCD)	14±4	15±4	0.174	8±8	10±7	0.250
Warm ischemic period 2 (DBD)	35±16	32±10	0.485	34±14	33±15	0.883
Warm ischemic period 2 (DCD)	33±11	33.6±14	0.817	35±10	33±15	0.694
Temperature at explantation	20±3	20.5±3	0.205	20±4	20±3	0.569
Temperature at packaging	15±4	15±4	0.79	15±4	15±3	0.656
Organ variables						
Kidney length	11.1±1.3	11.8±1.5	0.008	12±1	11±1	0.000
Kidney width	5.8±0.9	6.1±0.9	0.036	6±1	6±1	0.076
Plasticity of the renal artery	8±3	8±3	0.177	8±3	8±3	0.096
Quality of of perfusion	9±1	8±1	0.037	8±1	9±1	0.253
Aspect perfusion	8±2	8±2	0.757	8±2	9±1	0.126
Artherosclerosis of the aorta	4±3	4±2	0.101	4±3	4±3	0.593
Atherosclerosis at the renal artery origin	3±2	3±2	0.141	3±2	4±3	0.178
Quality of the parenchyma	8±1	8±1	0.457	8±1	8±1	0.676
Artherosclerosis of the renal artery	2±2	2±2	0.329	2±2	3±2	0.172
Overal quality of the left kidney	8±1	8±1	0.627	9±1	8±2	0.314
Overal quality of the right kidney	8±1	8±1	0.778	8±1	8±1	0.983
Parenchymal abnormalities	71	72	0.483	69	67	0.813
Blood vessel abnormalities	60	57	0.423	58	56	0.816
Cysts	7	6	0.556	8	6	0.616

Values are presented as means ± SD or percents.

<50 had: an older donor age, more females, a lower donor BMI and body weight, a shorter donor height, less smokers, and a lower first measured serum creatinine. Regarding the procurement variables, the size of the kidney was significantly higher.

Univariate binary logistic regression analysis of the 1-year graft function resulted in 9 variables with a significant influence, i.e., donor sex ($p = 0.003$), donor age ($p = 0.000$), donor height ($p = 0.000$), donor weight ($p = 0.000$), donor smoking ($p = 0.007$), first measured creatinine ($p = 0.010$), kidney length ($p = 0.000$), KDPI ($p = 0.000$), and IGF versus DGF and PNF ($p = 0.041$).

Multivariable binary regression analysis showed a significant influence of the first measured donor creatinine ($p = 0.008$, Exp[B] 0.965; 95% CI 0.938–0.994), KDRI ($p = 0.000$, Exp[B] 70.703; 95% CI 11.947–418.417), IGF versus DGF and PNG ($p = 0.019$, Exp[B] 0.274; 95% CI 0.089–0.847), and kidney length ($p = 0.000$, Exp[B] 0.428; 95% CI 0.254–0.720) on the 1-year graft function, while all other variables remained nonsignificant.

Discussion

Our study shows that the organ procurement surgeon is able to predict short-term transplant outcomes. At procurement, the kidney size is larger and the decoloration score of a graft is lower in kidneys with DGF or PNF compared to IGF. This influence was confirmed in our multivariable binary regression analysis, demonstrating that decoloration matters. A plausible explanation is that these kidneys might be insufficiently washed out, or even congested, which may predispose to DGF. DGF is associated with short-term complications, comorbidity, and a reduction of the 1-year graft survival [12, 13]. This results in a lower quality of life and a poor prognosis for the recipient [14, 15]. Although kidneys from DCD donors are known to have significantly higher rates of DGF [16, 17], early recognition of kidneys prone to DGF may improve graft and patient survival in transplanted patients. These DGF kidneys might benefit from reconditioning strategies, such as machine perfusion [16]. In our analysis, the influence on long-term graft survival was confirmed but KDRI did not predict the short-term graft survival. Zens et al. [17] confirmed that in 2018 as DCD kidneys had higher DGF rates than their DBD counterparts but in DCD kidneys, a higher KDPI score did not significantly affect the DGF rates.

The 1-year renal function was remarkably fair in our population. In order to obtain comparable groups, a fair function was defined as an eGFR >50 mL/min. In our multivariable binary regression analysis on the 1-year graft function, the variables that significantly influenced the prevalence of PNF, graft failure, or eGFR <50 were: KDRI, DGF, donor serum creatinine, and kidney length. This means that the short-term graft function and 1-year graft function are indeed influenced by different variables. The long-term graft function is predicted by the known variables that are included in donor risk scores as discussed in the Introduction, but the short-term function is predicted by other factors. The length and width of the explanted kidney and quality of perfusion expressing congestion of the kidney significantly influence the chance of PNF or DGF. As the short-term graft function largely influences patient survival in the direct postoperative phase, a predictive index might lead to preventive measures as reconditioning strategies.

There are several limitations to this study. This was a single-center study initially, but kidneys were transported to multiple centers in the Eurotransplant district. From some transplantations data were lacking because these were not collected or delivered by the centers where the transplantation procedures had taken place. Another limitation is the relatively small size of the study. Preferably, the groups with DGF and PNF would have been analyzed separately, but the small size of the PNF group did not allow for a separate analysis.

The assessment was done by the procurement surgeons and is a subjective measurement. Different procurement surgeons participated in gathering the data, which was partially based

on a ranking scale. In spite of this and in spite of the relatively small dataset, quality of perfusion and kidney size were significantly different in the populations with good versus bad short-term graft functions. This supports our hypothesis that the "subjective impression" of the surgeon relies on the observation of the degree of congestion and kidney size, together with the quality of perfusion. In univariate and multivariable analyses, the variable procurement surgeon did not influence the outcome.

In conclusion, poorly perfused kidneys would probably benefit most from reconditioning strategies, such as machine perfusion. A scoring system incorporating these surgical details could be helpful in the allocation process of ECD kidneys or in decision-making about reconditioning strategies such as machine perfusion. Being able to identify kidneys that might benefit from machine perfusion might increase short-term and long-term transplantation results and decrease short-term transplantation complications. Further research is indicated to determine the precise impact of a surgeon's view on the donor organ.

Acknowledgement

Our gratitude goes out to all of the procurement surgeons of the Erasmus MC procurement team for consciously taking measurements and filling out the forms, and to L.P. (Rita) Kleinepier at Erasmus MC, who helped us to gather data during this study. Furthermore, we would like to thank Cynthia Konijn of the Dutch Transplant Foundation and Marion J. van der Hoeven, donor coordinator at Erasmus MC, for their support.

Statement of Ethics

The authors have no ethical conflicts to disclose.

Disclosure Statement

The authors declare no conflict of interests.

Funding Sources

This study did not receive funding of any kind.

Author Contributions

Elise L. Tierie: acquisition, analysis, and interpretation of data for this work; drafting and writing of this paper; critical revision of this work for important intellectual content; final approval of the version to be published; and agreement to be accountable for all aspects of this work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Joke I. Roodnat: conception and design of this work; acquisition, analysis, and interpretation of data for this work. Drafting and writing of this paper; critical revision of this work critically for important intellectual content; final approval of the version to be published; and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of this work are appropriately investigated and resolved.

Frank J.M.F. Dor: conception and design of this work; critical revision of this work for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of this work are appropriately investigated and resolved.

References

1 Lai Q, Nudo F, Morabito V, et al. Donor quality scoring systems and early renal function measurements in kidney transplantation. In: Understanding the complexities of kidney transplantation. Rome: InTech; 2011. p. 574.
2 Schold JD, Kaplan B, Baliga RS, Meier-Kriesche HU. The broad spectrum of quality in deceased donor kidneys. Am J Transplant. 2005 Apr;5(4 Pt 1):757–65.
3 Locke JE, Segev DL, Warren DS, Dominici F, Simpkins CE, Montgomery RA. Outcomes of kidneys from donors after cardiac death: implications for allocation and preservation. Am J Transplant. 2007 Jul;7(7):1797–807.
4 Saidi RF, Elias N, Kawai T, Hertl M, Farrell ML, Goes N, et al. Outcome of kidney transplantation using expanded criteria donors and donation after cardiac death kidneys: realities and costs. Am J Transplant. 2007 Dec;7(12): 2769–74.
5 Johnston O, O'kelly P, Spencer S, Donohoe J, Walshe JJ, Little DM, et al. Reduced graft function (with or without dialysis) vs immediate graft function—a comparison of long-term renal allograft survival. Nephrol Dial Transplant. 2006 Aug;21(8):2270–4.
6 Siedlecki A, Irish W, Brennan DC. Delayed graft function in the kidney transplant. Am J Transplant. 2011 Nov; 11(11):2279–96.
7 Shoskes DA, Cecka JM. Deleterious effects of delayed graft function in cadaveric renal transplant recipients independent of acute rejection. Transplantation. 1998 Dec;66(12):1697–701.
8 Rodrigo E, Fernández-Fresnedo G, Ruiz JC, Piñera C, Palomar R, González-Cotorruelo J, et al. Similar impact of slow and delayed graft function on renal allograft outcome and function. Transplant Proc. 2005 Apr;37(3): 1431–2.
9 Parasuraman R, Zhang PL, Samarapungavan D, et al. Primary nonfunction of renal allograft secondary to acute oxalate nephropathy. Case Rep Transplant. 2011;2011:876906.
10 US Department of Health and Human Services. KDPI Calculator. [cited 2018 Mar 27]. Available: https://optn.transplant.hrsa.gov/resources/allocation-calculators/kdpi-calculator/.
11 Cockcroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. Nephron. 1976;16(1): 31–41.
12 Ploeg RJ, van Bockel JH, Langendijk PT, Groenewegen M, van der Woude FJ, Persijn GG, et al.; The European Multicentre Study Group. Effect of preservation solution on results of cadaveric kidney transplantation. Lancet. 1992 Jul;340(8812):129–37.
13 Lebranchu Y, Halimi JM, Bock A, Chapman J, Dussol B, Fritsche L, et al.; MOST International Study Group. Delayed graft function: risk factors, consequences and parameters affecting outcome-results from MOST, A Multinational Observational Study. Transplant Proc. 2005 Jan-Feb;37(1):345–7.
14 Stokes JB. Consequences of frequent hemodialysis: comparison to conventional hemodialysis and transplantation. Trans Am Clin Climatol Assoc. 2011;122(1):124–36.
15 Chan R, Brooks R, Erlich J, Chow J, Suranyi M. The effects of kidney-disease-related loss on long-term dialysis patients' depression and quality of life: positive affect as a mediator. Clin J Am Soc Nephrol. 2009 Jan;4(1): 160–7.
16 Moers C, Smits JM, Maathuis MH, Treckmann J, van Gelder F, Napieralski BP, et al. Machine perfusion or cold storage in deceased-donor kidney transplantation. N Engl J Med. 2009 Jan;360(1):7–19.
17 Zens TJ, Danobeitia JS, Leverson G, Chlebeck PJ, Zitur LJ, Redfield RR, et al. The impact of kidney donor profile index on delayed graft function and transplant outcomes: A single-center analysis. Clin Transplant. 2018 Mar; 32(3):e13190.