ORIGINAL ARTICLE

Kidney temperature during living donor kidney transplantation is associated with short-term measured glomerular filtration rate – a prospective study

Stan Benjamens[1,2†], Tamar A.J.van den Berg[1†], Thomas G.J. Kuipers[1], Cyril Moers[1], Stefan P. Berger[3], Henri G.D. Leuvenink[1] & Robert A. Pol[1]

1 Department of Surgery, Division of Transplant Surgery, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands
2 Medical Imaging Center, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands
3 Department of Internal Medicine, Division of Nephrology, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands

Correspondence
Stan Benjamens, Department of Surgery, University Medical Center Groningen, P.O. Box 30 001, 9700 RB Groningen, The Netherlands.
Tel.: +31 503613382;
fax: +31 503611745;
e-mail: s.benjamens@umcg.nl

†Both authors contributed equally.

SUMMARY

The duration of warm ischaemia time is associated with short- and long-term kidney transplant function. A quick rise in graft temperature is reported during the vascular anastomosis. This study was initiated to gain insight into the effect of graft temperature on short-term transplant function. From 2013 to 2015, data of living donor kidney transplant recipients were prospectively collected. At set intraoperative time points, the graft temperature was measured using a noncontact infrared thermometer. Primary endpoint was measured glomerular filtration rate (mGFR) at 3- and 6-month post-transplantation. Univariable and multivariable associations were identified using linear regression analyses. Multivariable analysis included models with donor, recipient and procedure characteristics. We evaluated 152 patients, 83 (55%) were male, mean ±SD age was 50.3 ± 13.4 years, and 79 (52%) were pre-emptively transplanted. In univariable analysis graft temperature, after 10 min of warm ischaemia was significantly associated with 3- and 6-month mGFR, β −0.22 (95% CI −0.39 to −0.04, $P = 0.01$) and β−0.22 (95% CI: −0.44 to −0.01, $P = 0.04$). The association remained significant in multivariable models. An independent association between kidney graft temperature and 3- and 6-month mGFR was identified. This association opens up the opportunity to further investigate the clinical impact of kidney rewarming during transplantation.

Transplant International 2020; 33: 174–180

Key words
graft function, ischaemia–reperfusion, kidney transplant, temperature

Received: 30 April 2019; Revision requested: 16 July 2019; Accepted: 17 September 2019;
Published online: 10 October 2019

Introduction

With the persistent shortage of kidney allografts available for transplantation, it is of utmost importance to achieve optimal kidney transplant function. However, the ischaemia–reperfusion injury that occurs during the donor and transplant procedures impairs organ recovery, with previous studies showing an association between both cold and warm ischaemia time and both short- and long-term kidney transplant function [1–3].

Several preventive strategies to reduce the ischaemic damage have been proposed, varying from adjustments of anastomotic techniques to remote ischaemic preconditioning [4,5]. With the knowledge that a quick rise in

doi:10.1111/tri.13528

kidney graft temperature occurs during the vascular anastomosis, reduction in second warm ischaemia time (WIT2) is one of the strategies to reduce ischaemic damage [6–8]. These strategies imply that a rushed vascular anastomosis, with rapid kidney rewarming, could have more detrimental effects on graft outcome than a longer vascular anastomosis, in which the kidney graft rewarms slower or is kept at a set low temperature [9].

Up to now, the effect of the duration of WIT2 and kidney temperature in this period has not been compared, making the effect of rapid kidney rewarming on short-term living donor transplant function still uncertain [6,9,10]. To establish the association between temperature at an early stage during the vascular anastomosis and short-term kidney transplant function, a prospective clinical study on living donor kidney transplant temperature was initiated.

Materials and methods

Between April 2013 and July 2015, a total of 160 consecutive adult living donor kidney transplant recipients were included in a prospective clinical study. Kidney graft temperature was measured at set time intervals during transplantation, using a noncontact infrared thermometer. Collection of clinical data included donor and recipient characteristics, perioperative variables and clinical follow-up.

Living donor kidney nephrectomy was performed by hand-assisted laparoscopic procedure and was previously published by our group [11]. After procurement, the kidney graft was flushed and perfused with cold University of Wisconsin Cold Storage solution (ViaSpan, DuPont, Wilmington, NC, USA; Belzer UW, Bridge to Life, Columbia SC, USA) and placed in static cold storage. Kidney transplantation was performed according to local protocol with exposure of the external iliac vein and artery by an oblique surgical incision from the pubic bone through about 2 cm cranial to the superior anterior iliac spine. The vascular anastomosis was performed in an end-to-side manner. Ureter–bladder anastomosis was performed by the modified Lich–Gregoir method. A comprehensive description of the kidney transplantation procedure was described by Kuipers *et al.* [7].

At set time intervals, kidney temperature was measured using a noncontact infrared thermometer (Voltcraft®, IR 800-20D Thermometer; Conrad Electronic, Hirschau, Germany). Target localization was achieved by a double laser with sharp-point optics and temperature is picked up within 150 ms (basic accuracy 2%), providing a 5–10 mm tissue infiltration. Multiple continuous measurements of the cortex resulted in an automatically calculated mean temperature (Celsius, °C).

Primary endpoint was measured glomerular filtration rate (mGFR) at 3- and 6-month post-transplantation. Measurement was performed by constant low-dose infusion of the radiolabeled tracer ^{125}I-iothalamate, as described by Apperloo *et al.* [12]. Three- and 6-month mGFR outcomes were present in 137 and 93 patients, respectively. The first warm ischaemia time (WIT1) was defined as the period between clamping of the renal artery during living donor kidney nephrectomy and the start of cold perfusion, after which cold ischaemia time (CIT) started. End of CIT was defined as the start of the vascular anastomosis, after which the WIT2 lasts until reperfusion in the recipient. Temperature at 10 min WIT2 was deemed the best time point for the temperature measurement during vascular anastomosis, as WIT2 is still short, but graft rewarming is already initiated. Recipients' follow-up ended at 6 months after transplantation, with post-transplantation events within the first 3 months, and delayed graft function (DGF) was defined as recipients receiving haemodialysis within 7 days of transplantation. Graft failure was defined as definitive return to dialysis or GFR < 15 ml/min.

Patient data were processed and electronically stored according to the declaration of Helsinki Ethical principles for medical research involving human subjects and the Institutional Ethics Review Board gave approval for this study (Medical Ethical Committee UMCG registration no. 2013424). The clinical and research activities were consistent with the Principles of the Declaration of Istanbul as outlined in the 'Declaration of Istanbul on Organ Trafficking and Transplant Tourism'.

Statistical methods and analyses

Distribution of variables was tested with Shapiro–Wilk test. Baseline characteristics were presented as mean ± standard deviation (SD) or median with interquartile range (IQR) for continuous variables depending on distribution. Categorical variables were presented as total with percentages (n (%)). Univariable linear regression analysis was performed, with the endpoints 3- and 6-month mGFR. Multivariable linear regression models were built using Enter method, allowing all variables to be entered to the model in a single step. The unadjusted association of temperature at 10 min WIT2 and 3- or 6-month mGFR was adjusted for potential confounders: Model 1 was adjusted for important donor determinants of recipient GFR (donor age, donor sex, donor Body mass index (BMI), total

human leucocyte antigen (HLA) mismatch, donor predonation GFR). In model 2, determinants of recipient GFR (age, sex, BMI, pretransplant smoking status, aetiology of kidney disease, duration of pretransplant dialysis, pre-emptive transplantation) were adjusted for. In model 3, the procedure characteristics (WIT1, CIT, WIT2, blood loss during transplantation) were adjusted for. To correctly interpret our results, variables were standardized using *z*-score. Results of the regression analyses were presented as standardized ß with 95% confidence interval (CI) and its corresponding *P*-value. Assumptions of homoscedasticity and normality of residuals for regression analysis were met. Tests of significance are two-tailed with significance set at $P < 0.05$. Statistical analyses were performed using the Statistical Package for the Social Sciences (IBM© SPSS Statistics© Version 23, SPSS Inc., Chicago, IL, USA).

Results

Temperature measurements were initially carried out during 160 kidney transplant procedures. In eight cases (5.0%), violation of the research protocol, due to the inability to (adequately) measure kidney temperature, led to patients' exclusion.

We evaluated 152 living kidney donor transplant recipients, of which 83 (54.6%) were male, with a mean age at time of transplantation of 50.3 ± 13.4 years. Of 152 recipients, 73 (48%) received pretransplant dialysis with a mean duration of 10.2 ± 20.3-months. The mean donor age was 54.9 ± 11.1 years and 74 (48.7%) were male. The median temperature at 10 min of warm ischaemia time was 12.7 [11.0–15.2], with a median WIT2 of 40 [33–46] minutes. Three- and 6-month mean mGFR was 61 ± 17 ml/min and 61 ± 18 ml/min, respectively. After 3-month follow-up, 18 (11.8%) patients had an event of biopsy-proven acute rejection and 5 (3.3%) patients had graft failure. Patient death did not occur. Additional donor, recipient, procedure and follow-up characteristics are summarized in Table 1.

Univariable linear regression analysis showed a significant association between 3-month mGFR and donor age (ß −0.29, 95% CI −0.45 to −0.13, $P = 0.001$), recipients' age (ß −0.19, −0.36 to −0.02, $P = 0.03$), recipients' gender (ß −0.19, −0.74 to 0.06, $P = 0.02$) and temperature at 10 min WIT2 (ß −0.22, −0.39 to −0.01, $P = 0.01$). The 6-month mGFR was significantly associated with donor age (ß −0.30, −0.52 to −0.10, P 0.004), recipients' age (ß −0.23, −0.45 to −0.02, $P = 0.03$), recipients' gender (ß −0.22, −0.86 to −0.03, $P = 0.03$), recipients' pretransplant smoking status (ß −0.30, −1.28 to −0.25, $P = 0.004$) and temperature at 10 min WIT2 (ß −0.22, −0.44 to −0.01, $P = 0.04$) in the univariable analysis. For all other variables,

Table 1. Donor and recipients characteristics

	Patients (n = 152)
Donor characteristics	
Age, years	54.9 ± 11.1
Sex, male (%)	74 (48.7)
BMI, kg/m^2	25.6 [23.5–27.7]
No. of HLA-AB mismatches, *n* (%)	
0	10 (7.9)
1	25 (16.4)
2	51 (33.6)
3	44 (28.9)
4	20 (13.2)
No. of HLA-DR mismatches, *n* (%)	
0	31 (20.4)
1	71 (46.7)
2	50 (32.9)
Total HLA mismatch, n	3.5 ± 1.5
Predonation GFR, ml/min	110 [98–123]
Recipient characteristics at time of transplantation	
Age, year	50.3 ± 13.4
Sex, male (%)	83 (54.6)
BMI, kg/m^2	25.4 [22.6–28.7]
Smoking, *n* (%)	26 (17.1)
Aetiology of kidney disease, *n* (%)	
Diabetic nephropathy	7 (4.60)
Renovascular disease	23 (15.1)
Primary IgA-nephropathy	16 (10.5)
Polycystic renal disease	45 (29.6)
Glomerulonephritis	8 (5.3)
Tubulointerstitial nephritis	15 (9.9)
Other/unknown	38 (25.0)
Pretransplant dialysis, months	10.2 ± 20.3
Pre-emptive transplantation, *n* (%)	79 (52.0%)
Procedure characteristics	
WIT1, minutes	4 [3–4]
CIT, minutes	151 [138–170]
WIT2, minutes	40 [33–46]
Temperature at 10 minutes WIT2, Celsius	12.7 [11.0–15.2]
Blood loss during transplantation, mL	200 [100–400]
Follow-up	
Post-transplantation events, *n* (%)	
Delayed graft function	1 (0.7)
Biopsy-proven acute rejection	18 (11.8)
Graft failure	5 (3.3)

Shown are donor and recipient characteristics in *n* (%). Ordinal data are given as median with IQR. Continuous data as mean ± SD.

BMI, body mass index; HLA, human leucocyte antigen; GFR, glomerular filtration rate; WIT, warm ischaemia time; CIT, cold ischaemia time.

Table 2. Univariable association between donor, recipient and procedure characteristics and measured GFR at 3 and 6 months after transplantation.

	Measured GFR					
	3 months			6 months		
	Standard β	(95% CI)	*P*-value	Standard β	(95% CI)	*P*-value
Donor characteristics						
Age donor, years	**−0.29**	**−0.45 to −0.13**	**0.001**	**−0.30**	**−0.52 to −0.10**	**0.004**
Sex donor (male)	−0.05	−0.44 to 0.24	0.57	−0.07	−0.57 to 0.27	0.49
BMI donor, kg/m^2	0.06	−0.11 to 0.24	0.49	0.04	−0.18 to 0.25	0.73
Total HLA mismatch, n	0.06	−0.11 to 0.24	0.46	0.10	−0.10 to 0.28	0.37
Predonation GFR, ml/min	0.00	−0.17 to 0.17	0.98	0.17	−0.03 to 0.37	0.10
Recipient characteristics						
Age recipient, year	**−0.19**	**−0.36 to −0.02**	**0.03**	**−0.23**	**−0.45 to −0.02**	**0.03**
Sex recipient, male (%)	**−0.19**	**−0.74 to −0.06**	**0.02**	**−0.22**	**−0.86 to −0.03**	**0.03**
BMI recipient, kg/m^2	0.09	−0.08 to 0.25	0.29	0.13	−0.08 to 0.34	0.23
Smoking (recipient), *n* (%)	−0.09	−0.67 to 0.20	0.28	**−0.30**	**−1.28 to −0.25**	**0.004**
Pretransplant dialysis, months	−0.02	−0.20 to 0.15	0.79	−0.10	−0.42 to 0.15	0.35
Pre-emptive transplantation, n	−0.00	−0.34 to 0.34	0.99	0.05	−0.33 to 0.51	0.67
Procedure characteristics						
Temperature at 10 min WIT2	**−0.22**	**−0.39 to −0.04**	**0.01**	**−0.22**	**−0.44 to −0.01**	**0.04**
WIT1, minutes	0.06	−0.11 to 0.23	0.47	0.09	−0.11 to 0.28	0.37
CIT, minutes	0.05	−0.12 to 0.22	0.57	0.03	−0.18 to 0.24	0.79
WIT2, minutes	−0.00	−0.18 to 0.17	0.96	0.14	−0.07 to 0.37	0.17
Blood loss during transplantation, ml	−0.02	−0.23 to 0.18	0.80	0.07	−0.16 to 0.30	0.56

Standardized β regression coefficient presented with 95% confidence interval (CI).

BMI, body mass index; HLA, human leucocyte antigen; GFR, glomerular filtration rate; WIT, warm ischaemia time; CIT, cold ischaemia time.

Bold values denote statistical significance at the $P < 0.05$ level. Three and 6 months measured GFR outcomes were present in 137 and 93 patients, respectively.

univariable associations with recipients' mGFR at 3 and 6 months after transplantation are presented in Table 2.

Multivariable linear regression analysis revealed that the association between mGFR at 3 months and temperature at 10 min WIT2 was independent of donor characteristics included in Model 1 (ß −0.20, −0.37 to −0.01, $P = 0.04$). The association remained significant when adjusted for recipient characteristics (Model 2, ß −0.23, −0.41 to −0.06, $P = 0.01$) or procedure variables (Model 3, ß −0.25, −0.46 to −0.06, $P = 0.01$) (Table 3). For 6-months mGFR, multivariable linear regression analysis revealed a significant association with temperature at 10 min WIT2, when adjusted for recipient characteristics (ß −0.23, −0.43 to −0.02, $P = 0.03$) or procedure characteristics (ß −0.28, −0.51 to −0.04, $P = 0.02$). In model 1, including donor characteristics, the association between 6-month mGFR and temperature at 10 min WIT2 was not significant (ß −0.18, −0.39 to 0.05, $P = 0.04$) (Table 3).

Discussion

This prospective clinical study showed an association between kidney temperature during living donor kidney transplantation, measured with a noncontact infrared thermometer, and short-term kidney function. The independent association reveals that a higher temperature after 10 min of WIT2 results in a lower mGFR at 3- and 6-month post-transplantation. While previous studies advocate to reduce the anastomosis time, based on the association between prolonged WIT and death, graft failure or DGF, our results did not indicate an association between cold or warm ischaemia time and short-term kidney function in living donor kidney transplant recipients [1,13–15].

This relatively large, single-centre, prospective study reveals a potentially modifiable factor to achieve optimal kidney transplant function. Therefore, the reported WIT2 should perhaps not be equal to anastomosis time,

Table 3. Multivariable association of donor, recipient and procedure models and measured GFR at 3 and 6 months after transplantation

	Measured GFR					
	3 months			6 months		
	Standard β	(95% CI)	*P*-value	Standard β	(95% CI)	*P*-value
Unadjusted						
Temperature at 10 min WIT2	**−0.22**	**−0.39 to −0.04**	**0.01**	**−0.22**	**−0.44 to −0.01**	**0.04**
Model 1*						
Temperature at 10 min WIT2	**−0.20**	**−0.37 to −0.01**	**0.04**	−0.18	−0.39 to 0.05	0.14
Age donor, years	**−0.29**	**−0.44 to −0.10**	**0.002**	**−0.26**	**−0.45 to −0.03**	**0.03**
Sex donor (male)	0.01	−0.34 to 0.38	0.91	0.03	−0.40 to 0.50	0.82
BMI donor, kg/m^2	0.07	−0.11 to 0.24	0.46	0.00	−0.21 to 0.21	0.98
Total HLA mismatch, *n*	0.08	−0.10 to 0.24	0.41	**0.23**	**0.01 to 0.38**	**0.04**
Predonation GFR, ml/min	−0.18	−0.36 to −0.00	0.05	0.01	−0.21 to 0.22	1.00
Model 2†						
Temperature at 10 min WIT2	**−0.23**	**−0.41 to −0.06**	**0.01**	**−0.23**	**−0.43 to −0.02**	**0.03**
Age recipient, year	**−0.18**	**−0.36 to −0.01**	**0.05**	−0.21	−0.42 to 0.01	0.06
Sex recipient, male (%)	**−0.19**	**−0.74 to −0.04**	**0.03**	−0.16	−0.71 to 0.07	0.11
BMI recipient, kg/m^2	**0.19**	**0.01 to 0.36**	**0.04**	0.21	−0.01 to 0.40	0.06
Smoking (recipient), *n* (%)	0.01	−0.42 to 0.45	0.94	**−0.22**	**−1.06 to −0.06**	**0.03**
Pretransplant dialysis, months	−0.04	−0.23 to 0.14	0.65	−0.18	−0.52 to 0.06	0.11
Pre-emptive transplantation, n	−0.05	−0.27 to 0.47	0.60	0.13	−0.18 to 0.70	0.24
Model 3‡						
Temperature at 10 min WIT2	**−0.25**	**−0.46 to −0.06**	**0.01**	**−0.28**	**−0.51 to −0.04**	**0.02**
WIT1, minutes	0.12	−0.07 to 0.31	0.22	0.18	−0.06 to 0.74	0.16
CIT, minutes	0.03	−0.18 to 0.24	0.78	0.03	−0.24 to 0.29	0.84
WIT2, minutes	0.00	−0.21 to 0.21	0.98	0.11	−0.14 to 0.35	0.38
Blood loss during transplantation, ml	0.01	−0.23 to 0.25	0.92	0.00	−0.31 to 0.31	1.00

Standardized β regression coefficient presented with 95% confidence interval (CI).

BMI, body mass index; HLA, human leucocyte antigen; GFR, glomerular filtration rate; WIT, warm ischaemia time; CIT, cold ischaemia time.

*Multivariable model 1: Temperature at 10 min warm ischaemia time + adjustment for donor determinants of recipient GFR (donor age, donor sex, donor BMI, total HLA mismatch, donor predonation GFR).

†Multivariable model 2: Temperature at 10 min warm ischaemia time + adjustment for recipients variables (age, sex, BMI, pre-transplant smoking status, duration of pretransplant dialysis, pre-emptive transplantation).

‡Multivariable model 3: Temperature at 10 min warm ischaemia time + adjustment for transplant procedure variables (WIT1, CIT, WIT2, blood loss during transplantation).

Bold values denote statistical significance at the $P < 0.05$ level. Three and 6 months measured GFR outcomes were present in 137 and 93 patients, respectively.

but rather to the duration that the kidney temperature has surpassed a certain temperature, that is the metabolic threshold of 15 °C, as suggested before [7]. Given these findings, it would be of interest to investigate the medical consequences of the presented association. Taking into consideration that the clinical relevance should be the focus on further research. Following the hypothesis of a clinical impact, efforts to keep the kidney temperature low during transplantation could be of relevance. Previous attempts to eliminate WIT2, resulted in lower rates of detrimental events (delayed graft function and/or acute rejection, $P = 0.015$) in 23 pairs of kidney transplant recipients, randomly assigned for kidney surface cooling during implantation [6], whereas a study on 134 kidney transplant recipients, randomly assigned for 'Ice Bag Technique' kidney cooling, did not find significant differences with regard to occurrence and duration of DGF [8]. The introduction of robotic kidney transplantation provides transplant surgeons with advanced techniques for regional hypothermia. The first study introducing this concept included 50 living donor kidney transplant recipients and

demonstrated its safety, but did not compare its outcomes to regular transplant procedures [16]. Controlled rewarming, as is used in experimental hypo- and normothermic machine perfusion models, or inducing hypometabolism through supplemental hydrogen sulphide are other opportunities to mitigate rewarming injury [17,18]. Furthermore, it would be interesting to know whether cooling from the core, by means of a ureteric catheter could be an approach to keep the graft at a low set temperature until reperfusion. Studies focusing on renal hypothermia during urological procedures, such as laparoscopic partial nephrectomy, show a positive effect of retrograde cold saline infusion through a ureteric access sheath [19].

Some limitations of our study need to be addressed. First, due to the fact that all included patients received a living donor kidney transplant, our findings cannot be extended to deceased donor transplant recipients. Although the effect of ischaemia–reperfusion injury is limited in living kidney donor transplantation, this phenomenon plays a critical role in kidney transplantation after deceased donation [3]. Second, in 9.9% of patients the 3-month and in 38.8% of patients the 6-month mGFR procedure was not part of the standard follow-up. An association with DGF is difficult to study in a living donor kidney transplant cohort due to the low incidence rate (n = 1 (0.7%)) [20]. However, there were 18 (11.8%) cases of biopsy-proven acute rejection and 5 (3.3%) cases of graft failure within 3-month follow-up. It is important to mention that this is a relatively high incidence of graft failure within this short follow-up period.

The strength of the presented study is the prospective design, including 137 patients, with the reliable and well-established endpoint of ^{125}I-iothalamate mGFR. To confirm the presented results, future studies focusing on cold and warm ischaemia time should include kidney temperature measurements. Furthermore, a prospective study is needed to see whether the results are maintained in a population with deceased donor kidney transplant recipients.

In conclusion, an independent association between kidney temperature during living donor kidney transplantation and 3- and 6-month mGFR was identified. This association between temperature and short-term transplant function opens up the opportunity to further investigate the clinical impact of kidney rewarming during transplantation.

Authorship

SB, TAJB: involved in research design, methodology, data collection, data analysis, visualization, writing–original draft preparation, writing–review and editing. TGJK: involved in research design, data collection, writing–review and editing. CM: involved in data collection, writing–review and editing. SPB, HGDL: involved in writing–review and editing. RAP: involved in conceptualization, research design, methodology, resources, data collection, writing–original draft preparation, writing–review and editing.

Funding

None declared.

Conflicts of interest

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

REFERENCES

1. Tennankore KK, Kim SJ, Alwayn IPJ, Kiberd BA. Prolonged warm ischemia time is associated with graft failure and mortality after kidney transplantation. *Kidney Int* 2016; **89**: 648.
2. Debout A, Foucher Y, Trébern-Launay K, *et al*. Each additional hour of cold ischemia time significantly increases the risk of graft failure and mortality following renal transplantation. *Kidney Int* 2015; **87**: 343.
3. Ponticelli C. Ischaemia-reperfusion injury: a major protagonist in kidney transplantation. *Nephrol Dial Transplant* 2014; **29**: 1134–1140.
4. Krogstrup NV, Oltean M, Bibby BM, *et al*. Remote ischaemic conditioning on recipients of deceased renal transplants, effect on immediate and extended kidney graft function: a multicentre, randomised controlled trial protocol (CONTEXT). *BMJ Open* 2015; **5**: e007941.
5. Ye G, Mo H-G, Wang Z-H, Yi S-H, Wang X-W, Zhang Y-F. Arterial anastomosis without sutures using ring pin stapler for clinical renal transplantation: comparison with suture anastomosis. *J Urol* 2006; **175**: 636, discussion 640.
6. Kamińska D, Kościelska-Kasprzak K, Chudoba P, *et al*. The influence of warm ischemia elimination on kidney injury during transplantation – clinical and molecular study. *Sci Rep* 2016; **6**: 36118.
7. Kuipers TGJ, Hellegering J, El Moumni M, *et al*. Kidney temperature course during living organ procurement and transplantation. *Transpl Int* 2017; **30**: 162.

8. Karipineni F, Campos S, Parsikia A, *et al*. Elimination of warm ischemia using the Ice Bag Technique does not decrease delayed graft function. *Int J Surg* 2014; **12**: 551.
9. Pol RA, Moers C. Minimizing warm ischemic injury in the recipient: don't rush the anastomosis, but keep the kidney cool. *Kidney Int* 2016; **90**: 226.
10. Feuillu B, Cormier L, Frimat L, *et al*. Kidney warming during transplantation. *Transpl Int* 2003; **16**: 307.
11. Zorgdrager M, van Londen M, Westenberg LB, *et al*. Chronic pain after hand-assisted laparoscopic donor nephrectomy. *Br J Surg* 2019; **106**: 711.
12. Apperloo AJ, de Zeeuw D, Donker AJ, de Jong PE. Precision of glomerular filtration rate determinations for long-term slope calculations is improved by simultaneous infusion of 125I-iothalamate and 131I-hippuran. *J Am Soc Nephrol* 1996; **7**: 567.
13. Weissenbacher A, Oberhuber R, Cardini B, *et al*. The faster the better: anastomosis time influences patient survival after deceased donor kidney transplantation. *Transpl Int* 2015; **28**: 535.
14. Heylen L, Pirenne J, Samuel U, *et al*. The impact of anastomosis time during kidney transplantation on graft loss: a Eurotransplant Cohort Study. *Am J Transplant* 2017; **17**: 724.
15. Heylen L, Naesens M, Jochmans I, *et al*. The effect of anastomosis time on outcome in recipients of kidneys donated after brain death: a cohort study. *Am J Transplant* 2015; **15**: 2900.
16. Menon M, Sood A, Bhandari M, *et al*. Robotic kidney transplantation with regional hypothermia: a step-by-step description of the Vattikuti Urology Institute-Medanta technique (IDEAL phase 2a). *Eur Urol* 2014; **65**: 991.
17. Minor T, Von Horn C, Paul A. Role of temperature in reconditioning and evaluation of cold preserved kidney and liver grafts. *Curr Opin Organ Transplant* 2017; **22**: 267.
18. Lobb I, Mok A, Lan Z, Liu W, Garcia B, Sener A. Supplemental hydrogen sulphide protects transplant kidney function and prolongs recipient survival after prolonged cold ischaemia-reperfusion injury by mitigating renal graft apoptosis and inflammation. *BJU Int* 2012; **110**(11 Pt C): E1187.
19. Ramani AP, Ryndin I, Lynch AC, Puthen Veetil RT. Current concepts in achieving renal hypothermia during laparoscopic partial nephrectomy. *BJU Int* 2006; **97**: 342.
20. Redfield RR, Scalea JR, Zens TJ, *et al*. Predictors and outcomes of delayed graft function after living-donor kidney transplantation. *Transpl Int* 2016; **29**: 81.