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Quantitative Assessment of Intraoperative Laser Fluorescence Angiography With Indocyanine Green Predicts Early Graft Function After Kidney Transplantation

Andreas L.H. Gerken, MD,* Kai Nowak, MD,† Alexander Meyer, MD,‡
Christel Weiss, PhD,§ Bernd Krüger, MD,‖ Nina Nawroth,* Ioannis Karampinis, MD,*
Katharina Heller, MD,¶ Hendrik Apel, MD,# Christoph Reissfelder, MD,*
Kay Schwenke, MD,* Michael Keese, MD,* Werner Lang, MD,‡ and Ulrich Rother, MD‡⊠

Objective: This study was designed to demonstrate the predictive ability of quantitative indocyanine green (ICG) fluorescence angiography for the short-term postoperative outcome, the occurrence of delayed graft function (DGF), and long-term graft survival.

Summary Background Data: DGF is a relevant problem after kidney transplantation; sufficient microperfusion of the allograft is crucial for postoperative organ function. Fluorescence angiography with ICG can serve as an intraoperative quality control of microperfusion.

Methods: This prospective diagnostic study, conducted in 2 German transplantation centers from November 2015 to October 2018, included 128 consecutive kidney transplantations. Intraoperative assessment of the allograft microperfusion was performed by near-infrared fluorescence angiography with ICG; a software was used for quantitative analysis. The associations between perfusion parameters (eg, ICG Ingress) and donor, recipient, peri-procedural, and postoperative characteristics were evaluated.

Results: DGF occurred in 23 (24%) kidney recipients from deceased donors. ICG Ingress ($P = 0.0027$), donor age ($P = 0.0452$), recipient age ($P = 0.0139$), and recipient body mass index ($P = 0.0017$) were associated with DGF. ICG Ingress correlated significantly with recipient age ($r = -0.27662$, $P = 0.0016$), cold and warm ischemia time ($r = -0.25204$, $P = 0.0082$; $r = -0.19778$, $P = 0.0283$), operating time ($r = -0.32208$, $P = 0.0002$), eGFR on postoperative days 1 ($r = +0.22674$, $P = 0.0104$) and 7

($r = +0.33189$, $P = 0.0001$). The cutoff value for ICG Ingress was 106.23 AU with sensitivity of 78.3% and specificity of 80.8% ($P < 0.0001$) for the prediction of DGF.

Conclusion: Fluorescence angiography with ICG allows intraoperative quantitative assessment of microperfusion during kidney transplantation. The parameter ICG Ingress reflects recipient and procedure characteristics and is able to predict the incidence of DGF.

Trial registration: Clinicaltrials.gov: NCT-02775838

Keywords: allograft cortical microperfusion, DGF, fluorescence angiography, ICG, near-infrared, perfusion imaging

K idney transplantation is the gold standard in treatment of end-stage kidney disease. According to the Global Observatory on Donation and Transplantation, 90,306 kidney transplantations were reported worldwide in 2017 (http://www.transplant-observatory.org/contador1). However, in times of organ shortage and less restrictive criteria for donors, delayed graft function (DGF) after kidney transplantation is an increasing clinical problem with negative implications for long-

term graft survival.[1,2] The incidence of DGF varies between 8% and 50%.[2–4] Different reasons for DGF have been described, namely risk factors associated with the donor or recipient, such as sex, race, obesity, prior sensitization, and prolonged waiting time,[5] and risk factors associated with the procurement, such as cold ischemia time.[2,5] These risk factors mainly promote immunologic and ischemic responses and cause ischemia-reperfusion injury followed by acute tubular necrosis, leading to impairment of renal microperfusion.[6] Sufficient macro- and microperfusion of the kidney allograft is essential for postoperative organ function. In order to ensure postoperative graft function, intraoperative assessment of allograft perfusion is essential for detecting organs at risk. Close surveillance of such organs is particularly important in the early postoperative period to evaluate the need for early therapeutic intervention. Various diagnostic measures have been employed to visualize graft perfusion after revascularization during kidney transplantation.

Intraoperative near-infrared fluorescence angiography with indocyanine green (ICG) is a diagnostic tool for the assessment of microperfusion. It can be employed during kidney transplantation to evaluate the microperfusion of the renal allograft's cortex noninvasively in real time. The changes in the fluorescence intensity signal can further be quantified by use of an appropriate software for quantitative assessment. Studies using different fluorescence systems have shown that ICG fluorescence angiography can be performed safely during kidney transplantation.[7–11] However, fluorescence videos were not quantitatively assessed in these publications. Our study group has already established an ICG dosing scheme for the quantitative intraoperative assessment of allograft microperfusion with the Spy Elite system (Stryker, Kalamazoo, MI) to ensure the comparability of perfusion assessment.[12] To the best of our knowledge, the predictive ability of intraoperative ICG angiography for postoperative organ function after kidney transplantation has not been prospectively evaluated in sufficiently large patient cohorts.

The aim of this study was to evaluate the benefit of quantitative intraoperative fluorescence angiography with ICG for the prediction of postoperative graft function and the occurrence of DGF after kidney transplantation.

METHODS

Patients

A prospective analysis was conducted of 128 patients (87 men, 41 women; median age 59 years, range 21-76 years) who presented with end-stage renal disease and underwent kidney transplantation. Deceased-donor and living-donor transplantations were consecutively included. All patients listed for kidney transplantation at 2 university hospitals between November 2015 and December 2018 were screened for study inclusion. In the absence of exclusion criteria, such as allergic diathesis or iodine allergy, patients were prospectively enrolled in the study (Erlangen, n = 84, and Mannheim, n = 44), which was registered at clinicaltrials.gov (NCT-02775838). The study was conducted in congruence with the Declaration of Helsinki and the Declaration of Istanbul and was approved by the ethics committees of the Universities of Erlangen and Mannheim (162_15B, 2016-513N-MA); all patients gave their written informed consent. The study adhered to the STARD guidelines.[13]

Study Design and Procedure

The standard techniques were used for preoperative diagnostics, organ procurement, and the transplantation procedure.

After completion of the vascular anastomosis of the kidney allograft, cortical graft perfusion was assessed using intraoperative fluorescence angiography with ICG. For visualization of graft perfusion the SPY Elite System was used. This system has been described in detail in previous studies.[10–12,14] Before graft reperfusion, the systolic blood pressure was normalized to approximately 100 mm Hg in all patients.

The ICG (ICG-Pulsion Medical Systems, Germany or Verdye, Diagnostic Green, Belgium) was injected systemically via a central venous catheter 5 minutes after reperfusion of the kidney. This way of application was chosen for reasons of standardization. The standardized dose of 0.02 mg ICG per kg body weight was administered.[12] Measurements were conducted over a period of 138 seconds to monitor organ inflow and outflow. All assessments were performed in a shaded operating room to avoid ambient light interfere. Quantitative assessment was performed in a postoperative analysis with the integrated SPY-Q software as described previously.[12,14]

Clinical Parameters of Graft Function

The periprocedural transplant characteristics were assessed, and early kidney function was monitored until hospital discharge. Therefore, patients with primary kidney function could be differed from patients with DGF. For DGF, the definition used by Schnuelle et al[15] was employed. Patients with the need for 2 or more sessions of hemodialysis postoperatively were defined as suffering from DGF. The association of fluorescence perfusion values with other clinical parameters of short-term kidney function (diuresis in the 1st hour and in the first 24 hours after transplantation, estimated glomerular filtration rate [eGFR] on postoperative days [POD] 1 and 7) as well as long-term kidney function (graft survival and serum creatinine level 1 year after transplantation) was assessed. Furthermore, cardiocirculatory parameters at the time of fluorescence angiography were recorded to rule out their possible influence on the measurements.

Analysis of Fluorescence Angiography Video Sequences

The fluorescence angiography videos are displayed in a gray scale of 256 different shades, enabling analysis of fluorescence intensity. For quantitative assessment, the software integrated in the fluorescence imaging system was used (SPY-Q, Stryker).

Four parameters are defined in the quantitative analysis by the SPY-Q software: Ingress, IngressRate, Egress, and EgressRate. IngressRate quantifies the inflow in terms of the increase of the fluorescence intensity per second (increase in gray stats per second). EgressRate is a parameter of the outflow of blood, measured as the decrease in fluorescence intensity per second. Ingress represents the difference between the initial baseline fluorescence intensity and the maximum intensity assessed, and Egress is the difference between maximum intensity and final intensity.

Statistical Analysis

At least 100 patients were needed to achieve 90% power to detect a mean difference in ICG Ingress of 50 AU (SD = 60 AU).

All statistical calculations were performed using SAS statistical software, release 9.4 (SAS Institute Inc, Cary, NC). Quantitative variables are presented as median values together with minima and maxima. For qualitative factors, absolute and relative frequencies are given. The comparison of 2 independent groups (eg, DGF versus non-DGF) was performed using the chi-squared test, Fisher exact test, the Cochran Armitage trend test, the Mann-Whitney Utest, or a 2-sample t test, as appropriate. The CKD-EPI equation was used to estimate GFR.

TABLE 1. Patient and Periprocedural Characteristics (n = 128)

Recipient characteristics	
Age (yr)	58.5 (21–76)
Sex (♀;♂)	41 (32); 87 (68)
Body mass index (kg/m^2)	25 (18–39)
Preoperative creatinine (mg/dL)	7.45 (2.7–13.4)
Time on dialysis (mo)	49 (2–171)
Smoker	59 (48)
Renal insufficiency stage	
4	8 (6)
5	120 (94)
Renal anemia	88 (71)
Diabetes mellitus	23 (18)
Dyslipidemia	53 (41)
Hypertension	117 (91)
Peripheral arterial occlusive disease	9 (7)
Periprocedural characteristics	
Living-donor transplantations	33 (26)
Deceased-donor transplantations	95 (74)
Arterial supply	
1 artery	94 (73)
2 arteries	30 (23)
3 arteries	4 (3)
Venous outflow	
1 vein	121 (95)
2 veins	7 (6)
Operating time (min)	165 (91–433)
Cold ischemia time (min)	577 (48–1680)
Warm ischemia time (min)	28 (12–120)
Postoperative characteristics eGFR	
POD 1 (mL/min/1.73 m^2)	10 (4–94)
POD 7 (mL/min/1.73 m^2)	32 (3–112)
1 year after transplant (mL/min/1.73 m^2)	53 (12–117)
DGF	
Deceased donors	23 (24)
Living donors	0 (0)

Quantitative variables are expressed as median, minimum, and maximum. For qualitative factors, absolute and relative frequencies are given.

To investigate the correlation between 2 quantitative variables, Pearson's correlation coefficient was assessed. For correlation analysis of diuresis, urine volumes were adjusted for residual excretion before transplantation.

Logistic and multiple logistic regression analyses were performed to identify parameters potentially associated with DGF. A receiver operating characteristic (ROC) curve was generated for the parameter ICG Ingress. To exclude the influence of living kidney donation with short cold ischemia times as a confounder, the ischemia time was divided into 3 equal segments and subset analysis was performed for each segment.

For all statistical tests, $P < 0.05$ was considered to show a statistically significant difference.

RESULTS

Patients and Procedure Characteristics

A total of 128 patients were included in this study (95 deceased-donor and 33 living-donor kidney transplantations). An overview of the patient and donor characteristics can be found in Table 1. Eight patients received their transplants preemptively, while 120 patients were already on dialysis. The median time on dialysis was 49 (2–171) months.

With regard to vascularization, 94 organs were transplanted with a single-artery supply, 30 organs had 2 arteries, and 4 organs had 3 arteries. All organs were drained by a single vein, except for 7 organs that had 2 veins. The median operation time was 164.5 (91–433) minutes. Median cold ischemia time was 576.5 (48–1680) minutes; the median warm ischemia time was 28 (12–120) minutes.

Postoperative Results and Delayed Graft Function

During the early postoperative period, 35 patients (27.34%) needed intermittent dialysis. Of all 128 patients, 23 (18%) were defined as having DGF, i.e., they needed more than a single dialysis session. In the DGF group, the median number of dialysis sessions was 5 (2–20). No statistically significant impact of preexisting comorbidities such as hypertension or diabetes on DGF could be shown. Concerning the perioperative parameters, the only factor that was found to have a significant influence on DGF was the type of donation: the group of 95 deceased-donor transplants included 23 (24%) patients with DGF, whereas in the group of living donors no patient suffered from DGF (P = 0.0018). The DGF and non-DGF subgroups after deceased-donor transplantation are compared in Table 2. Living donors were excluded from this analysis, as no DGF occurred in this group.

The 1-year results after transplantation showed a graft survival rate of 92.2% (n = 118). The median creatinine level was 1.4mg/dL (0.7–4.3 mg/dL) after 1 year. In the group of deceased-donor transplants, the graft survival rate after 1 year was significantly lower in the subgroup with DGF (DGF: 74%, non-DGF: 96%; P = 0.0018). There was no significant difference in the incidence of DGF between the 2 centers.

Association Between Intraoperative Perfusion Analysis and Delayed Graft Function

The influence of intraoperative ICG fluorescence perfusion assessment on DGF was investigated separately. For all parameters (Ingress, IngressRate, Egress, EgressRate), a significant difference was found between those with early postoperative normal kidney function and those developing DGF (Table 3).

The ROC analysis of the perfusion parameter Ingress yielded an optimum cutoff value of 106.23 AU for the parameter Ingress, with sensitivity of 0.783 and specificity of 0.808 (area under the curve [AUC]: 0.816, P < 0.0001) for the prediction of DGF. The ROC curve is shown in Figure 1. The subset analysis of the 3 segments of cold ischemia time is presented in Table 4. This analysis revealed similar cutoff values for ICG Ingress in segments 2 and 3. In segment 1, no cutoff could be identified due to the rare occurrence of DGF.

Association Between Intraoperative Perfusion Analysis and Donor, Recipient, Graft, Periprocedural, and Postoperative Characteristics

The median values for ICG Ingress in grafts obtained from living versus deceased donors differed significantly: 193.00 (72.00–252.00) AU and 130.50 (14.00–252.00) AU, respectively (P < 0.0001). The corresponding boxplots are shown in Figure 2.

Correlation analyses for the ICG fluorescence parameter Ingress showed significantly negative correlations for the variables recipient age (r = −0.27662, P = 0.0016), cold ischemia time (r = −0.25204, P = 0.0082), warm ischemia time (r = −0.19778, P = 0.0283), operating time (r = −0.32208, P = 0.0002), and serum creatinine levels 1 year after transplantation (r = −0.21561, P = 0.0201). Significantly positive correlations were found for eGFR on POD 1 and 7 (r = +0.22674, P = 0.0104 and r = +0.33189, P = 0.0001, respectively), as well as cumulative diuresis 1 and 24hours postoperatively (r = +0.25065, P = 0.0060

TABLE 2. Comparison of Recipient, Donor, and Periprocedural Characteristics Between Recipients With Normal Graft Function and Those With Delayed Graft Function (DGF) After Deceased-donor Kidney Transplantation (n = 95)

	DGF	Non-DGF	*P* Value
Recipient characteristics			
Age (yr)	63 (26–74)	62(31–76)	0.6536
Sex (♀;♂)	7 (30); 16 (70)	25 (35); 47 (65)	0.7049
Body mass index (kg/m^2)	26 (19–38)	25 (18–39)	0.5222
Smoker	13 (57)	28 (39)	0.2820
Preoperative creatinine (mg/dL)	8.19 (4.16–11.40)	58 (2.70–13.40)	0.9308
Comorbidities			
Renal anemia	16 (73)	50 (71)	0.9061
Diabetes	7 (30)	13 (18)	0.2433
Dyslipidemia	14 (61)	31 (43)	0.1363
Hypertension	21 (91)	67 (93)	0.6748
Peripheral arterial occlusive disease	3 (13)	4 (6)	0.3545
Hyperuricemia	3 (13)	14 (20)	0.7552
Donor characteristics			
Age (yr)	66 (29–81)	60 (22–83)	0.0716
Sex (♀;♂)	8 (45); 10 (56)	30 (46); 35 (54)	0.8975
Donor creatinine	0.85 (0.50–2.80)	0.82 (0.45–4.00)	0.9773
Smoker	2 (20)	11 (31)	0.6983
Procurement and periprocedural characteristics			
Centre: Erlangen/ Mannheim	18 (28)/5 (17)	47 (72)/25 (83)	0.2436
Arterial supply 1/2/3 arteries	15 (65)/30 (23)/1 (4)	51 (71)/18 (25)/3 (4)	0.6642
Venous outflow 1/2 veins	23 (100)/0 (0)	65 (90)/7 (10)	0.1896
Operating time (min)	182 (105–433)	176 (91–425)	0.4929
Cold ischemia time (min)	672 (350–1376)	720 (120–1680)	0.9073
Warm ischemia time (min)	28 (12–40)	28 (14–120)	0.6509
Graft survival for 1 yr	17 (74)	69 (96)	0.0018

Quantitative variables are expressed as median, minimum, and maximum. For qualitative factors, absolute and relative frequencies are given.

and r = +0.30201, *P* = 0.0008, respectively). Bivariable logistic regression analysis confirmed the significant association of ICG Ingress with diuresis after 1 hour (*P* = 0.0114) and 24 hours (*P* = 0.0012), adjusted for residual diuresis.

At the time of ICG angiography, the median pulse rate was 68 (50–100) bpm and the median systolic blood pressure was 110 (85–150) mm Hg. There was no significant correlation between ICG Ingress and intraoperative pulse rate or systolic blood pressure at the time of fluorescence angiography (r = 0.11778, *P* = 0.3076 and r = 0.11807, *P* = 0.3164, respectively).

The median intraoperative ICG Ingress was 151.00 (14.00–252.00) AU in recipients with graft survival at 1 year compared with 104.50 (17.00–209.00) in those with graft failure at 1 year. This difference was not quite statistically significant (*P* = 0.0601).

In logistic regression analysis, ICG Ingress was the most important independent factor significantly associated with DGF (*P* < 0.0001). The numbers of renal arteries and veins, however, were not associated significantly with ICG Ingress (*P* = 0.2800

and *P* = 0.8285, respectively). Multiple logistic regression analysis identified the following 4 factors associated significantly with DGF: ICG Ingress (*P* = 0.0027), donor age (*P* = 0.0452), recipient age (*P* = 0.0139), and recipient body mass index (BMI) (*P* = 0.0017). In subset analysis for cold ischemia times longer than 740 minutes, ICG Ingress was the only factor significantly associated with DGF (*P* = 0.0242).

DISCUSSION

This study clearly demonstrates the utility of intraoperative fluorescence angiography for the prediction of postoperative allograft function after kidney transplantation. Our results show that quantitative assessment of intraoperative perfusion by ICG fluorescence angiography may help to predict postoperative short- and long term graft function. These findings give us a better understanding of the risk factors for DGF and may improve postoperative clinical care.

We identified the parameters donor age, recipient age, and recipient BMI as risk factors for DGF. These and other factors have already been described in previous studies.[5,16,17] It is also well known that cold ischemia time is closely associated with DGF,[2,3,6] promoting ischemia-reperfusion injury with detrimental consequences for the microperfusion and function of the kidney allograft.[1] In the present study, we have identified a new parameter, ICG Ingress, as the most important independent risk factor for DGF. In the event of long ischemia times, which cannot always be prevented on grounds of logistics and transport, ICG Ingress might therefore serve to further stratify the risk for DGF, as ICG Ingress itself seems to be a surrogate parameter for different individual factors affecting the quality of cortical microperfusion of the renal allograft.

TABLE 3. Association Between Intraoperative Perfusion Assessment of the Allograft With ICG Fluorescence Angiography and Delayed Graft Function (DGF) After Kidney Transplantation

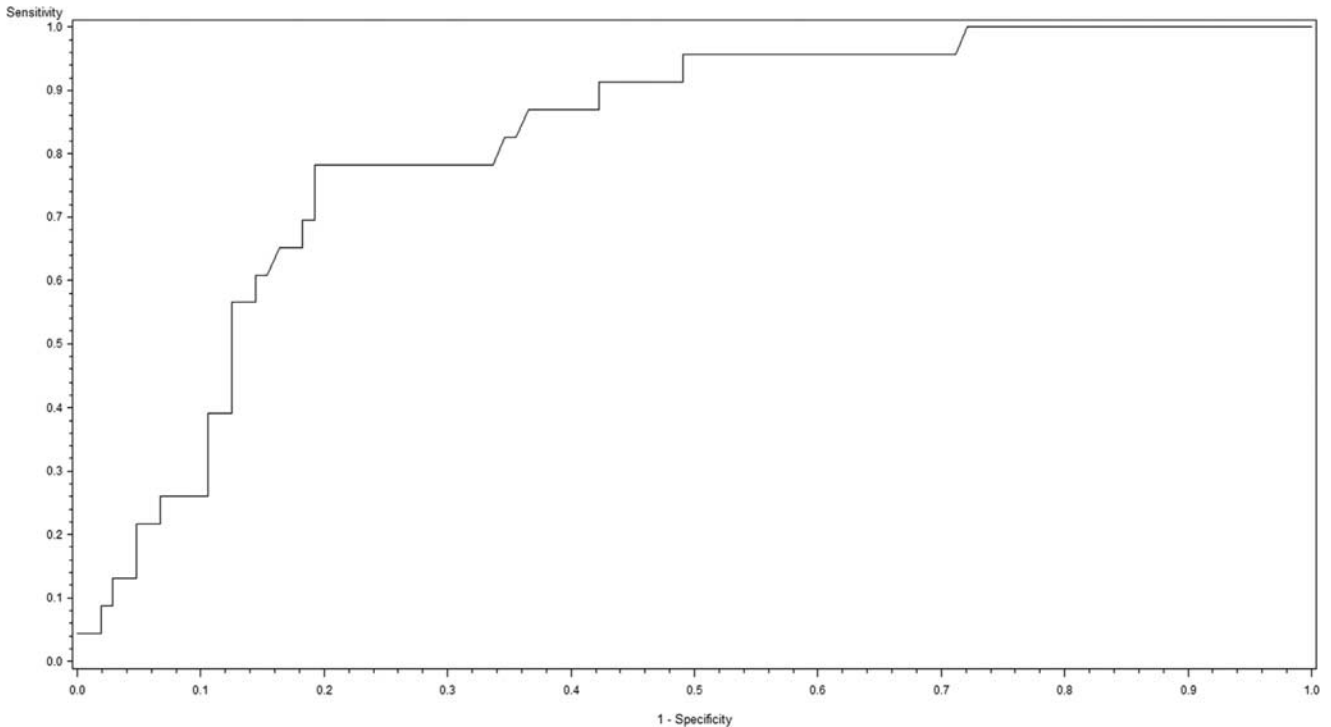|	DGF Median AU (Range)	Non-DGF Median AU (Range)	*P*
Ingress	76.00 (14.00–209.00)	167.00 (16.00–252.00)	< 0.0001
IngressRate	13.20 (0.20–32.60)	31.15 (0.20–84.40)	< 0.0001
Egress	50.00 (6.00–116.00)	107.00 (2.00–200.00)	< 0.0001
EgressRate	4.45 (0.30–15.30)	12.40 (0.20–39.70)	0.0009

Significance value *p* < 0.05.

FIGURE 1. Receiver operating characteristic (ROC) analysis of the perfusion parameter ICG Ingress as a predictor for delayed graft function (DGF). (Cut-off value: ICG Ingress 106.2 AU, sensitivity 0.78261, specificity 0.80769, AUC 0.816, P < 0.0001).

In a recently published article, quantitative assessment of ICG fluorescence angiography with the IC-View system (PULSION Medical Systems) in 36 recipients showed encouraging results for the prediction of DGF.[18] In the present study, with a much larger prospective cohort of 128 kidney transplant recipients, we confirmed the predictive ability of intraoperative ICG Ingress for the occurrence of DGF using a different fluorescence system (Spy Elite).

Here, DGF was defined as the requirement for more than 1 single posttransplant dialysis session. We believe that this definition represents impairment of the graft more precisely than the definition of DGF most commonly used to date (one dialysis session in the first postoperative week), because a single dialysis session can also be indicated for reasons arising from the recipient's overall state of health (fluid overload, hyperkalemia), depending on the treating nephrologist's assessment.[15,19] The definition used here has a specificity of 77.6% for the detection of DGF, higher than other definitions.[20] Even though the incidence of DGF was comparatively low using this definition, at 24%, we were able to show that all parameters of quantitative perfusion assessment were significantly associated with DGF. ICG Ingress reflects the quality of inflow of blood into the allograft, while ICG Egress represents the outflow. The latter factor would be affected by venous problems, such as congestion. In the present study, hemodynamic parameters and the number of arteries and veins did not affect quantitative ICG perfusion parameters significantly.

We observed a significant difference in ICG Ingress between grafts obtained from living donors and those from deceased donors. As shown before, intraoperative cortical microperfusion is affected by the type of donation.[21,22] In a previous publication, our study group demonstrated that ICG Ingress reflects preexisting histopathological changes of the allograft's cortex.[14] In the present study, we analyzed the association of cortical microperfusion with different transplant characteristics. Intraoperative ICG Ingress showed a significantly negative correlation for recipient-specific variables (age) and for procurement and periprocedural characteristics (cold ischemia time, warm ischemia time, and operating time). On the basis of these results it can be assumed that the characteristics mentioned above affect the quality of microcirculation in the allograft cortex and are therefore reflected in ICG fluorescence angiography. In conclusion, this study adds value to the identification of mechanisms for the causes of DGF.

TABLE 4. Cut-off Values of the Parameter ICG Ingress in AU for Different Periods of Duration of the Cold Ischemia Time (in min)

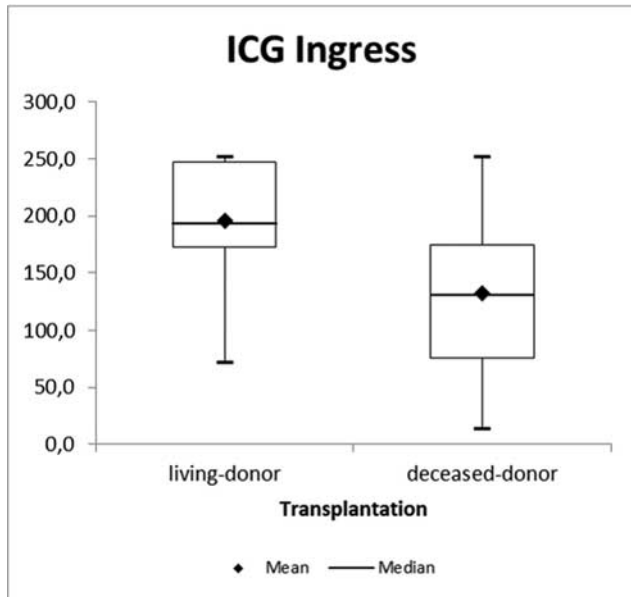| Segment of Cold Ischemia Time	Cold Ischemia Time (min)	AUC	Cutoff ICG Ingress (AU)	Sensitivity (%)	Specificity (%)	Significance (P Value)
All	48–1680	0.816	106.2	78	81	**< 0.0001**
1	≤ 380	0.882	135.9	100	79	0.1061
2	381–740	0.742	105.8	89	68	**0.0420**
3	> 740	0.781	102.8	86	79	**0.0242**

Significance value *p* < 0.05.

FIGURE 2. ICG Ingress in allografts from living and deceased donors on quantitative perfusion assessment with ICG fluorescence angiography during kidney transplantation (P < 0.0001).

Furthermore, intraoperative ICG Ingress correlated significantly with parameters of early graft function (postoperative diuresis in the first 24 hours, eGFR on POD 1 and 7). Previous studies assessing cortical microperfusion obtained similar results using different tools for assessment of perfusion. Scheeren et al[22] assessed cortical tissue oxygenation using the O2C technique and showed correlation of tissue oxygenation with postoperative plasma creatinine level and the need for hemodialysis. The assessment of intraoperative cortical microperfusion by Angelescu et al[21] employing thermodiffusion and by Fechner et al[23] using O2C were both predictive for the occurrence of DGF.

With regard to the long-term outcome after kidney transplantation, ICG Ingress correlated negatively with creatinine level after 1 year, but there was no significant association of ICG Ingress with graft survival after 1 year. However, graft failure occurred in only 10 recipients. Therefore, the analysis is not statistically valid and should be repeated in a study with a larger cohort.

This is the first study to report a cutoff value for the intraoperative ICG ingress after reperfusion that significantly predicts DGF, with fairly good sensitivity of 78% along with specificity of 81%. This information helps to categorize patients in the postoperative course. Potentially critical kidney recipients with ICG Ingress below 106.23 AU can be identified early, and postoperative care could be improved by close monitoring allowing early therapeutic or preventive interventions if DGF is confirmed. The therapeutic options for DGF include a change of the immunosuppressive regimen such as the withdrawal of calcineurin inhibitors,[24] the administration of thymoglobulin,[25] or dialysis in the case of anuria. On the other hand, patients with unremarkable intraoperative ICG Ingress might benefit from a shorter monitoring period, leading ultimately to a shorter overall hospital stay and lower treatment costs.

The necessity of intravenous ICG application represents one limitation of the performance of fluorescence angiography. In our patient cohort, there were no side effects associated with ICG application. In literature, the occurrence of severe, mainly anaphylactoid adverse reactions, is reported to be very low (0.05%).[26] However, patients with allergic diathesis and iodine allergy should be excluded from this investigation, as performed in the present study.

In summary, it can be stated that intraoperative ICG fluorescence angiography may not only serve as an instant quality control for the surgeon, allowing reevaluation of the quality of anastomoses with regard to the visual aspect of cortical allograft perfusion in the video sequences.[7–11] Quantitative assessment of the intraoperatively acquired video sequences also allows the surgeon to differentiate between arterial and venous problems. Furthermore, the extent of ICG Ingress reflects several factors of organ and periprocedural quality and has a significant predictive ability for short-term postoperative organ function and the occurrence of DGF, which itself bears the inherent risk of long-term graft failure.

CONCLUSION

To the best of our knowledge, this is the largest prospective study to report the use of quantitative intraoperative fluorescence angiography with ICG to predict short-term postoperative graft function after kidney transplantation. We demonstrated that impairment of intraoperative microperfusion in the allograft cortex is a risk factor for the occurrence of DGF. Moreover, we identified ICG Ingress as an independent parameter predicting DGF and established a cutoff value for the intraoperative ingress of ICG fluorescence intensity, allowing the detection of kidneys at risk of developing DGF. This information might be useful especially for patients receiving organs with a long ischemia time. Further studies are warranted to analyze the effect of early therapeutic approaches for the prevention of DGF in these kidney transplant recipients with the aim of improving long-term graft survival. Future studies should also address the influence of cardiocirculatory parameters and a complex vascular status on ICG perfusion assessment.

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