Impact of High-spec Infrared Video Camera for Intraoperative Evaluation of Kidney Graft Perfusion during Living Donor Kidney Tansplantation : A Pilot Study

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Background : Good kidney graft perfusion (KGP) is extremely important in kidney transplantation, although the methodology to evaluate intraoperative KGP has not yet been established. The present study tested the hypothesis that intraoperative KGP could be assessed via thermal changes using a modern high-spec infrared video camera.

Methods : Patients scheduled to receive kidney transplantation from a living donor were enrolled prior to surgery in this pilot study. The thermal changes of the transplanted kidney were visually and quantitatively evaluated for 1 minute just after unclamping the renal artery. The region of interest was the surface of the transplanted kidney. Maximal, minimal, and mean temperatures were measured and compared before and at 15, 30, and 60 seconds after unclamping. Serum creatinine levels were monitored before surgery and on post-operative days 1, 3, and 6.

Results : A total of 5 recipient-donor pairs were analyzed. Thermal increases of the transplanted kidney were clearly visualized. The effects of a spastic renal artery could be detected as a delay in thermal recovery. The presence of perirenal fatty tissue partially obstructed the monitoring of thermal increases after unclamping the renal artery. The findings of the infrared video camera did not impact post-operative serum creatinine level recovery.

Conclusions : A high-spec infrared video camera may be a useful tool to evaluate KGP of transplanted kidneys intraoperatively, especially for detecting spasms of the renal artery. *Shinshu Med J 72 : 219―225, 2024*

(Received for publication January 17, 2024 ; accepted in revised form April 2, 2024)

Key words : living donor kidney transplantation, infrared video camera, kidney graft perfusion

Abbreviations : KGP, kidney graft perfusion ; KT, kidney transplantation ; LDKT, living donor kidney transplantation ; PEKT, preemptive kidney transplantation ; POD, post-operative day ; ROI, region of interest

Ⅰ Introduction

Kidney transplantation (KT) has become the procedure of choice for treating patients with chronic terminal renal dysfunction. The causes leading to delayed graft function include a variety of donor and recipient factors, among which one of the most studied has been the length of graft preservation time along with consecutive ischemia-reperfusion injury causing endothelial damage and acute tubular necrosis[1)2)]. Therefore, monitoring kidney graft perfusion (KGP) is extremely important for successful KT. KGP in the transplanted kidney is generally evaluated using gross appearance including color and size, physical findings such as hardness, and ultrasonographic findings that include color Doppler ultrasonography. However, gross appearance and physical findings of the kidney are not objective, and resistive index and pulsatility in-

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dex tend to ultrasonographer's skills. Meanwhile, significant advances have been made in imaging technology, with infrared video cameras producing clear, high-resolution images and footage that can be analyzed in many situations. However, the use of such technology is currently limited in the medical field and has not been reported sufficiently. We hypothesized that KGP was reflected by thermal changes in the kidney surface, which could be visualized and monitored using a high-spec infrared video camera. The present study analyzed the thermal changes of transplanted kidneys using an infrared video camera towards the intraoperative evaluation of KGP in living donor kidney transplantation (LDKT).

Ⅱ Materials and Methods

A Study design and ethical statement

This pilot study was conducted as an observative single-arm trial. All procedures were performed in accordance with the standards of the Ethics Committee of Shinshu University School of Medicine, the Helsinki Declaration of 1975 (2008 revision), and the Ethical Guidelines for Clinical Studies issued by the Ministry of Health, Labor, and Welfare of Japan, which was revised in 2008 and enforced in April 2009. Permission number was 4755-2020 (accepted : June 1, 2020).

B Participants

Patients who were scheduled to receive LDKT were enrolled in this investigation prior to surgery. Since this trial was conducted as a pilot study towards exploring further steps with a high-spec infrared video camera, no exclusion criteria were specified.

C Surgical procedures and protocol

All transplanted kidneys were obtained by hand-assisted laparoscopic donor nephrectomy. The removed kidney was immediately perfused with 930 mL of preservation solutions (Euro Collins solution, CritiCare Pharma Co., Ltd., Atsugi, Japan). The transplanted kidney was placed on the right iliac fossa of the recipient. The renal artery was connected to the internal iliac artery by end-to-end anastomosis. The renal vein was connected to the external iliac vein by end-to-side anastomosis. The ureter was connected to the urinary bladder using the Lich-Gregoir method, with 1.5 cm of spatulated ureter and 1.5 cm of submucosal tunnel. After unclamping the renal vein connected to the external iliac vein, the renal artery was then unclamped. Next, the reperfusion of blood supply in the transplanted kidney was recorded using an infrared video camera (X-HR, ViewOhre imaging Co., Ltd., Tokyo, Japan) set to a high resolution of 0.05 degrees Celsius. The thermal changes of the transplanted kidney surface were visually and quantitatively evaluated for 1 minute just after unclamping the renal artery.

All of the images were obtained using a high-spec infrared video camera almost 30 cm away from the transplanted kidneys. The region of Interest (ROI) on the images was the surface of the transplanted kidney. The ROI was set using oval shape range conformable to transplanted kidney excluding renal arteries, veins, and ureters. Maximal, minimal, and mean temperatures on the ROI were measured and compared before and at 15, 30, and 60 seconds after unclamping. All data were automatically analyzed using the software included with the infrared video camera (Thermal ViewX-HR-B, ViewOhre imaging Co., Ltd., Tokyo, Japan).

D Visual and quantitative analysis of kidney surface temperature

To establish a methodology for evaluating thermal changes of the kidney surface after LDKT, the mean, maximal, and minimal temperatures of each case were recorded before unclamping and at 15, 30, and 60 seconds after unclamping along with visual assessment. Similarly, to examine the effects of such kidney conditions as fatty tissue accumulation and renal artery spasms, the changes in mean, maximal, and minimal temperature of each case were compared before and after unclamping.

E Serum creatinine levels and urine volume

Before and after KT, serum creatinine levels were determined and compared among the recipients and donors. Blood samples at 1 week before KT were employed for the highest value of serum creatinine levels. Blood samples after KT were obtained on postoperative day (POD) 1, 3, and 6. Moreover, urine volume was measured after surgery on POD 0, 1, and 2. Urine volume on POD 0 was measured from KT to 6 : 00 am in the day after KT.

Ⅲ Results

A Patients

A total of 5 recipient-donor pairs involved in LDKT were enrolled in this study. All kidney grafts were obtained from the left side. The characteristics of the enrolled patients are summarized in **Table 1**. Data were not acquired at 30 seconds after unclamping in case 2 and at 60 seconds after unclamping in case 5 due to intraoperative management, including hemostasis.

B Visual evaluation

The representative findings of 3 cases are shown in **Fig. 1**. In case 1, the typical intraoperative thermal changes are visible in a time-dependent manner just after unclamping the renal artery. Visualization of the thermal changes of the transplanted kidney was hampered in case 2, in which perirenal fatty tissue covered the renal surface. In case 3, the thermal changes were suppressed due to a spastic renal artery after unclamping. Renal aortic spasm was diagnosed with intraoperative physical appearance and ultrasonographic findings of renal artery. The spasm recovered spontaneously almost 5 to 10 minutes after unclumping.

C Quantitative analysis of ROI

The baseline tempareture of the transplanted kidney surface temperature of each case are presented in **Fig. 2**. Moreover, timedependent changes (Δ) of each case were presented in **Fig. 3**. In general, maximal temperatures did not change remarkably before and after unclamping the renal artery. In contrast, the maximal, mean, and minimal temperatures reflected the condition of the transplanted kidney, such as arterial spasms. Regarding the changes in mean, maximal, and minimal kidney surface temperature, the mean and minimal temperatures showed comparable tendencies apart from the cases of spastic renal artery and fatty kidney.

D Serum creatinine levels and urine volume

The serum creatinine levels of recipients and do-

Table 1 Characteristics of the enrolled patients

	ABO Compatibility	Operative time (min)	TIT (min)	WIT (sec)	Recipient							Donner					
					Underlyning cause of CKD	Gender	Age(y.o)	Hight (cm)	Weight (kg)	BMI (cm2/kg)	Renal replacement therapy	Gender	Age (y.o)	Hight (cm)	Weight (kg)	BMI (cm2/kg)	Number of renal artery
Case 1	Incompatible	405	169	215	Infectious nephritis	M	64	160	52	20.3	HD	F	65	154	48	20.2	1
Case 2	Incompatible	512	155	177	IgA nephropathy	M	35	171	72	24.6	PEKT	M	65	167	72	25.8	1
Case 3	Compatible	370	125	139	Alport syndrome	M	19	173	55	18.4	HD	M	49	168	72	25.5	1
Case 4	Compatible	381	141	100	IgA nephropathy	F	69	153	52	22.2	PEKT	M	73	163	60	22.6	2
Case 5	Compatible	575	197	200	Diabetic kidney disease	M	63	167	66	23.7	PEKT	F	60	159	52	20.6	1

CKD : chronic kidney disease, BMI : body mass index, HD : hemodyalysis, KT : kidney transplantation, PEKT : pre-emptive kidney transplantation, POD : post-operative day, TIT : total ischemic time, WIT : warm ischemic time

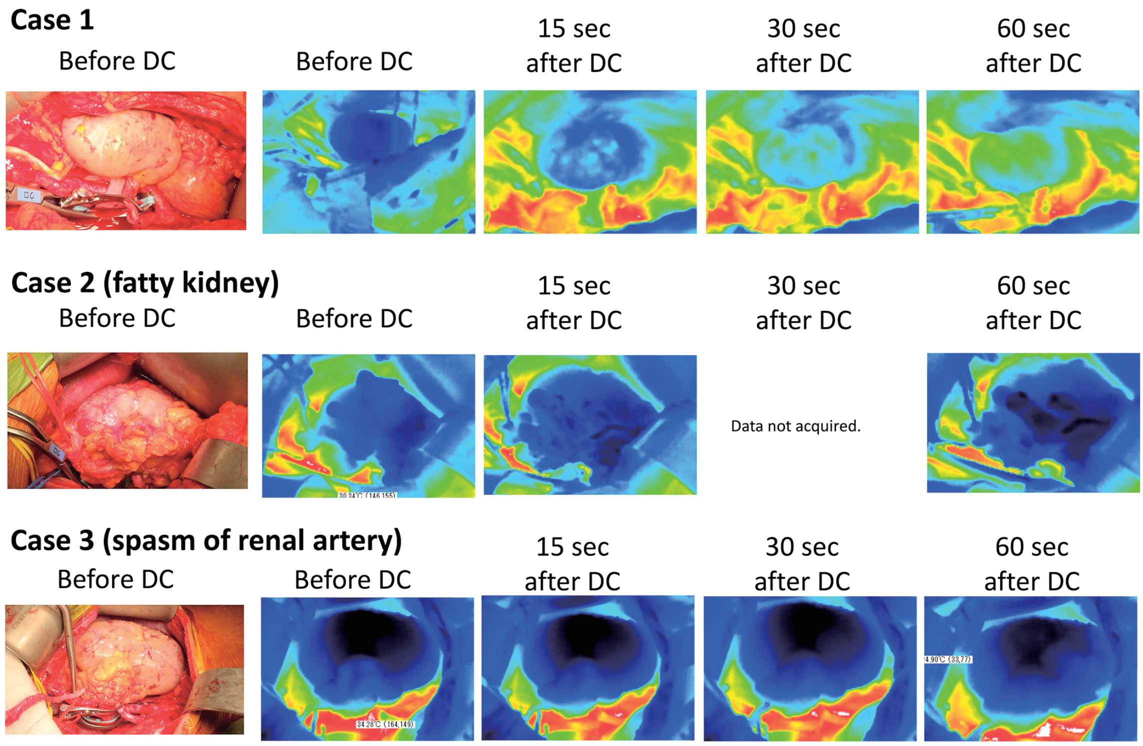

Fig. 1 Representative findings of intraoperative transplanted kidney using an infrared video camera
(A) Case 1. The typical case of a time-dependent increase in transplanted kidney surface temperature. (B) Case 2. A case of kidney graft with fatty tissue adheasion. The surface temperature did not recovere on the area covered with fatty tissue after unclamping. (C) Case 3. A case of renal artery spasm just after unclamping the renal artery. No time-dependent increase in kidney surface temperature was observed.

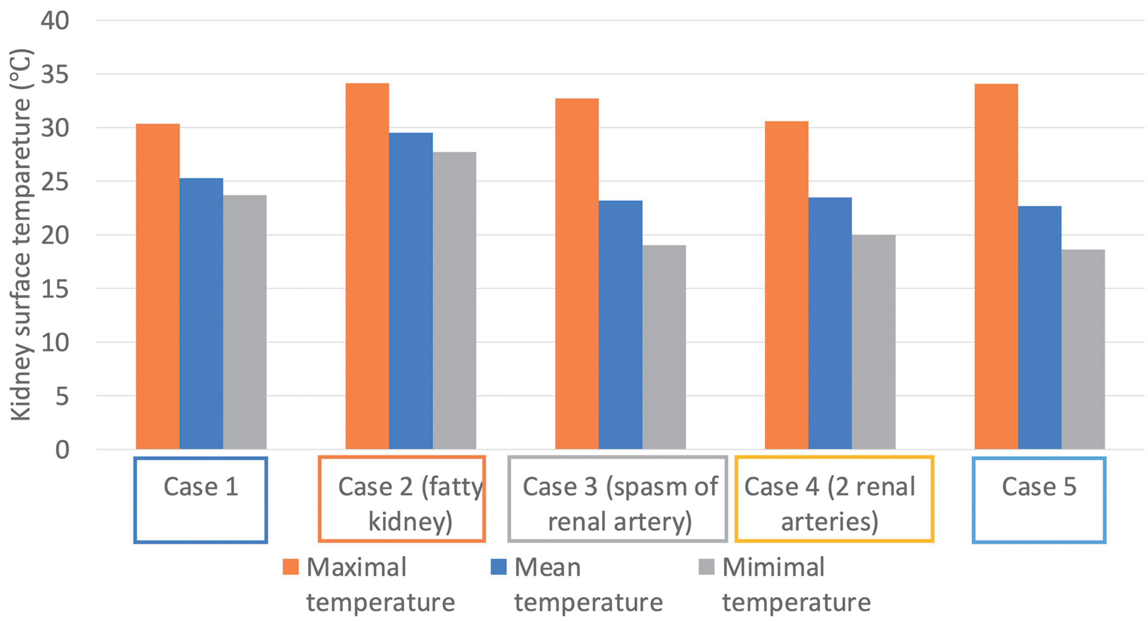

Fig. 2 The baseline temperature of kidney surface just before declumping of renal aretery.
Maximal, minimal, and mean tempareture were presented in each case.

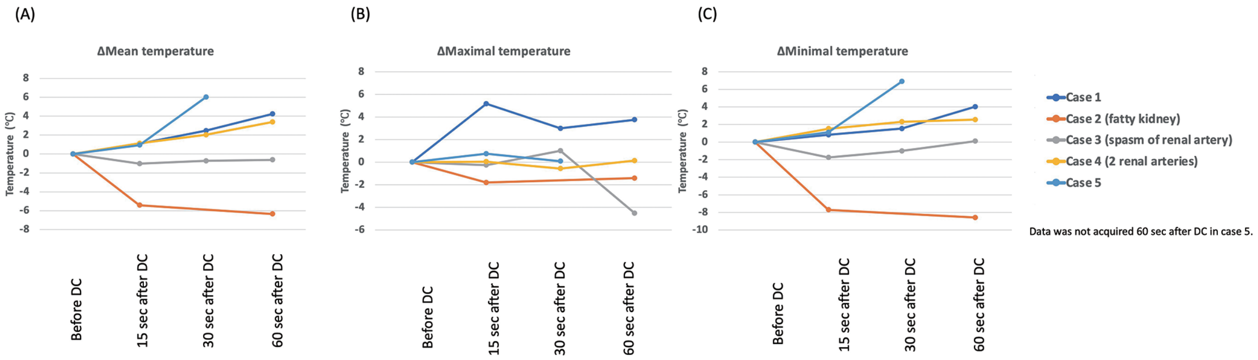

Fig. 3　Time-dependent changes (Δ) in transplanted kidney surface temperature for each case
(A) Mean temperature. (B) Maximal temperature. (C) Minimal temperature.

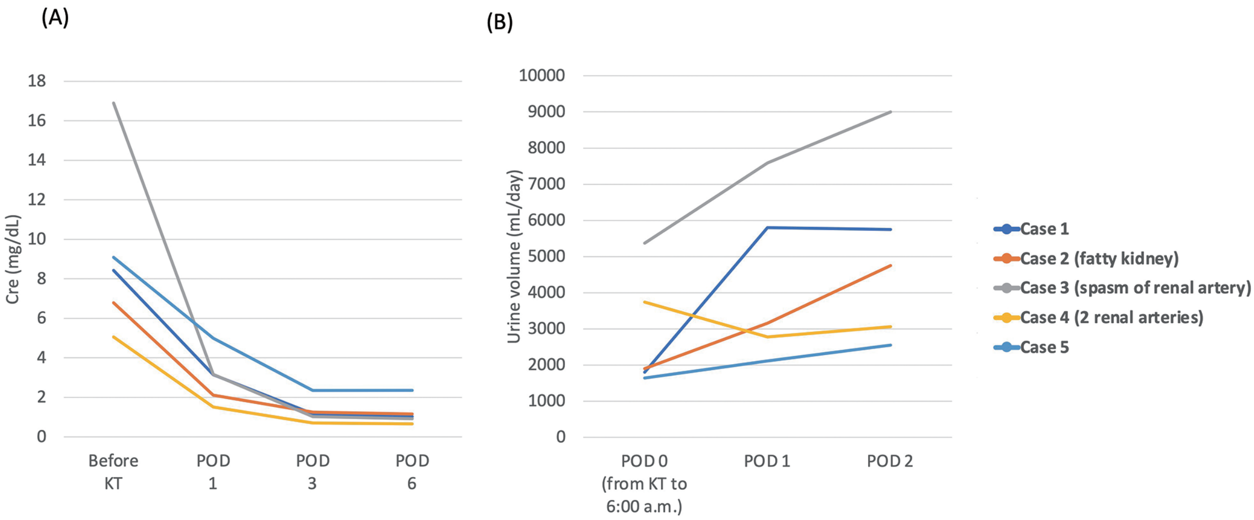

Fig. 4　Serum creatinine levels before and after KT
(A) Recipients before and on POD 1, 3, and 6. (B) Donors before and on POD 1.

nors are shown in **Fig. 4** for pre-transplantation and on POD 1, 3, and 6. No remarkable differences in serum creatinine levels and urine folume were detected after KT.

Ⅳ　Discussion

KT has evolved significantly since its beginnings in the early 1900's and even more after the first successful transplant performed by Dr. Joseph Murray in 1954[3]. Ischemia times in KT have been shown as accurate predictors of future graft function. The present pilot study was conducted to explore the utility of intraoperative KGP assessment using a high-spec infrared video camera in LDKT patients. Our results demonstrated that thermal changes of the kidney surface could be visualized just after unclamping the renal artery, which supported this method as a candidate for evaluating KGP towards the preservation of kidney function, excluding cases of spasm of the renal artery. Theoretically, areas of poor perfusion may be detectable by this method. In the quantitative ROI analysis, the findings were easily interpreted while monitoring the thermal changes of the transplanted kidney surface. These results indicate that the mean or minimal temperatures of the implanted kidney using the infrared video camera may be useful to evaluate KGP and signal further investigation. Considering the findings of each case, the summarized results of mean and minimal temperatures had similar results and might be a useful tool for monitoring KGP in LDKT. However, the post-surgical serum creatinine levels of recipients did not change remarkably, indicating that a short delay in thermal recovery did not lead to serious functional damage of the transplanted kidney. Indeed, avoiding a long delay in thermal recovery and segmental infarction of the transplanted kidney is extremely important in KD. Although the reported cohort did not contain segmental infarction of the transplanted kidney, post-surgical kidney function is influenced by multiple factors, including donor kidney function, immunological reactions, and more. Further investigations are needed to establish the exact role of the infrared video camera.

This trial was conducted as a pilot study to explore a recent methodology to evaluate thermal changes of the renal surface in LDKT. This modality may be useful to detect spastic conditions of the renal artery and have value in the intraoperative management of KGP. However, perirenal fatty tissue might obstruct detection of the exact thermal changes of the kidney surface and KGP measurement using the device. Accordingly, such tissue should be thoroughly removed in further investigations. Moreover, this modality may be also useful to detect spastic change of renal artery intraoperatively. Periarterial papaverine application was used for improvement of kidney function to prevent renal arterial spasms in the previous reports[4)-7)]. Indeed, detection of renal spastic change is often difficult under KT, although intraoperative spastic change of renal aretery should be avoided for smooth recovery of renal function. High-spec infrared video cameras may contribute for adequate intraoperative management of KT via early detection of renal areterial spasms.

On the other hand, the specific finding can be found in the process of maximal temperature of kidney surface in the case 3. Spastic change might influence on change of the maximal temperature. The maximal temperature was decreased at 60 seconds after declumping of renal artery. This finding may indicate that insufficient blood flow of renal arteries may increase of kidney surface temperature just after declumping. However, insufficient blood flow cannot increase the surface temperature continuously, and the heated surface was cooled down by surrounding cold area of transplanted kidney. Therefore, this finding can be a clue to detect spasm of renal artery. This hypothesis should be confirmed in the further investigations.

Reports on infrared cameras and video-capturing instruments are few, especially in the clinical field. The usefulness of an infrared camera was described for evaluating inflammation and neuropathy of the foot in diabetic patients[8)9)]. Such devices have also been used to diagnose skin cancer[10)11)] and evaluate peripheral vascular diseases[12)13)]. In a previous study on KT, the importance of thermodiffusion was investigated to highlight perioperative cortical microperfusion for transplanted kidney function[14)]. Furthermore, the merits of an infrared camera were described for evaluating transplanted kidneys in children by Fernandez et al.[15)], although they used spot monitoring of thermal changes and not area monitoring. Therefore, to the best of our knowledge, the present study is the first to demonstrate the usefulness of a high-spec infrared video camera for assessing intraoperative KGP in KT with the surface of the kidney as the ROI.

This trial had certain limitations that must be considered when interpreting the results. First, the number of enrolled participants was small and should be increased in future studies. Second, the correlations between the infrared video camera and kidney function findings after KT were not investigated in detail. Especially, post-surgical kidney function should be evaluated with long-term follow up. Third, the thermal changes of the transplanted kidney surface might not have directly corresponded to KGP. Since the transplanted kidney can be heated by the attaching organs and ambient temperature, the observation conditions should be more closely taken into consideration. Lastly, the lack of data points is an area of concern. In the clinical setting, obtaining a movie for 1 minute may be difficult considering the intraoperative management of bleeding. Additional investigations addressing the above limitations are necessary. Nonetheless, the advantages of a high-spec infrared video camera are numerous, including non-invasiveness and objectivity. Especially, objectivity, such as quantitative analysis, of infrared video-camera may be important considering lack of that about color Doppler ultrasonography. Therefore, comparison between ultrasonography and infrared video-camera should be done in the further steps. Our results indicate a valuable role of such a device that warrants further study.

V Conclusions

A high-spec infrared video camera may be useful to evaluate renal blood perfusion of the transplanted kidney intraoperatively based on the obtained visual and quantitative evaluation results. Especially, a spastic renal artery may be easily and promptly detected by this method.

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(2024. 1. 17 received ; 2024. 4. 2 accepted)