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Impact of Surgeon's Experience on Vascular and Haemorrhagic Complications After Kidney Transplantation

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WHAT THIS PAPER ADDS

This study demonstrates that the independent risk factors of vascular and haemorrhagic complications after kidney transplantation (KTx) are surgeon experience, donor age >60 years, and recipient cardiovascular disease. Donor age and recipient cardiovascular disease cannot be easily influenced, whereas the surgeon's experience can be improved. To the authors' knowledge, the previous number of KTx operations required to reduce surgeon dependent complications has not been evaluated. In this study, the risk of vascular and haemorrhagic complications decreased significantly after 26 KTx operations were performed. Therefore, a minimum of 26 KTx operations is suggested to decrease surgeon dependent complications, especially in high risk patients.

Objective: The aim of this study was to investigate the independent risk factors of vascular and haemorrhagic complications after kidney transplantation (KTx) and to evaluate how the surgeon's experience affects the rate of vascular and haemorrhagic complications.

Methods: After exclusion of paediatric and multi-organ transplantations, 1462 KTx operations between 2000 and 2016 were analysed. Independent risk factors were evaluated by multivariable logistic regression analysis. The generalised estimating equation logit model was used to display learning curve progression and determine the best cut off number of KTx operations to reduce vascular and haemorrhagic complications.

Results: Vascular and haemorrhagic complications occurred in 38 KTx cases (2.6%). Renal vein thrombosis was the most common complication (0.6%). Graft loss occurred in 11 of 38 (28.9%) cases. Donor age of >60 years (OR 3.687, 95% CI 1.663–8.175, $p = 0.001$), recipient cardiovascular disease (CVD) (OR 2.270, 95% CI 1.071–4.810, $p = 0.032$), and surgeon's experience (OR 0.875, 95% CI 0.783–0.977, $p = 0.018$) were independent predictors of vascular and haemorrhagic complications. Twenty-six previous KTx operations are needed to decrease predicted probability of post-KTx vascular and haemorrhagic complications below 2.6%.

Conclusions: The surgeon's experience is an independent risk factor for vascular and haemorrhagic complications after KTx. Acceptable post-operative vascular and haemorrhagic complications are achieved after a minimum of 26 KTx. As a donor age of >60 years and recipient CVD are also independent risk factors for vascular and haemorrhagic complications, it is suggested that these patients should preferably be operated on by surgeons who have performed more than 26 KTx operations.

Keywords: Kidney transplantation, Renal transplantation, Vascular complication, Haemorrhagic complication, Surgeon's experience, Surgical education

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INTRODUCTION

Kidney transplantation (KTx) is the treatment of choice for patients with end stage renal disease. It provides a better quality of life and improves survival.[1–4] New improvements in peri-operative care, surgical techniques, and immunosuppressive therapies have significantly enhanced graft survival in recent years.[5–8] However, allograft failure following KTx remains an important problem and vascular complications are one of the leading causes of morbidity and graft loss.[9–13] Vascular and haemorrhagic complications are related to various factors. These factors are dependent on donor or graft state (including living or deceased donor, organs retrieved from transplant pools, donor age, side of the graft, etc.), recipient conditions (including underlying diseases, recipient age, transplantation site, etc.), or surgery (including

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haemodynamic stability, surgeon's experience, technical difficulties, etc.).[3,7,14–20]

Complications caused by donor and recipient related factors are mostly inevitable and cannot be easily influenced. In contrast, surgery dependent factors, particularly surgeon's expertise, can be improved. The surgeon's experience affects the intra- and post-operative outcomes of KTx.[13,20] However, the threshold at which the surgeon's experience affects outcome has, to the present authors' knowledge, still not been evaluated.[21,22] Determining the minimum number of completed transplants required to minimise post-operative complications may help to determine the qualifications for transplant fellowship programs.

The aim of this study was to investigate the factors that influence vascular and haemorrhagic complications after KTx. As vascular and haemorrhagic complications are usually caused by surgical errors,[13,20–23] the role of the surgeon's experience in these complications was also investigated. In particular, the cut off number of transplants necessary to avoid these complications was examined.

MATERIALS AND METHODS

Study population and data extraction

Between January 2000 and August 2016, 1813 consecutive KTx were performed at the study transplant centre. The surgical and clinical data for each patient were recorded in a prospective database. Relevant data were extracted from the database and analysed retrospectively. Extracted data included donor and recipient characteristics, indication for transplantation, comorbidities, re-transplantation, dialysis, cold ischaemia time, site of implantation, operation time, intra-operative blood loss, and hospital stay. Recipients under 18 years of age (268 patients) and multi-organ transplants (83 patients) were excluded, leaving 1462 transplantation cases for analysis. The study protocol was approved by the university ethics committee.

Surgical team and surgical procedure

KTx operations were performed by general and/or visceral surgeons. All the surgeons were attending surgeons who received surgical transplantation training at the study centre and did not have vascular surgery experience. In cases of complicated vascular anatomy and anastomosis, the attending surgeon from the vascular surgery department assisted in the operation. Surgeon's experience was defined as the number of KTx operations performed as the first (responsible) operator. Donor nephrectomies for living donor transplantation were performed using an open (median laparotomy), hand assisted laparoscopic, or pure laparoscopic approach. Kidneys were obtained from deceased donors using an aortic and cava patch for vascular anastomosis. In the standardised KTx procedure, the kidney is transplanted extraperitoneally through a J-shape incision, then the peritoneum is mobilised from the psoas muscle. Afterwards, the arterial and venous iliac axes are dissected freely and the renal artery and vein are anastomosed in an end to side manner between the iliac artery (common or external) and external iliac vein. To avoid kinking the renal artery and impairing venous drainage, the renal artery and vein are shortened as much as possible. Using an extravesical uteroneocystostomy approach, the ureter is anastomosed to the urinary bladder. Until 2003, a double J ureteral stent was inserted in all patients after ureterovesical anastomosis. After 2003, a single J catheter was inserted instead. All patients received a transurethral and suprapubic catheter to completely drain the urinary bladder. Approximately 7 days after surgery, the single J and transurethral catheters were removed. The suprapubic catheter exercised and enlarged the urinary bladder capacity as necessary.

Peri-operative care

All recipients received a 30 U/kg heparin bolus intraoperatively before the vessels were clamped. Six hours after surgery, all patients were infused with anticoagulants and the dose was adjusted according to the individual's risk score. Post-operative immunosuppression varied based on the date of the KTx. Today, triple immunosuppressive therapy is used, consisting of cyclosporine or tacrolimus, methylprednisolone, and mycophenolate mofetil. Patients receive a single post-operative dose of pentamidine, followed by oral trimethoprim-sulfamethoxazole as a *Pneumocystis jirovecii* prophylaxis. Patient follow up was performed every month for one year and then every six months thereafter.

Assessment of clinical outcome

After KTx, patients stayed for three to five days at the interdisciplinary Intermediate Care Unit. According to the standard care at the centre, all patients underwent ultrasound examination immediately after the KTx operation and then each day for the first three to five post-operative days. Abnormalities in graft vascular supply were evaluated. Different vascular and haemorrhagic complications were reviewed, including arterial and venous thrombosis, arterial and venous stenosis, perirenal hematoma, arterial and venous bleeding, and vascular kinking/torsion. Focal acceleration of the arterial flow to 2.5 times higher than the pre- or post-stenotic velocity was the diagnostic criterion for arterial stenosis. Arterial kinking and torsion can also increase arterial flow velocity. Arterial thrombosis, kinking, and torsion were suspected by minimal or absent arterial supply within the graft, along with absent arterial and venous flow. Venous thrombosis is characterised by scarce or absent compressibility with renal enlargement and venous color signal with reverse diastolic flow within the renal artery. A venous peak systolic velocity more than three to four times higher than normal indicated venous thrombosis. Perihilar hematoma was defined as a fluid collection around the graft hilum, which was confirmed by further workup. The diagnosis of vascular and haemorrhagic complications was confirmed by further radiological evaluations (magnetic resonance imaging, computed tomography scan, angiography) or re-operation when necessary. Immediate re-operation and re-exploration were indicated if blood

supply to the transplanted kidney was negatively affected (e.g. by thrombosis, haematoma, bleeding, or stenosis). Vascular and haemorrhagic complications were classified as major and minor morbidities based on the Clavien-Dindo classification.[24] Complications occurring during early post-operative hospitalisation (30 days after surgery) were considered early period complications. Primary non-function (PNF), delayed graft function (DGF), one year graft loss, and 90 day mortality were also evaluated. PNF refers to a graft that does not function, necessitating permanent dialysis after transplantation. DGF was defined as the need for temporary dialysis in the first post-operative week. One year graft loss refers to re-transplantation, transplant nephrectomy, or permanent dialysis during the first year after transplantation. Ninety day mortality was defined as all deaths occurring in the first 90 post-operative days.

Statistical analysis

Categorical data were expressed as percentages and continuous variables were shown as means ± standard deviations. To explore the factors associated with vascular and haemorrhagic complications after KTx, a multivariable logistic regression analysis was performed. Variables with a *p* value less than 0.1 in univariable analysis were evaluated by multivariable analysis. For univariable and multivariable analyses, donor and recipient ages were categorised as >60 years and ≤60 years. The number of transplantations performed was categorised as one or two versus more than two. Surgeon's experience was defined as the number of KTx operations performed as the first (responsible) operator. The generalised estimating equation (GEE) was used with logit as the link function to account for the clustering and dependence of operations for each surgeon using an exchangeable correlation matrix. The probability of vascular complications was regressed on the number of operations performed by each surgeon. To allow for a non-linear association between the two variables, several models were created and polynomial functions of the number of operations were entered as predictors. Model fits were compared using the quasi-likelihood under the independence model criterion (QIC). Using this criterion, the model with restricted quadratic splines[25] was chosen as the final GEE logit model. The predicted probability of developing vascular complications (from the model) was then plotted against the number of operations to display the learning curve progression. Cut offs considered were (1) the point where the probability of complication fell below the centre's average and the average reported in major transplant centres around the world (2.6%, internal and external cut points), and (2) the point where the probability plateaued (1.1%, absolute cut point). Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., released 2013, Armonk, NY, USA). Learning curve analyses were done using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). A two tailed *p* value <0.05 was considered statistically significant in all analyses.

RESULTS

Patient demographics and clinical data

A total of 1462 KTx were included in the analyses. The mean donor age was 51.2 ± 15.2 years, and 50.6% of donors were female. The majority (66.3%) of donors were brain dead and organs were recovered from 50.8% of deceased and living donors by right sided nephrectomy. Comparisons between clinicopathological characteristics of brain dead and living donors are shown in Table 1. The mean recipient age was 48.5 ± 14.2 years, and 60.1% of recipients were male. Glomerulonephritis was the most common (42.7%) indication for KTx and 92.4% of recipients underwent pre-operative dialysis for a mean duration of 64.8 ± 48.2 months. The most common medical condition in recipients was hypertension (53.4%), followed by cardiovascular disease (CVD) (21.4%), diabetes mellitus (16.8%), and peripheral vascular disease (7.3%). Detailed demographics and clinical data of recipients are shown in Table 2.

Vascular and haemorrhagic complications and clinical outcome

In the study centre, vascular and haemorrhagic complications occurred in 38 KTx cases (2.6%). As shown in Table 3, renal vein thrombosis (9 cases, 0.6%), renal artery stenosis (5 cases, 0.3%), and haematoma (5 cases, 0.3%) were the most common type of vascular and haemorrhagic complication after KTx. Twenty-six (68.4%) of the vascular and

Table 1. Clinicopathologic characteristics of kidney donors

Variables	Total (n=1462)	Brain dead donors (n=969)	Living donors (n=493)	*p* value
Age, years (mean±SD)	51.2±15.2	52.4±15.9	49.9±11.6	0.003
Gender, n (%)				
Male	722 (49.4)	530 (54.7)	192 (39.0)	<0.001
Female	740 (50.6)	439 (45.3)	301 (61.0)	
Side of graft, n (%)				
Right	743 (50.8)	506 (52.2)	237 (48.1)	0.243
Left	719 (49.2)	463 (47.8)	256 (51.9)	
Multiple arteries, n (%)	313 (21.4)	242 (24.9)	71 (14.4)	0.003
Multiple veins, n (%)	134 (9.2)	100 (10.3)	34 (6.9)	0.221
Cold ischemia time, hours (mean±SD)	13.4±7.5	15.2±5.5	2.7±1.4	<0.001

Data are presented as means ± standard deviation, or as absolute numbers (percentages).

Table 2. Clinicopathologic characteristics of the recipients

Variables	Total (n=1462)
Age, years (mean±SD)	48.5±14.2
Gender, n (%)	
Male	878 (60.1)
Female	584 (39.9)
Indication for transplant, n (%)	
Glomerulonephritis	624 (42.7)
Congenital disease	297 (20.3)
Diabetes/hypertension	129 (8.8)
Obstructive nephropathy	73 (5.0)
Peripheral vascular disease	72 (4.9)
Tubulointerstitial renal disease	48 (3.3)
Other/unknown	219 (15.0)
Comorbidities, n (%)	
BMI ≥ 35.0	77 (5.3)
Hypertension	681 (46.6)
Cardiovascular disease	313 (21.4)
Diabetes mellitus	246 (16.8)
Peripheral vascular disease	107 (7.3)
History of nephrectomy, n (%)	550 (37.6)
Number of transplantations, n (%)	
1	1222 (83.6)
>1	240 (16.4)
Preoperative dialysis, n (%)	1349 (92.3)
Duration of dialysis, months (mean±SD)	64.8 ± 48.2
Intraoperative blood loss, ml (mean±SD)	461.2 ± 670.2
Operation time, min (mean±SD)	203.6 ± 98.3
Hospital stay, days (mean±SD)	22.9 ± 13.6

Data are presented as means ± standard deviation, or as absolute numbers (percentages).

haemorrhagic complications were diagnosed in the early post-operative period (≤30 days after surgery). DGF occurred in 15 cases (39.5%) and PNF in five cases (13.2%) with vascular and haemorrhagic complications. According to the Clavien-Dindo classification, 29 cases (76.3%) of vascular and haemorrhagic complications were major (grade 3 or higher). Only one death (2.6%) occurred in patients with vascular and haemorrhagic complications within 90 days of KTx. Graft loss during the first post-transplantation year occurred in 18 (47.4%) patients with vascular and haemorrhagic complications.

The side of the donated kidney and side of implantation had no effect on the rate of vascular and haemorrhagic complications ($p = 0.88$). The vascular and haemorrhagic complication rates were as follows: right side explant implanted to right: 2.2%; right side explant implanted to left: 2.3%; left side explant implanted to left: 2.4%; and left side explant implanted to right: 3.0%. Of 38 recipients with vascular and haemorrhagic complications, 18 (47.4%) had atherosclerosis, and seven (18.4%) of them had atherosclerosis of the anastomotic vessels.

Factors predictive of vascular and haemorrhagic complications after KTx

To identify predictors of vascular and haemorrhagic complications after KTx, univariable and multivariable logistic regression analyses were performed. Table 4 presents the results of these analyses, showing relationships among donor, recipient, and surgical variables and vascular and haemorrhagic complications after KTx. Univariable analysis revealed

Table 3. Site and consequences of vascular and haemorrhagic complications

Complications[a]			Consequences[b]		
	Total *n* (%)	Early period[c] *n* (%)	Major morbidity[d]	90 day mortality	One year graft loss
Stenosis	9 (0.6)	4 (0.3)	5 (55)	–	3 (33.3)
Arterial	8 (0.5)	3 (0.2)	5 (62)	–	3 (37.5)
Renal artery	5 (0.3)	1 (0.1)	3 (60)	–	1 (20.0)
Common iliac artery	3 (0.2)	2 (0.1)	2 (67)	–	2 (66.7)
Renal vein	1 (0.1)	1 (0.1)	–	–	–
Thrombosis	15 (1.0)	12 (0.8)	11 (73)	–	7 (46.7)
Arterial	4 (0.3)	4 (0.3)	3 (75)	–	1 (25.0)
Renal artery	3 (0.2)	3 (0.2)	3 (100)	–	1 (33.3)
External iliac artery	1 (0.1)	1 (0.1)	–	–	–
Venous	11 (0.8)	8 (0.6)	8 (73)	–	6 (54.5)
Renal vein	9 (0.6)	7 (0.5)	8 (89)	–	6 (66.7)
External iliac vein	2 (0.1)	1 (0.1)	–	–	–
Kinking/torsion	4 (0.3)	3 (0.2)	4 (100)	–	2 (50.0)
Renal artery	3 (0.2)	3 (0.2)	3 (100)	–	1 (33.3)
Common iliac artery	1 (0.1)	0 (0.0)	1 (100)	–	1 (100)
Haematoma/bleeding	10 (0.7)	7 (0.5)	9 (90)	1 (10.0)	6 (60.0)
Haematoma	5 (0.3)	5 (0.3)	5 (100)	–	3 (60.0)
Arterial bleeding	4 (0.3)	1 (0.1)	3 (75)	1 (25.0)	2 (50.0)
Venous bleeding	1 (0.1)	1 (0.1)	1 (100)	–	1 (100)
Overall	38 (2.6)	26 (1.8)	29 (76.3)	1 (2.6)	18 (47.4)

-: zero.
[a] Percentages are calculated from total transplants performed.
[b] Percentages are calculated from complications occurred.
[c] Vascular and haemorrhagic complications occurred during the 30 days after transplantation.
[d] 90 day major morbidity according to Clavien-Dindo classification.

Table 4. Univariate and multivariate analysis of predictive factors of vascular and hemorrhagic complications after kidney transplantation in 1462 patients

Variables	Univariate			Multivariate		
	Odds ratio	95% CI	*p*	Odds ratio	95% CI	*p*
Donor						
Brain dead/living donor	0.60	0.28–1.28	0.190			
Age >60 years	3.05	1.53–6.07	0.001	3.687	1.66–8.18	0.001
Gender	0.82	0.43–1.58	0.560			
Side of graft	0.78	0.41–1.49	0.447			
Multiple arteries	1.67	0.80–3.47	0.172			
Multiple veins	0.31	0.04–2.30	0.25			
Cold ischemia time (per additional hour)	0.98	0.92–1.04	0.513			
Recipient						
Age >60 years	1.82	0.94–3.53	0.070	0.638	0.27–1.52	0.310
Gender	1.14	0.59–2.23	0.693			
Indication of kidney transplantation[a]	1.04	0.88–1.22	0.668			
BMI ≥ 35.0	1.56	0.47–5.20	0.466			
Hypertension	1.03	0.54–1.97	0.921			
Cardiovascular disease	2.76	1.43–5.32	0.002	2.270	1.07–4.81	0.032
Diabetes mellitus	3.00	1.53–5.88	0.001	1.697	0.79–3.63	0.173
Peripheral vascular disease	1.51	0.53–4.33	0.445			
History of nephrectomy	0.92	0.46–1.84	0.821			
Number of transplantation (>2)	1.93	0.92–4.04	0.083	1.649	0.71–3.82	0.243
Preoperative dialysis	0.69	0.24–2.00	0.498			
Duration of dialysis (Years)	1.00	0.99–1.01	0.785			
Surgeon experience (per 10 transplants)	0.85	0.77–0.94	0.002	0.875	0.78–0.98	0.018
Side of kidney implantation	1.23	0.64–2.35	0.533			
Operation time (per additional hour)	1.05	0.87–1.26	0.601			
Blood loss (per additional litre)	1.07	0.61–1.87	0.826			

CI: confidence interval; BMI: body mass index.
[a] Indications for kidney transplantation are shown in Table 2.

that a donor age of >60 years ($p = 0.001$), recipient CVD ($p = 0.002$), recipient diabetes mellitus ($p = 0.001$), and the surgeon's KTx experience ($p = 0.002$) significantly correlated with the occurrence of vascular and haemorrhagic complications after KTx. Multivariable regression analysis was performed on the six variables determined significant by univariable analysis. This analysis identified a donor age of >60 years, recipient CVD, and surgeon's experience as independent predictors of vascular and haemorrhagic complications after KTx (Table 4). As expected, the risk of vascular and haemorrhagic complications after KTx correlated negatively with the number of previous transplants performed by the surgeon (OR 0.875, 95% CI 0.783–0.977, $p = 0.018$). Furthermore, a donor age of >60 years (OR 3.687, 95% CI 1.663–8.175, $p = 0.001$) and recipient CVD (OR 2.270, 95% CI 1.071–4.810, $p = 0.032$) predicted post-operative vascular and haemorrhagic complications. Additional analysis was also performed whereby haemorrhagic complications ($n = 10$) were excluded and only vascular complications were evaluated (Table 5). A donor age >60 years (OR 3.249, 95% CI 1.330–7.938) and surgeon's experience (OR 0.839, 95% CI 0.728–0.966) were independent determinants of vascular complications after KTx, but cardiovascular diseases were not significant risk factors according to multivariable analysis.

Role of surgeon's experience

The analysis revealed 26 as the best cut off number of previous KTx operations to decrease the predicted probability of post-KTx vascular and haemorrhagic complications being below the average reported in major transplant centres around the world and in the study centre (2.6% internal and external cut point). The absolute cut point (predicted probability of vascular and haemorrhagic complications, 1.1%) was achieved after the surgeon completed 57 KTx operations. (Fig. 1). In agreement with this, most vascular and haemorrhagic complications occurred before the first 25 transplants were completed (5.3%) and the vascular and haemorrhagic complication rate decreased significantly ($p < 0.001$) from 5.3% to 1.1% between 26 and 50 KTx, 1.1% between 51 and 75 KTx, 0.8% between 76 and 100 KTx, and 0.6% after 100 transplants (Fig. 2).

The demographic and clinical characteristics of recipients who were operated on by a less experienced surgeon (≤25 previous KTx operations) were compared with those operated on by more experienced surgeons (>25 previous KTx operations) (Table 6). More experienced surgeons operated on a higher proportion of recipients receiving kidneys from living donors and older donors compared with less experienced surgeons. The recipients who were operated on by more experienced surgeons were younger, had a higher prevalence of hypertension, and history of previous nephrectomy, but lower diabetes mellitus and pre-operative dialysis compared with those operated on by less experienced surgeons.

The proportion of left versus right grafts and single versus multiple artery grafts were also compared before and after 25 KTx operations were performed. There were no

Table 5. Univariate and multivariate analysis of predictive factors of vascular complications after kidney transplantation

Variables	Univariate			Multivariate		
	Odds ratio	95% CI	*p*	Odds ratio	95% CI	*p*
Donor						
Brain dead/living donor	0.65	0.26–1.54	0.328			
Age >60 years	3.26	1.48–7.17	0.003	3.249	1.33–7.94	0.010
Gender	0.89	0.42–1.88	0.751			
Side of graft	0.62	0.29–1.33	0.221			
Multiple arteries	1.37	0.57–3.33	0.483			
Multiple veins	0.40	0.05–3.03	0.378			
Cold ischemia time (per additional hour)	0.99	0.92–1.05	0.678			
Recipient						
Age >60 years	2.09	0.98–4.46	0.057	0.831	0.33–2.12	0.698
Gender	0.88	0.42–1.89	0.750			
Indication of kidney transplantation[a]	1.09	0.91–1.31	0.341			
BMI ≥35.0	2.21	0.65–7.47	0.204			
Hypertension	1.15	0.54–2.43	0.714			
Cardiovascular disease	2.43	1.12–5.23	0.024	1.737	0.73–4.12	0.209
Diabetes mellitus	2.82	1.29–6.19	0.010	1.533	0.65–3.60	0.327
Peripheral vascular disease	1.54	0.46–5.17	0.489			
History of nephrectomy	0.84	0.37–1.88	0.671			
Number of transplantation (>2)	1.16	0.44–3.10	0.767			
Preoperative dialysis	1.08	0.25–4.60	0.921			
Duration of dialysis (years)	1.00	0.99–1.01	0.443			
Surgeon experience (per 10 transplants)	0.87	0.78–0.97	0.012	0.839	0.73–0.97	0.015
Side of kidney implantation	1.54	0.72–3.32	0.267			
Operation time (per additional hour)	0.96	0.73–1.26	0.780			
Blood loss (per additional litre)	0.53	0.11–2.49	0.421			

Confidence Interval, CI; Body Mass Index, BMI.
[a] Indications for kidney transplantation are shown in Table 2.

differences in graft side (40.3% left kidneys [before experience] versus 59.7% left kidneys [after experience], $p = 0.91$) or number of graft arteries (21.4% multiple artery grafts [before experience] versus 21.6% multiple artery grafts [after experience], $p = 0.99$). In the present study, the mean operation time significantly decreased ($p < 0.001$) as the number of previous KTx operations performed by the surgeon increased (Fig. 3).

DISCUSSION

The present analyses revealed that a donor age of >60 years, recipient CVD, and surgeon's experience are independent risk factors of vascular and haemorrhagic complications after KTx. The extended donor criteria and increasing number of recipients waiting for a KTx mean that transplanting grafts from donors >60 years old or into recipients with CVD is inevitable. It remains controversial whether transplanting grafts from older donors into recipients with CVD should be avoided to prevent complications.[14,26–32] Donor and recipient related risk factors cannot usually be modified. On the other hand, the surgeon's experience can be considered. Vascular and haemorrhagic complications are usually caused by surgical errors.[13,20–23] Therefore, evaluating the rate of vascular and haemorrhagic complications may be a feasible tool for evaluating surgeon experience in KTx. Based on the present findings, a minimum of 25 supervised KTx operations are required before allowing independent surgery, to minimise vascular and haemorrhagic complications after KTx. Surgeon expertise was evaluated according to vascular complications because vascular anastomosis is the "key step" or "Achilles heel" in KTx and the rate of vascular complications may be the optimal indicator of adequate surgical experience.

The incidence of early and late vascular and haemorrhagic complications in the study cohort was 2.6%. This is within the lower range of complication rates (2.1%–16.0%) reported by other high volume centres.[9,10,13,20,22,33–35] The published rates of renal vein thrombosis range from 0.2% to 3.7%. In the present study, renal vein thrombosis was the most common vascular complication (0.6%), followed by renal artery stenosis (0.3%), haematoma, and arterial bleeding. These complications accounted for more than half of total vascular and haemorrhagic complications. In comparison, others have reported renal artery stenosis as the most common vascular complication (0.6%–10.5%).[10,13,20,22,33] Perirenal haematomas may not originate from vascular anastomosis but from bleeding in the renal hilar region caused by explantation. Therefore, only haematomas that were near the site of anastomosis were included as vascular complications and all other perirenal haematomas were excluded. Vascular complications can have a significant impact on graft survival. In the present study, grafts were lost in 28.9% of patients with vascular and haemorrhagic complications. This was within the range of graft loss rates following vascular and haemorrhagic complications reported in the literature (12.6–66.7%).[10,16,20,36]

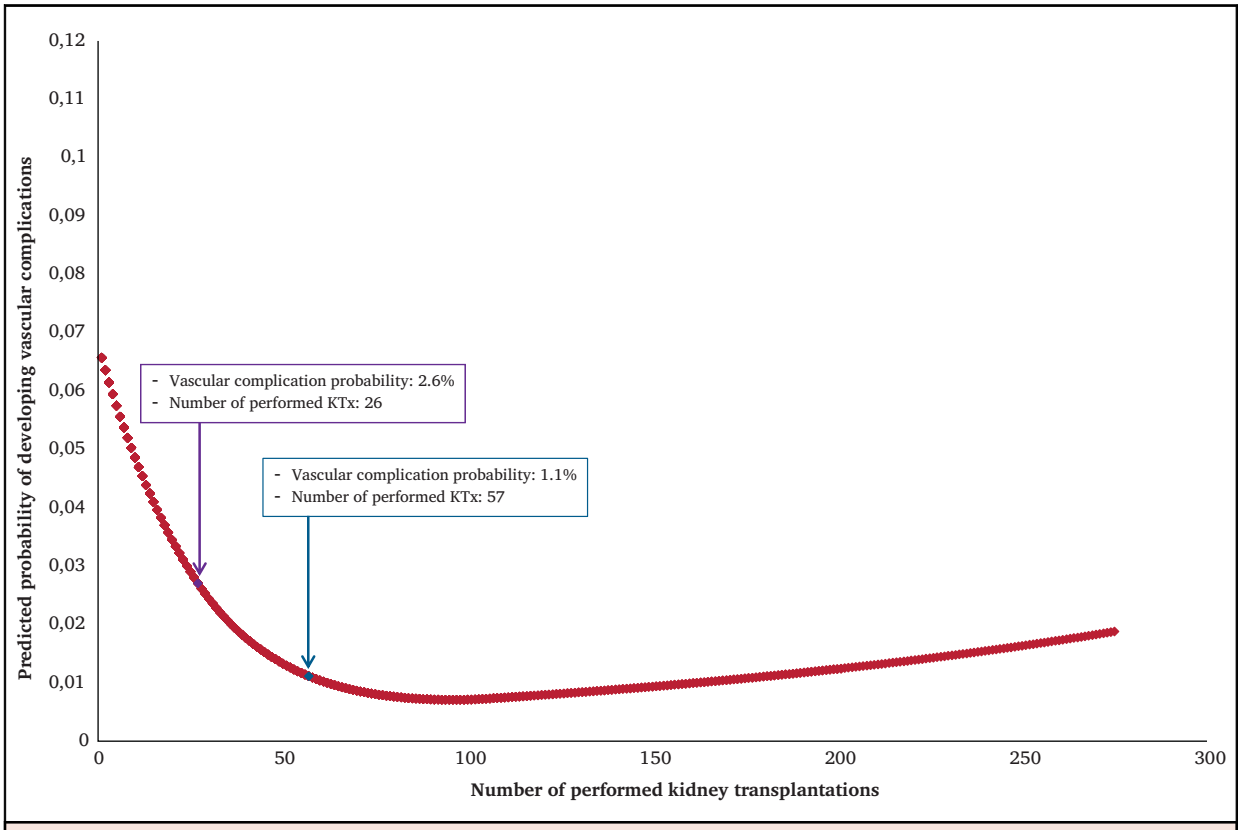

Figure 1. Correlation between previous kidney transplantations of each surgeon and the predictive probability of developing vascular and haemorrhagic complications after kidney transplantation. KTx = kidney transplantation.

The effect of surgeon's experience on the occurrence of vascular surgical complications after KTx has been investigated. Ammi et al.[13] reported a 16% vascular complication rate in a series of 312 KTx operations. In this study, 44.8% of the transplants were performed by "junior" surgeons and the authors assumed that greater surgeon expertise would maintain lower rates of post-transplant vascular complications and graft loss. The present results are in line with this

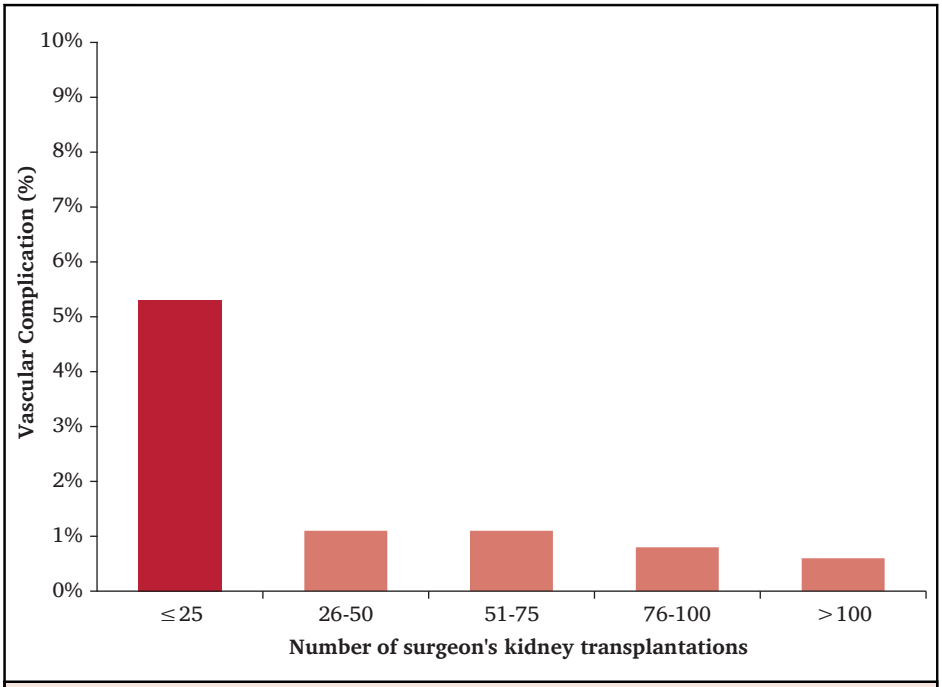

Figure 2. Percentage of vascular and haemorrhagic complications in relation to the number of previous kidney transplants performed by the surgeon.

Table 6. Comparison of patients clinical and demographic data betweem less and more experienced surgeons

Variables	KTx performed by less experienced surgeons[a] (n=573)	KTx performed by more experienced surgeons[b] (n=889)	p
Donor			
Brain dead donor, n (%)	467 (81.5)	502 (56.6)	<0.001
Living donor, n (%)	106 (18.5)	387 (43.4)	
Age, years (mean±SD)	49.6±17.0	52.3±13.8	0.004
Gender, n (%)			
Male	286 (49.9)	436 (49.1)	0.817
Female	287 (50.1)	453 (50.9)	
Side of graft, n (%)			
Right	286 (49.9)	457 (51.5)	0.627
Left	287 (50.1)	432 (48.5)	
Multiple arteries, n (%)	124 (21.6)	189 (21.2)	0.928
Multiple veins, n (%)	53 (9.3)	81 (9.1)	0.999
Cold ischemia time, hours (mean±SD)	13.8±7.4	12.7±7.4	0.096
Recipient			
Age, years (mean±SD)	49.9±13.4	47.6±14.7	0.003
Gender, n (%)			
Male	351 (61.3)	527 (59.2)	0.486
Female	222 (38.7)	362 (40.8)	
Indication for transplant, n (%)			
Glomerulonephritis	239 (41.6)	385 (43.3)	0.969
Congenital disease	113 (19.8)	184 (20.7)	
Diabetes/hypertension	53 (9.1)	76 (8.6)	
Obstructive nephropathy	29 (5.2)	44 (4.9)	
Peripheral vascular disease	31 (5.4)	41 (4.6)	
Tubulointerstitial renal disease	18 (3.2)	30 (3.4)	
Other/unknown	90 (15.7)	129 (14.5)	
Comorbidities, n (%)			
BMI ≥ 35.0	28 (4.9)	49 (5.5)	0.633
Hypertension	207 (36.1)	474 (53.3)	<0.001
Cardiovascular disease	125 (21.8)	188 (21.1)	0.794
Diabetes mellitus	129 (22.5)	117 (13.2)	<0.001
Peripheral vascular disease	42 (7.3)	65 (7.3)	0.999
History of nephrectomy, n (%)	169 (29.5)	381 (42.9)	<0.001
Number of transplantations, n (%)			
1	468 (81.7)	754 (84.8)	
>1	105 (18.3)	135 (15.2)	0.154
Preoperative dialysis, n (%)	544 (95.0)	805 (90.5)	0.002
Duration of dialysis, months (mean±SD)	69.5±41.6	61.0±52.5	0.003

Data are presented as mean ± standard deviation, or as absolute number (percentage).
KTx, kidney transplantation.
[a] Patients operated by surgeons with an experience of ≤ 25 kidney transplantations.
[b] Patients operated by surgeons with an experience of >25 kidney transplantations.

study. A minimum number of previous transplants necessary for lowering vascular and haemorrhagic complication rates has been determined. Conversely, Oitchayomi et al.[21] reported that the warm ischaemia and operation time, but not the surgical learning curve, affected the occurrence of surgical complications or outcomes after KTx. However, they did not investigate the surgeon's experience as an independent risk factor of vascular or surgical complications. Additionally, their analysis did not evaluate all transplants performed by the participating surgeons. Wolff et al.[22] studied the correlation between the surgical learning curve and general KTx outcomes. They reported that surgeon's experience (even <10 transplants) did not significantly correlate with the rate of surgical complications, 30 day mortality, or one year graft loss. They concluded that an experienced general surgeon can perform a high standard KTx even after a very limited training program. However, the authors of this study did not explicitly analyse how the number of KTx operations performed by the surgeon affected the rate of vascular complications.

The results of this study revealed 25 previous KTx operations to be a reasonable cut off number of transplants to reduce vascular surgical complications. To the present authors' knowledge, this is the first study to investigate the independent risk factors of vascular and haemorrhagic complications after KTx and determine a minimum threshold of previous KTx operations required to reduce surgeon dependent complications after KTx. There are qualification requirements for transplant surgery fellowships. The European Union of Medical Specialists (European Board of Surgery Qualification) requires a minimum of 20 KTx operations to be performed as the main operating surgeon,[37] and the American Society of Transplant Surgeons requires fellows to play a principal role in at least 40 KTx operations.[38] However, it is unclear how these

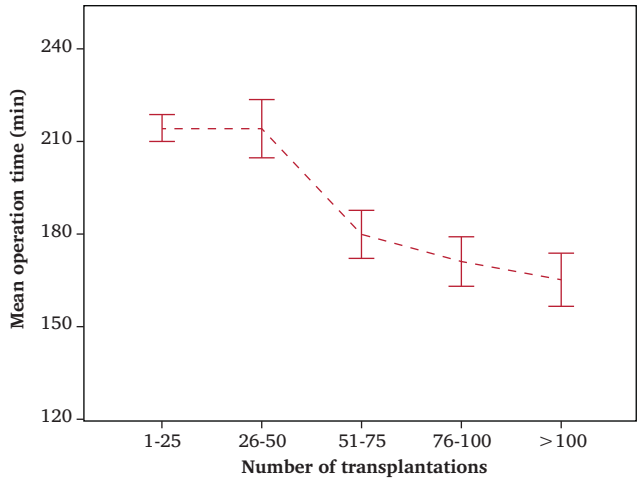

Figure 3. Mean operation times in relation to the number of previous kidney transplants performed by the surgeons. Error bars show standard error of the mean.

minimum requirements were chosen. The present results are comparable with the two best known of these board qualification requirements. Despite the retrospective nature of this study, the present results may help to define the qualification requirements for fellowship programs in the future. Expert supervision and careful patient selection during training are important for successful organ transplantation.[22,39,40] Based on the present findings, it is suggested that all transplant surgeons with experience of less than 25 transplants should perform their operations under close supervision (assistance) by an attending transplant surgeon.

The present results suggest that a donor age of >60 years and recipient CVD are independent risk factors of vascular and haemorrhagic complications after KTx. Vascular repair such as endarterectomy is often needed on older grafts and it is more difficult to prepare suitable aortic patches in older donor kidneys because of atherosclerosis. In older grafts it is necessary to cut the renal artery back to find a better segment for arterial anastomosis. Therefore, older grafts are accompanied by increased risk of vascular and haemorrhagic complications. Similarly, sclerotic recipient arteries with CVD could explain the increased rate of vascular and haemorrhagic complications. Clinical practice guidelines of the European Society for Vascular Surgery (ESVS) also emphasise the importance of efficient prevention and management strategies for patients with CVD.[41] The concurrence of other independent risk factors (e.g. donor age of >60 years and recipient CVD) with an inexperienced surgeon could synergistically increase the risk of vascular and haemorrhagic complications and eventual graft loss. Other factors analysed in this study, including donor related, recipient related, and surgery related variables and risk factors did not correlate significantly with vascular and haemorrhagic complications in the multivariable analysis (Table 4). The correlation of these other factors with post-transplant vascular and haemorrhagic complications was also controversial in previous reports.[9,14,19–21,23,33,36,42,43] Further multi-centre prospective studies should be performed to validate the suggested threshold of surgical experience for fellowship programs and to investigate the concurrence of the surgeon's experience, donor age, and recipient CVD risk factors in the future.

There were some limitations to the present study. First, the study was retrospective, therefore the results may be affected by observation and/or assessment bias and should be interpreted with caution. The collected donor data, especially the data of brain dead donors such as those with atherosclerosis were incomplete and could not be included in the multivariable analysis. Second, the most prevalent complication in the study was vascular thrombosis, but there were no data on pre-transplant antithrombotic administration. Furthermore, genetic testing was not performed to rule out inherited thrombophilia in all cases, although thrombophilic disorders were not mentioned in the patients' histories. Differences in patient characteristics and selection criteria may cause variable findings from the same analyses performed in other centres. Although the number of KTx operations performed does play an important role in gaining experience, the surgeon's competence can also affect the minimum required number. Therefore, prospective competence based models that identify the key steps and high risk steps during KTx are needed to evaluate the combined role of expertise and competence on KTx outcome.

In conclusion, the surgeon's experience is an independent risk factor of vascular and haemorrhagic complications after KTx. It is suggested that adequate vascular surgery training should be added to transplant surgery fellowship programs to improve KTx outcomes. A multidisciplinary approach (i.e. including a vascular surgeon in the surgical team) could help reduce vascular complications. The threshold number of unsupervised KTx operations to achieve an acceptable level of post-operative vascular complications is at least 26. A donor age of >60 years and recipient CVD are also independent risk factors of post-KTx vascular and haemorrhagic complications, therefore it is suggested that these high risk patients should preferably be operated on by surgeons with experience of more than 26 transplantations.

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CONFLICTS OF INTEREST

None.

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REFERENCES

1 Kimmel PL, Patel SS. Quality of life in patients with chronic kidney disease: focus on end-stage renal disease treated with hemodialysis. *Semin Nephrol* 2006;**26**:68–79.

2 Weitz J, Koch M, Mehrabi A, Schemmer P, Zeier M, Beimler J, et al. Living-donor kidney transplantation: risks of the donor—benefits of the recipient. *Clin Transpl* 2006;**20**:13—6.
3 Merion RM, Ashby VB, Wolfe RA, Distant DA, Hulbert-Shearon TE, Metzger RA, et al. Deceased-donor characteristics and the survival benefit of kidney transplantation. *Jama* 2005;**294**:2726—33.
4 Valderrabano F, Jofre R, Lopez-Gomez JM. Quality of life in end-stage renal disease patients. *Am J Kidney Dis* 2001;**38**:443—64.
5 Watson CJ, Dark JH. Organ transplantation: historical perspective and current practice. *Br J Anaesth* 2012;**108**:i29—42.
6 Susal C, Fichtner A, Tonshoff B, Mehrabi A, Zeier M, Morath C. Clinical relevance of HLA antibodies in kidney transplantation: recent data from the Heidelberg transplant center and the collaborative transplant study. *J Immunol Res* 2017;**2017**:5619402.
7 Mehrabi A, Wiesel M, Zeier M, Kashfi A, Schemmer P, Kraus T, et al. Results of renal transplantation using kidneys harvested from living donors at the University of Heidelberg. *Nephrol Dial Transpl* 2004;**19**. iv48—54.
8 Libicher M, Radeleff B, Grenacher L, Hallscheidt P, Mehrabi A, Richer GM, et al. Interventional therapy of vascular complications following renal transplantation. *Clin Transpl* 2006;**20**:55—9.
9 de Freitas RAP, de Lima ML, Mazzali M. Early vascular thrombosis after kidney transplantation: can we predict patients at risk? *Transpl Proc* 2017;**49**:817—20.
10 Araujo JC, Barbosa RW, Machado MF, Furtado PS, Pugas CM, Filho JS, et al. Clinical impact of surgical complications in kidney transplant recipients in a reference hospital in Salvador, Bahia, Brazil. *Transpl Proc* 2016;**48**:2301—5.
11 Granata A, Clementi S, Londrino F, Romano G, Veroux M, Fiorini F, et al. Renal transplant vascular complications: the role of Doppler ultrasound. *J Ultrasound* 2015;**18**:101—7.
12 Penny MJ, Nankivell BJ, Disney AP, Byth K, Chapman JR. Renal graft thrombosis. A survey of 134 consecutive cases. *Transplantation* 1994;**58**:565—9.
13 Ammi M, Daligault M, Sayegh J, Abraham P, Papon X, Enon B, et al. Evaluation of the vascular surgical complications of renal transplantation. *Ann Vasc Surg* 2016;**33**:23—30.
14 Sagban TA, Baur B, Schelzig H, Grabitz K, Duran M. Vascular challenges in renal transplantation. *Ann Transpl* 2014;**19**:464—71.
15 Glicklich D, Vohra P. Cardiovascular risk assessment before and after kidney transplantation. *Cardiol Rev* 2014;**22**:153—62.
16 Aktas S, Boyvat F, Sevmis S, Moray G, Karakayali H, Haberal M. Analysis of vascular complications after renal transplantation. *Transpl Proc* 2011;**43**:557—61.
17 Audard V, Matignon M, Hemery F, Snanoudj R, Desgranges P, Anglade MC, et al. Risk factors and long-term outcome of transplant renal artery stenosis in adult recipients after treatment by percutaneous transluminal angioplasty. *Am J Transpl* 2006;**6**:95—9.
18 Humar A, Matas AJ. Surgical complications after kidney transplantation. *Semin Dial* 2005;**18**:505—10.
19 Sezer TO, Solak I, Toz H, Kardaslar B, Er A, Hoscoskun C. Long-term outcomes of kidney transplants with multiple renal arteries: a retrospective study. *Transpl Proc* 2012;**44**:1697—9.
20 Bessede T, Droupy S, Hammoudi Y, Bedretdinova D, Durrbach A, Charpentier B, et al. Surgical prevention and management of vascular complications of kidney transplantation. *Transpl Int* 2012;**25**:994—1001.
21 Oitchayomi A, Brichart N, Monleon L, Boutin JM, Bruyere F. [Impact of learning curve in renal transplantation]. *Prog Urol* 2015;**25**:1146—52.
22 Wolff T, Schumacher M, Dell-Kuster S, Rosenthal R, Dickenmann M, Steiger J, et al. Surgical complications in kidney transplantation: no evidence for a learning curve. *J Surg Educ* 2014;**71**:748—55.
23 Tavakkoli M, Zafarghandi RM, Taghavi R, Ghoreifi A, Zafarghandi MM. Immediate vascular complications after kidney transplant: experience from 2100 recipients. *Exp Clin Transpl* 2016;**15**:504—8.
24 Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004;**240**:205—13.
25 Howe CJ, Cole SR, Westreich DJ, Greenland S, Napravnik S, Eron Jr JJ. Splines for trend analysis and continuous confounder control. *Epidemiology* 2011;**22**:874—5.
26 Hourmant M, Lerat L, Karam G. Donation from old living donors: how safe is it? *Nephrol Dial Transpl* 2013;**28**:2010—4.
27 Machado S, Figueiredo N, Neves M, Macario F, Alves R, Mota A, et al. Kidney transplantation using donors over 70 years old: are the criteria for organ allocation too expanded? *Transpl Proc* 2012;**44**:2289—92.
28 Yazbek DC, de Carvalho AB, Barros CS, Marcassi AP, Pestana JO, Fachini FC, et al. Cardiovascular disease in early kidney transplantation: comparison between living and deceased donor recipients. *Transpl Proc* 2012;**44**:3001—6.
29 Kittleson MM. Preoperative cardiac evaluation of kidney transplant recipients: does testing matter? *Am J Transpl* 2011;**11**:2553—4.
30 Humar A, Kerr SR, Ramcharan T, Gillingham KJ, Matas AJ. Perioperative cardiac morbidity in kidney transplant recipients: incidence and risk factors. *Clin Transpl* 2001;**15**:154—8.
31 Steiner RW. 'Normal for now' or 'at future risk': a double standard for selecting young and older living kidney donors. *Am J Transpl* 2010;**10**:737—41.
32 Tabakovic M, Mesic E, Trnacevic S, Hodzic E, Barakovic F, Tulumovic D, et al. Hypertension and donor age in living-related kidney transplantation. *Med Arh* 2009;**63**:335—8.
33 Ayvazoglu Soy EH, Akdur A, Kirnap M, Boyvat F, Moray G, Haberal M. Vascular complications after renal transplant: a single-center experience. *Exp Clin Transpl* 2017;**15**:79—83.
34 Mekeel KL, Halldorson JB, Berumen JA, Hemming AW. Kidney clamp, perfuse, re-implant: a useful technique for graft salvage after vascular complications during kidney transplantation. *Clin Transpl* 2015;**29**:373—8.
35 Salehipour M, Salahi H, Jalaeian H, Bahador A, Nikeghbalian S, Barzideh E, et al. Vascular complications following 1500 consecutive living and cadaveric donor renal transplantations: a single center study. *Saudi J Kidney Dis Transpl* 2009;**20**:570—2.
36 Dimitroulis D, Bokos J, Zavos G, Nikiteas N, Karidis NP, Katsaronis P, et al. Vascular complications in renal transplantation: a single-center experience in 1367 renal transplantations and review of the literature. *Transpl Proc* 2009;**41**:1609—14.
37 UEMS Section and Board of Surgery. *European board of surgery qualification (EBSQ) in tranplantation surgery*. 2013 [cited 2017 Sep 7]; Available from: www.uemssurg.org www.uemssurg.org.
38 American Society of Transplant Surgeons. *ASTS transplant fellowship requirements*. 2016 [cited 2017 Sep 7]; Available from: www.asts.org www.asts.org.
39 Sambuis C, Dugardin F, Barbier S, Sibert L, Plissonnier D, Grise P, et al. Retrospective analysis of vascular complications in renal allograft after five years: single center study. *Prog Urol* 2010;**20**:40—8.
40 Jurgaitis J, Paskonis M, Mehrabi A, Kashfi A, Gragert S, Hinz U, et al. Controlled-surgical education in clinical liver transplantation is not associated with increased patient risks. *Clin Transpl* 2006;**20**:69—74.
41 Aboyans V, Ricco JB, Bartelink MEL, Bjorck M, Brodmann M, Cohnert T, et al. Editor's choice - 2017 ESC guidelines on the diagnosis and treatment of peripheral arterial diseases, in collaboration with the European Society for Vascular Surgery (ESVS). *Eur J Vasc Endovasc Surg* 2018;**55**:305—68.

42 Orlic P, Vukas D, Drescik I, Ivancic A, Blecic G, Budiselic B, et al. Vascular complications after 725 kidney transplantations during 3 decades. *Transpl Proc* 2003;**35**:1381–4.

43 Mehrabi A, Golriz M, Maier J, Fonouni H, Garoussi C, Hafezi M, et al. Long-Term follow-up of kidney transplant recipients with polycystic kidney disease. *Exp Clin Transpl* 2015;**13**:413–20.

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COUP D'OEIL

A Stent Graft Visualised Through an Infected Haemodialysis Graft Pseudoaneurysm

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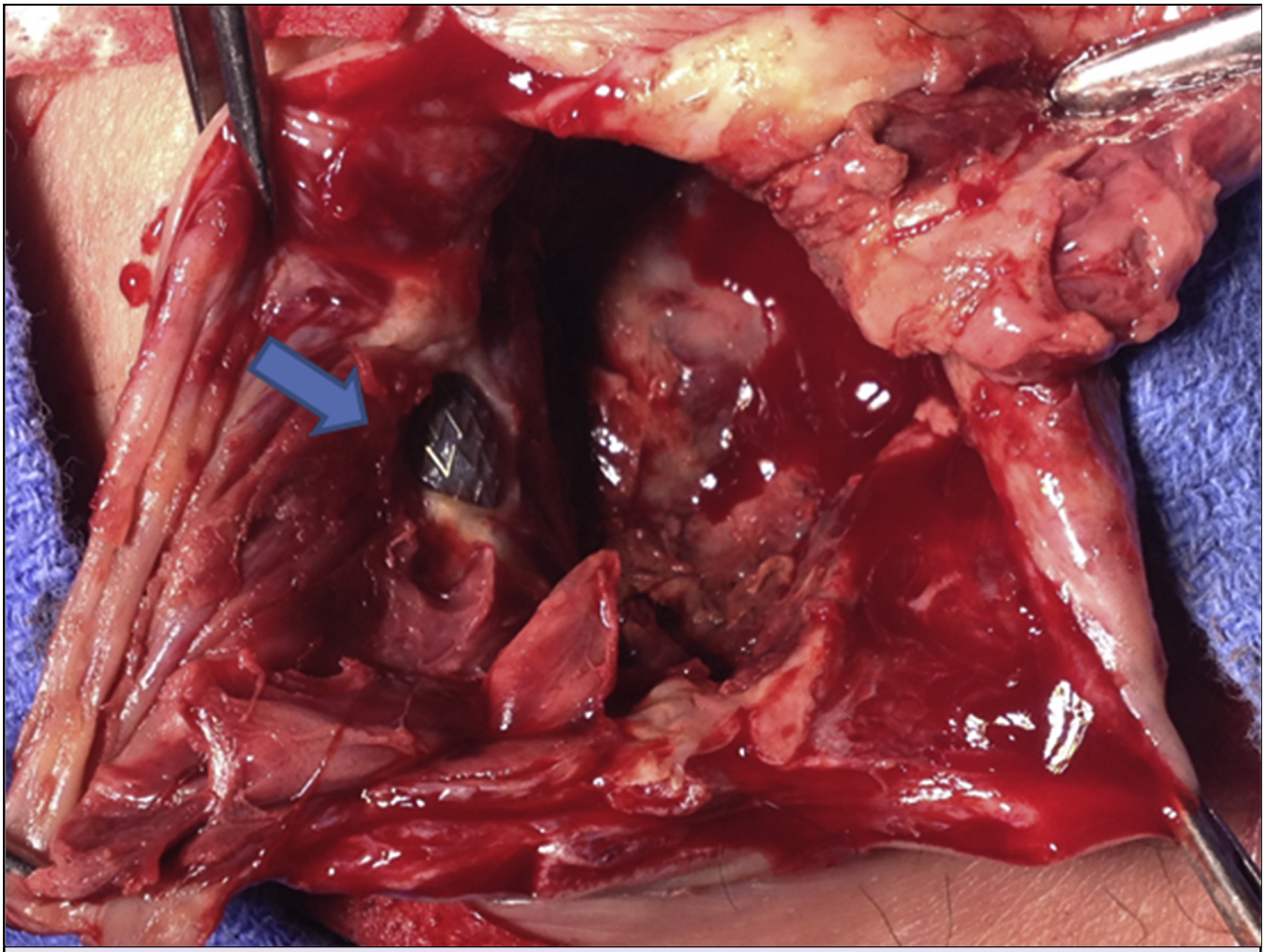

A 64 year old male presented with two needlestick pseudoaneurysms of a brachio-axillary PTFE haemodialysis graft; these were repaired by endovascular means using 7 × 40 mm and 7 × 60 mm Covera stent grafts (Bard, Tempe, AZ, USA) with peri-operative teicoplanin antibiotic prophylaxis. Two weeks later he presented with infection of the largest (5 cm) pseudoaneurysm, which was managed by partial graft excision. Intra-operatively the pseudoaneurysm was incised and pus drained. The stent graft was visualised through the graft defect (arrow). The aneurysm sac, part of the graft, and stent graft were excised. Culture results were normal. The wound healed by secondary intention, after a six week vancomycin/ciprofloxacin antibiotic course.

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