Cohort study: "Outcomes of kidney transplantation in patients with prosthetic heart valves"

Hajar Ouahmi, Pamela Moceri, Kévin Zorzi, Laetitia Albano, Matthieu Durand, Fatimaezzahra Karimi, Emmanuel Morelon, Fanny Buron, Moglie Le Quintrec, Vincent Pernin, et al.

Transplant International

ORIGINAL ARTICLE

Cohort study: "Outcomes of kidney transplantation in patients with prosthetic heart valves"

Hajar Ouahmi[1,2], Pamela Moceri[2,3], Kevin Zorzi[1,2], Laetitia Albano[1], Matthieu Durand[4], Fatimaezzahra Karimi[1], Emmanuel Morelon[5], Fanny Buron[5], Moglie Le Quintrec[6], Vincent Pernin[6], Marc Ladriere[7], Sophie Girerd[7], Jacques Dantal[8,9], Alexandre Loupy[10], Lionel Couzi[11,12], Emile Ferrari[3], Vincent Esnault[1,2], Pierre Merville[11,12], Christophe Legendre[10], Magali Giral[8,9], Antoine Sicard[1,2,13] & DIVAT Consortium*

1 Nephrology, Dialysis and Transplantation Department, Pasteur 2 Hospital, Nice University Hospital, Nice, France
2 Clinical Research Unit of Côte d'Azur University (UR2CA), Nice, France
3 Cardiology Department, Pasteur 2 Hospital, Nice University Hospital, Nice, France
4 Urology Department, Pasteur 2 Hospital, Nice University Hospital, Nice, France
5 Nephrology, Transplantation and Clinical Immunology Department, RTRS « Centaure », Edouard Herriot University Hospital, Hospices Civils, Lyon, France
6 Nephrology, Dialysis and Transplantation Department, Lapeyronie University Hospital, University of Montpellier, Montpellier, France
7 Renal Transplantation Department, Brabois University Hospital, Nancy, France
8 CRTI UMR 1064, Inserm, ITUN, CHU Nantes, RTRS Centaure, Université de Nantes, Nantes, France
9 Centre d'Investigation Clinique en Biothérapie, Nantes, France
10 Kidney Transplant Center, Necker University Hospital, APHP, RTRS «Centaure», Paris Descartes and Sorbonne Paris Cité Universities, Paris, France
11 Department of Nephrology, Transplantation, Dialysis and Apheresis, Pellegrin Hospital, Bordeaux University Hospital, Bordeaux, France

SUMMARY

The number of kidney transplant candidates with prosthetic heart valves (PHVs) is increasing. Yet, outcomes of kidney transplantation in these patients are still unclear. This is the first report of post-transplant outcomes in patients with PHVs at time of kidney transplantation. We conducted a matched cohort study among recipients from the multicentric and prospective DIVAT cohort to compare the outcomes in patients with left-sided PHVs at time of transplantation and a group of recipients without PHV matched according to age, dialysis time, initial disease, pretransplant DSA, diabetes, and cardiovascular events. Of 23 018 patients, 92 patients with PHVs were included and compared to 276 patients without PHV. Delayed graft function and postoperative bleeding occurred more frequently in patients with PHVs. Kidney graft survival was similar between groups. 5-year overall survival was 68.5% in patients with PHV vs. 87.9% in patients without PHV [HR, 2.72 (1.57–4.70), $P = 0.0004$]. Deaths from infection, endocarditis, and bleeding were more frequent in patients with PHV. Mechanical valves, but not bioprosthetic valves, were independent risk factors for mortality [HR, 2.89 (1.68–4.97), $P = 0.0001$]. Patients with PHV have high mortality rates after kidney transplantation. These data suggest that mechanical valves, but not biological valves, increase risks of post-transplant mortality.

Transplant International 2021; 34: 2297–2304

Key words
biological heart valve, cardiac valve replacement, end-stage kidney disease, kidney transplantation, mechanical heart valve, prosthetic heart valve

Received: 2 April 2021; Accepted: 11 July 2021; Published online: 19 October 2021

doi:10.1111/tri.14008

12 UMR CNRS 5164,
ImmunoConcEpT, Bordeaux
University, Bordeaux, France
13 CNRS, UMR7370, Laboratory of
Molecular PhysioMedicine, LP2M,
Nice, France

Correspondence
Antoine Sicard MD, PhD, Nephrology,
Dialysis, Transplantation Department,
Nice University Hospital, Pasteur 2
Hospital, 30 voie Romaine, 06000
Nice, France.
Tel.: +33 (0)4 92 03 79 10;
fax: +33 (0)4 92 03 87 52;
e-mail: sicard.a@chu-nice.fr

*See DIVAT Consortium in Appendix.

Introduction

The prevalence of valvular heart disease is increasing in patients with end-stage kidney disease (ESKD) [1]. There is a corresponding increase in the number of ESKD patients who require heart valve replacement [2,3]. Mortality is high in these patients, with only about half the patients younger than 65 years surviving beyond 2 years after heart valve surgery [4]. There is currently no recommendation on the type of valve prosthesis to choose in ESKD patients because studies comparing mid-long-term survivals after bioprosthetic or mechanical valve replacement have yielded conflicting results in this population [5–12]. As for renal replacement therapy, kidney transplantation is theoretically the best option [13–15]. If successful, it provides patients with the best possible quality of life and reduces cardiovascular mortality as compared to dialysis [16–18]. However, patients with prosthetic heart valves (PHV) are high-risk kidney transplant recipients. Transplantation should only proceed in these patients if there is an expectation of the graft and patient surviving for a significant period of time. Given the risks of failure, transplantation from a living donor may also be problematic. Although the clinical team requires a realistic prediction of possible success and risks of failure to evaluate eligibility for transplantation and inform patients, there are currently no data on the incidence of complications, graft failures, and deaths after transplantation in patients with PHVs. The aim of the present study was to assess post-transplant outcomes in patients with PHVs at time of transplantation. To this end, we conducted a matched cohort study among kidney transplant recipients from the French multicentric and prospective DIVAT (Données Informatisées et VAlidées en Transplantation) cohort.

Materials and methods

Study type and data source

An observational, multicenter, matched cohort study was conducted in kidney transplant recipients of the French DIVAT (Données Informatisées et VAlidées en Transplantation) database, which is a prospectively maintained database including transplant and follow-up data of all adult kidney and/or pancreas transplant recipients from French university hospitals including Lyon, Montpellier, Nancy, Nantes, Necker (Paris), Bordeaux, and Nice.

Patients

The study included all adult patients (≥18 years old) who underwent left-sided cardiac surgical valve replacement before kidney transplantation and received transplantation between March 9, 2000 and August 21, 2019. One patient was excluded because he had transcatheter aortic valve replacement. Each recipient with PHV was matched individually with three kidney transplant recipients without PHV on (i) four possible confounders known to be at time of transplantation major risk factors for post-transplant mortality: recipient age (±10 years), pretransplant dialysis (no dialysis or dialysis time ≤6 months vs. dialysis time >6 months),

Transplant International 2021; 34: 2297–2304

diabetes, cardiovascular events [19–21] and (ii) two possible confounders known to be at time of transplantation risks factors for allograft loss: recurrent nephropathy and preformed donor-specific anti-HLA antibodies (DSA) [22–24]. Matching ensured an equal distribution of these variables among patients with or without PHVs (Table 1).

An appropriate written informed consent for data collection was obtained from all the participants at time of transplantation. The consent form contained information on the possibility of later anonymous use of the data for research purposes. All the procedures were carried out in accordance with the ethical standards of the institutional review boards, national research committees and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Data collection

Characteristics of the study population

Variables analyzed included: (i) recipient characteristics at time of transplantation: age, sex, duration of dialysis before transplantation, initial nephropathy, diabetes, malignancies, cardiac events (cardiac arrest, heart failure, coronary events, conduction disorders, rhythm disorders,

Table 1. Baseline characteristics of patients with or without prosthetic heart valves (PHVs) at time of transplantation.

Variable	PHV (n = 92)	No PHV (n = 276)	P value
Recipient characteristics			
Age (year)*	56 ± 13	56 ± 13	1
Men	61 (66.3)	202 (73.2)	0.29
Retransplantation	27 (29.3)	56 (20.3)	0.08
Preemptive transplantation or dialysis <6 months*	7 (7.6)	21 (7.6)	1
Time since dialysis (mo)	62.7 ± 53.2	48.1 ± 46.1	0.006
Recurrent nephropathy*	33 (35.9)	99 (35.9)	1
Cardiovascular events*	79 (85.9)	237 (85.9)	1
Diabetes	17 (18.5)	51 (18.5)	1
Neoplasia	11 (12.0)	38 (13.8)	0.73
Time since valve replacement (year)†	5.4 ± 5.6	–	–
Mechanical valve	59 (64.1)	–	–
Biological valve	33 (35.9)	–	–
Valve location			
Aortic	72 (78.3)	–	–
Mitral	13 (14.1)	–	–
Aortic and mitral	7 (7.6)	–	–
Donor characteristics			
Age (year)	56 ± 17	57 ± 16	0.65
Deceased	84 (91.3)	248 (89.9)	0.84
Transplant data			
Preformed DSA*	23 (25.0)	69 (25.0)	1
Cold ischemic time (min)	1059 ± 501	1045 ± 541	0.62
Number of mismatches A, B, DR	3.6 ± 1.3	3.2 ± 1.4	0.01
Immunosuppression‡			
Anti-ILR2	35 (38.0)	91 (33.0)	0.31
Thymoglobulins	53 (57.6)	175 (63.4)	0.32
Tacrolimus	78 (84.8)	209 (75.7)	0.08
Ciclosporine	14 (15.2)	64 (23.2)	0.14
MMF/MPA	89 (96.7)	258 (93.5)	0.31
Prednisone	90 (97.8)	263 (95.3)	0.37
Sirolimus/everolimus	4 (4.3)	13 (4.7)	1

Anti-ILR2, anti-interleukin receptor 2; DSA, donor-specific antibodies; MMF, Mycophenolate mofetil; MPA, Mycophenolic acid.
Data are no. (%) of patients unless otherwise indicated. Continuous variables are reported as mean ± SD.

*Matching criteria between the PHV and No PHV group.

†Data missing for 4 patients in PHV group.

‡Data missing for 3 patients in No PHV group.

pulmonary arterial hypertension), cerebrovascular events (stroke), peripheral vascular events (peripheral artery disease, venous thromboembolic disease), cardiovascular events (i.e. history of cardiac events, cerebrovascular and/or peripheral vascular events as defined above), type of PHV (biological versus mechanical), and location, time since cardiac valve replacement, (ii) donor characteristics: age and deceased status, iii) transplant characteristics: cold ischemic time, HLA mismatches, induction agent and immunosuppressive treatments at transplantation.

Outcomes

The onset of the following events was retrieved: delayed graft function (defined as the need for dialysis within the first week after kidney transplantation), hemorrhagic complications, biopsy-proven rejection, *de novo* donor-specific antibodies, graft loss, infections, endocarditis, deaths with and without a functioning graft. Graft survival was calculated from the date of transplantation until the beginning of hemodialysis. Patient survival was calculated from the date of transplantation to death. Causes of death were ascertained from the Centers.

Statistics

Categorical variables were expressed as percentages and compared with the chi-square test or Fisher exact test whenever appropriate. Continuous variables were expressed as mean ± SD and compared using the Mann–Whitney *U* test. Survival curves were constructed with the Kaplan–Meier method and compared with the log-rank test. The Cox proportional hazards regression model was used in both univariate and multivariate models. All significant variables in the univariate analysis with a level set at $P < 0.1$ were incorporated into multivariate cox models considering the number of events. All tests were two sided, and P values <0.05 were considered to represent statistically significant differences. Analyses were performed with GRAPHPAD PRISM 5 and SAS 9.4 Software.

Results

Baseline characteristics of the study population

Twenty-three thousand and eighteen patients who received kidney transplantation between 2000 and 2019 were screened. Ninety-two (0.4%) of them had left-sided prosthetic heart valves at time of transplantation and were compared to 276 patients without PHV. Baseline characteristics of the groups are shown in Table 1. Patients with PHV remained longer on dialysis before transplantation than patients without PHV (14.6 ± 7.1 months more). Fifty-nine patients had mechanical prosthesis and 33 biological prosthesis. As expected, patients with mechanical prosthesis were younger than patients with biological prosthesis (52 ± 12 vs. 62 ± 13 years old, $P = 0.0002$, Table S1), and vascular nephropathies were more frequent in patients with bioprosthetic valves than in patients with mechanical valves (36.4% vs. 13.6%, respectively, $P = 0.02$, Table S1). Glomerulopathies were more frequent in patients with mechanical valves than in those with biological valves (49.2% vs. 27.3%, respectively, $P = 0.048$, Table S1).

Renal allograft outcomes

Recipients with PHV exhibited a higher percentage of delayed graft function (DGF) (34.8% vs. 14.1%, $P < 0.0001$, Table 2) and postoperative hemorrhagic complications at the surgical site (47.8% vs. 11.6%, $P < 0.0001$, Table 2) than recipients without PHV. Incidences of de novo DSAs (26.1% vs. 29.0% in the PHV and No PHV groups, respectively), cellular rejections (8.7% vs. 11.2% in the PHV and No PHV groups, respectively), and humoral rejections (8.7% vs. 4.7% in the PHV and No PHV groups, respectively) were not significantly different between groups (Table 2). Proteinuria and estimated glomerular filtration rate at 1- and 5-years post-transplant were also similar between groups (Table 2) as was kidney allograft survival (HR, 1.50 [0.82–2.74], $P = 0.19$ by log-rank, Fig. S1).

Post-transplant overall survival and causes of death

After a mean follow-up of 4.6 ± 4.3 years in the group of patients with PHVs and 4.2 ± 1.2 years in the group of patients without PHV ($P = 0.20$), 30 patients with PHVs (32.6%) and 36 patients without PHV (13.0%) died. The 5-year survival was 68.5% in the PHV group and 87.9% in the group of patients without PHV. Overall survival was lower in patients with PHVs than in those without PHV [HR, 2.72 (1.57–4.70), $P = 0.0004$ by log-rank, Fig. 1]. A higher proportion of patients died from infection and endocarditis in the PHV group (14.1% vs. 4.7%, $P = 0.004$ and 3.2% vs. 0.4%, $P = 0.02$, respectively, Table 3). Deaths from bleeding were also more frequent in patients with PHVs (3.3% vs. 0.0%, $P = 0.02$, Table 3) and occurred only in

Table 2. Renal outcomes in patients with or without prosthetic heart valves (PHVs).

Variables	PHV (n = 92)	No PHV (n = 276)	P value
Delayed graft function, yes/no	32 (34.8)	39 (14.1)	<0.0001
Hemorrhagic complications*	44 (47.8)	32 (11.6)	<0.0001
Immunological outcomes			
DSA de novo	24 (26.1)	80 (29.0)	0.69
Rejection, yes/no	16 (17.4)	51 (18.5)	0.88
Cellular rejection	8 (8.7)	31 (11.2)	0.56
Humoral rejection	8 (8.7)	13 (4.7)	0.19
Humoral and cellular rejection	0 (0.0)	7 (2.5)	0.20
Kidney graft function at 12 months			
Proteinuria (g/g)	0.47 ± 1.10	0.36 ± 0.62	0.50
eGFR	53 ± 29	48 ± 18	0.48
Kidney graft function at 60 months			
Proteinuria (g/g)	0.82 ± 2.61	0.40 ± 0.68	0.89
eGFR	50 ± 22	47 ± 17	0.60

DGF, delay graft function; eGFR, estimate glomerular filtration rate was calculated with the Modification of Diet Renal Disease formula.

Data are no. (%) of patients, unless otherwise indicated. Continuous variables are reported as mean ± SD.

*Postoperative hemorrhagic complications at the surgical site.

patients with mechanical valves (not shown). There was no significant difference between groups regarding deaths from cardiovascular events or cancer (4.3% vs. 1.8%, P = 0.24 and 4.3% vs. 3.3%, P = 0.74, respectively, Table 3).

Independent risk factors for post-transplant mortality

Exploratory univariate analysis identified seven risk factors for post-transplant mortality in the study population (Table 4): recipient age [HR, 1.06 (1.03–1.09), P < 0.0001], biological prosthesis [HR, 2.90 (1.42–5.94), P = 0.002], mechanical prosthesis [HR, 2.35 (1.40–3.96), P = 0.0009], pretransplant dialysis time [HR, 1.05 (1.00–1.11), P = 0.07], diabetes [HR, 2.59 (1.51–4.44), P = 0.0003], cerebrovascular and/or peripheral vascular events [HR, 1.62 (0.99–2.65), P = 0.05], and cardiac events [HR, 1.81 (1.02–3.23), P = 0.04]. Of note, the type of initial nephropathy, time since valve replacement and localization of the PHV (aortic or mitral) were not identified as risk factors for mortality (not shown). The seven identified variables were integrated in a multivariate analysis (Table 4), which identified five independent predictors for mortality. In contrast with the presence of a bioprosthetic valve, the presence of a mechanical valve was an independent risk factor for mortality [HR, 2.89 (1.68–4.97); P = 0.0001]. Other

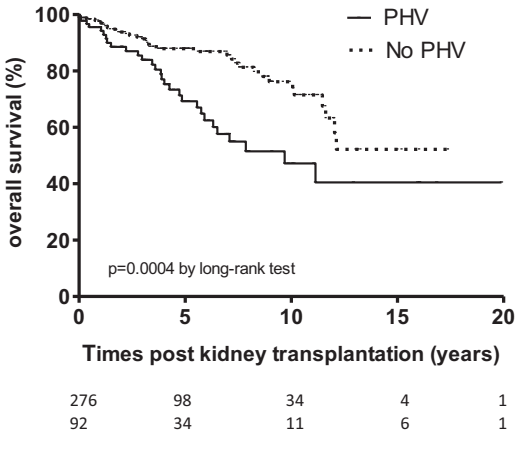

Figure 1 Prosthetic heart valves are associated with poorer post-transplant overall survival. Kaplan-Meier curves for overall survival are shown for patients with or without PHV.

Table 3. Causes of death in patients with or without prosthetic heart valves (PHVs).

Causes of death	PHV (n = 92)	No PHV (n = 276)	P value
Infection	13 (14.1)	13 (4.7)	0.004*
Endocarditis	3 (3.2)	1 (0.4)	0.049*
Hemorrhage	3 (3.3)	0 (0.0)	0.02*
Cardiovascular	4 (4.3)	5 (1.8)	0.24
Cancer	4 (4.3)	9 (3.3)	0.74
Other/unknown	6 (6.5)	9 (3.3)	0.22

*P-value<0.05 is significant.

Table 4. Univariate and multivariate analyses of risk factors for post-transplant death in the study population (n = 368).

	Univariate		Multivariate	
Variable	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Recipient age (per 1-year increment)	1.06 (1.03–1.09)	<0.0001	1.06 (1.04–1.09)	<0.0001*
Biological prosthesis	2.90 (1.42–5.94)	0.002	–	NS
Mechanical prosthesis	2.35 (1.40–3.96)	0.0009	2.89 (1.68–4.97)	0.0001*
Time since dialysis (per 1-year increment)	1.05 (1.00–1.11)	0.07	1.07 (1.02–1.13)	0.01*
Diabetes	2.59 (1.51–4.44)	0.0003	1.99 (1.13–3.53)	0.02*
Cerebrovascular and peripheral events	1.62 (0.99–2.65)	0.05	–	NS
Cardiac events	1.81 (1.02–3.23)	0.04	1.88 (1.04–3.40)	0.04*

**P*-value<0.05 is significant.

independent predictors of mortality were recipient age [HR, 1.06 (1.04–1.09), $P < 0.0001$], pretransplant dialysis time [HR, 1.07 (1.02–1.13), $P = 0.01$], diabetes [HR, 1.99 (1.13–3.53), $P = 0.02$], and cardiac events [HR, 1.88 (1.04–3.40), $P = 0.04$].

Discussion

Due to the aging of the population, an increasing number of patients with end-stage kidney disease require cardiac valve replacement and may be candidates for kidney transplantation. While cardiac valve replacement has been associated with poor outcomes in kidney transplant patients [25], outcomes of kidney transplantation in ESKD patients with PHVs at time of transplantation remain unknown. This study is the first to evaluate the results of kidney transplantation in recipients with left-sided prosthetic heart valves. We found that mechanical valves were associated with a 3-fold increased risk of post-transplant mortality. In contrast, biological valves were not identified as a risk factor for post-transplant mortality. This observation suggests that the presence of a biological valve in a kidney transplant candidate should not, or only marginally, influence the medical decision to allow or not registration on the transplant waiting list. Since the presence of a mechanical valve is an additional risk factor of post-transplant mortality, a clear information should be given to patients about their specific risk. Eligible patients should be referred for transplantation as soon as possible to anticipate and limit dialysis time that was identified as an additional independent risk factor for mortality. In our study population, patients with PHVs remained for a longer period of time on dialysis before transplantation than patients without PHVs, which may reflect some hesitation in referring these high-risk patients to transplantation centers.

It is likely that anticoagulant therapy is a key explanation for the poor outcomes of recipients with mechanical valves. Indeed, postoperative hemorrhage at the surgical sites occurred in almost half of these patients who also had a higher risk of death from bleeding. This may be due to their high target INRs since the use of warfarin at lower dose for atrial fibrillation in kidney transplant patients was not associated with an increased risk of mortality [26]. Perioperative management of anticoagulation in these patients varies according to the transplant teams. A limit of this study is the lack of information on the perioperative management of anticoagulation by the different centers. Standardized protocols for anticoagulation management in kidney transplant recipients with mechanical valves are still required. Direct oral anticoagulants, which show a better tolerance than vitamin K antagonists, could be an alternative. However, they have not proved their noninferiority in the prevention of thromboembolic events in patients with mechanical valves and a trial has been discontinued because of high numbers of thromboembolic and bleeding events in patients with mechanical valves receiving Dabigatran [27]. Another alternative could be the use of new generation mechanical valves with lower anticoagulation requirements [28], but no analysis of these valves has been performed in ESKD patients [2].

The choice of prosthetic heart valve in patients with ESKD on dialysis remains debated. Mid-long-term survival was similar after bioprosthetic or mechanical valve replacement and [8,10,12], despite a lower rate of bleeding and thromboembolic events in the bioprosthetic groups [5,11], there is currently no guideline on the type of valve prosthesis to choose in ESKD patients [29]. The choice is based on an individual risk assessment. To our knowledge, none of the above-mentioned studies have analyzed long-term outcomes of valve replacement in ESKD patients separately in those who did or did not

Transplant International 2021; 34: 2297–2304

receive subsequent kidney transplantation. The correction of abnormal calcium and phosphate metabolism, chronic inflammation or malnutrition after transplantation may decrease the risk of accelerated calcification and degeneration of bioprosthetic valves observed in dialysis patients [30]. We believe that the potential eligibility of patients to kidney transplantation has to be taken into account, with the standard criteria, when choosing the type of prosthetic heart valves in ESKD patients.

In conclusion, this is the first report of kidney transplantation outcomes in patients with a prosthetic heart valve at time of transplantation. We here show that the post-transplant mortality is high in these patients and that mechanical valves, but not biological valves, are independent risk factors of post-transplant mortality. These data will help clinical teams in (i) assessing eligibility of PHV patients for transplantation and (ii) choosing the type of valve in ESKD patients eligible for subsequent kidney transplantation.

Authorship

All authors certify that they have participated sufficiently in the work to take public responsability for the content, including participation in the concept, design, analysis, writing, and/or revision of the manuscript.

Funding

We thank the Roche Pharma, Novartis, and Sanofi laboratories for supporting the DIVAT Cohort as the CENTAURE Foundation (http://www.fondation-centaure.org).

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Acknowledgements

The authors would like to thank the members of the DIVAT consortium for their involvement in the study, the physicians who helped recruit patients (please see the list of collaborators below), and all patients who participated in this study. We also thank the clinical research associates who participated in the data collection. Data were collected from the French DIVAT multicentric prospective cohort of kidney and/or pancreatic transplant recipients (www.divat.fr, N° CNIL 914184). The analysis and interpretation of these data are the responsibility of the authors.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Baseline characteristics of patients with mechanical and biological prosthesis at time of transplantation.

Figure S1. Graft survival is similar between PHV and No PHV groups.

REFERENCES

1. Samad Z, Sivak JA, Phelan M, Schulte PJ, Patel U, Velazquez EJ. Prevalence and outcomes of left-sided valvular heart disease associated with chronic kidney disease. *J Am Heart Assoc Cardiovasc Cerebrovasc Dis* 2017; **6**, e006044.
2. Marwick TH, Amann K, Bangalore S, *et al*. Chronic kidney disease and valvular heart disease: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) controversies conference. *Kidney Int* 2019; **96**: 836.
3. Rattazzi M, Bertacco E, Del Vecchio A, Puato M, Faggin E, Pauletto P. Aortic valve calcification in chronic kidney disease. *Nephrol Dial Transplant* 2013; **28**: 2968.
4. Williams ML, Bavaria JE, Acker MA, *et al*. Valve selection in end-stage renal disease: should it always be biological? *Ann Thorac Surg* 2016; **102**: 1531.
5. Phan K, Zhao DF, Zhou JJ, Karagaratnam A, Phan S, Yan TD. Bioprosthetic versus mechanical prostheses for valve replacement in end-stage renal disease patients: systematic review and meta-analysis. *J Thorac Dis* 2016; **8**: 769.
6. Brinkman WT, Williams WH, Guyton RA, Jones EL, Craver JM. Valve replacement in patients on chronic renal dialysis: implications for valve prosthesis selection. *Ann Thorac Surg* 2002; **74**: 37.
7. Böning A, Boedeker R-H, Rosendahl U, *et al*. Long-term results of mechanical and biological heart valves in dialysis and non-dialysis patients. *Thorac Cardiovasc Surg* 2011; **59**: 454.
8. Manghelli JL, Carter DI, Khiabani AJ, *et al*. A 20-year multicenter analysis of dialysis-dependent patients who had aortic or mitral valve replacement: implications for valve selection. *J Thorac Cardiovasc Surg* 2019; **158**: 805.
9. Chi K-Y, Chiang M-H, Kang Y-N, *et al*. Mechanical or biological heart valve for dialysis-dependent patients? A meta-analysis. *J Thorac Cardiovasc Surg* 2020.).
10. Ikeno Y, Mukohara N, Fukumura Y, *et al*. Outcomes of valve replacement with mechanical prosthesis versus bioprosthesis in dialysis patients: a 16-year multicenter experience. *J Thorac Cardiovasc Surg* 2019; **158**: 48.

11. Altarabsheh SE, Deo SV, Dunlay SM, *et al.* Tissue valves are preferable for patients with end-stage renal disease: an aggregate meta-analysis. *J Card Surg* 2016; **31**: 507.
12. Chan V, Chen L, Mesana L, Mesana TG, Ruel M. Heart valve prosthesis selection in patients with end-stage renal disease requiring dialysis: a systematic review and meta-analysis. *Heart Br Card Soc* 2011; **97**: 2033.
13. Wolfe RA, Ashby VB, Milford EL, *et al.* Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant. *N Engl J Med* 1999; **341**: 1725.
14. Meier-Kriesche HU, Ojo AO, Port FK, Arndorfer JA, Cibrik DM, Kaplan B. Survival improvement among patients with end-stage renal disease: trends over time for transplant recipients and wait-listed patients. *J Am Soc Nephrol JASN* 2001; **12**: 1293.
15. Tonelli M, Wiebe N, Knoll G, *et al.* Systematic review: kidney transplantation compared with dialysis in clinically relevant outcomes. *Am J Transplant* 2011; **11**: 2093.
16. Laupacis A, Keown P, Pus N, *et al.* A study of the quality of life and cost-utility of renal transplantation. *Kidney Int* 1996; **50**: 235.
17. Aasebø W, Homb-Vesteraas NA, Hartmann A, Stavem K. Life situation and quality of life in young adult kidney transplant recipients. *Nephrol Dial Transplant* 2009; **24**: 304.
18. Meier-Kriesche H-U, Schold JD, Srinivas TR, Reed A, Kaplan B. Kidney transplantation halts cardiovascular disease progression in patients with end-stage renal disease. *Am J Transplant* 2004; **4**: 1662.
19. Meier-Kriesche H-U, Port FK, Ojo AO, *et al.* Effect of waiting time on renal transplant outcome. *Kidney Int* 2000; **58**: 1311.
20. Goldfarb-Rumyantzev A, Hurdle JF, Scandling J, *et al.* Duration of end-stage renal disease and kidney transplant outcome. *Nephrol Dial Transplant* 2005; **20**: 167.
21. Gill JS, Abichandani R, Kausz AT, Pereira BJG. Mortality after kidney transplant failure: the impact of non-immunologic factors. *Kidney Int* 2002; **62**: 1875.
22. Lefaucheur C, Suberbielle-Boissel C, Hill GS, *et al.* Clinical relevance of preformed HLA donor-specific antibodies in kidney transplantation. *Am J Transplant* 2008; **8**: 324.
23. Ponticelli C, Villa M, Cesana B, Montagnino G, Tarantino A. Risk factors for late kidney allograft failure. *Kidney Int* 2002; **62**: 1848.
24. Van Loon E, Bernards J, Van Craenenbroeck AH, Naesens M. The causes of kidney allograft failure: more than alloimmunity. A viewpoint article. *Transplantation* 2020; **104**: e46.
25. Sharma A, Gilbertson DT, Herzog CA. Survival of kidney transplantation patients in the United States after cardiac valve replacement. *Circulation* 2010; **121**: 2733.
26. Lenihan CR, Montez-Rath ME, Shen JI, *et al.* Correlates and outcomes of warfarin initiation in kidney transplant recipients newly diagnosed with atrial fibrillation. *Nephrol Dial Transplant* 2015; **30**: 321.
27. Eikelboom JW, Connolly SJ, Brueckmann M, *et al.* Dabigatran versus warfarin in patients with mechanical heart valves. *N Engl J Med* 2013; **369**: 1206.
28. Puskas JD, Gerdisch M, Nichols D, *et al.* Anticoagulation and antiplatelet strategies after On-X mechanical aortic valve replacement. *J Am Coll Cardiol* 2018; **71**: 2717.
29. Nishimura RA, Gentile F, Bonow RO. Guideline update on evaluation and selection of prosthetic valves. *JAMA Cardiol* 2018; **3**: 260.
30. Alappan HR, Vasanth P, Manzoor S, O'Neill WC. Vascular calcification slows but does not regress after kidney transplantation. *Kidney Int Rep* 2020; **5**: 2212.

APPENDIX

DIVAT (Données Informatisées et VAlidées en Transplantation) Consortium, DIVAT Cohort Collaborators (Medical Doctors, Surgeons, HLA Biologists): Lyon E. Hériot: Lionel Badet, Maria Brunet, Fanny Buron, Rémi Cahen, Ricardo Codas, Sameh Daoud, Valérie Dubois, Coralie Fournie, Arnaud Grégoire, Alice Koenig, Charlène Lévi, Emmanuel Morelon, Claire Pouteil-Noble, Maud Rabeyrin, Thomas Rimmelé, Olivier Thaunat; Montpellier: Nicolas Abdo, Sylvie Delmas, Moglie Le Quintrec, Vincent Pernin, Hélène Perrochia, Jean-Emmanuel Serre, Ilan Szwarc; Nancy: Alice Aarnink, Asma Alla, Pascal Eschwege, Luc Frimat, Sophie Girerd, Jacques Hubert, Raphaël Kormann, Marc Ladriere, François Lagrange, Emmanuelle Laurain, Pierre Lecoanet, Jean-Louis Lemelle; Anthony Mannuguerra, Charles Mazeaud, Michael Peres; Nantes: Gilles Blancho, Julien Branchereau, Diego Cantarovich, Agnès Chapelet, Jacques Dantal, Clément Deltombe, Lucile Figueres, Claire Garandeau, Magali Giral, Caroline Gourraud-Vercel, Maryvonne Hourmant, Georges Karam, Clarisse Kerleau, Aurélie Meurette, Simon Ville, Christine Kandell, Anne Moreau, Karine Renaudin, Anne Cesbron, Florent Delbos, Alexandre Walencik, Anne Devis; Nice: Laetitia Albano, Fatimaezzahra Karimi, Antoine Sicard, Hajar Ouahmi; Daniel Chevallier, Brannwel Tibi, Matthieu Durand, Younes Ahallal; Paris-Necker: Lucile Amrouche, Dany Anglicheau, Olivier Aubert, Lynda Bererhi, Christophe Legendre, Alexandre Loupy, Frank Martinez, Rébecca Sberro-Soussan, Anne Scemla, Claire Tinel, Julien Zuber; Paris-Saint-Louis: Denis Glotz, Carmen Lefaucheur.