

# Outcomes in Living Donor Kidney Transplantation: The Role of Donor's Kidney Function

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## Keywords

Chronic patients · Kidney transplant · Living donor · Survival · Chronic kidney disease

## Abstract

**Introduction:** Living donor kidney transplant (LDKT) is one of the best therapeutic options for end-stage kidney disease (ESKD). Guidelines identify different estimated glomerular filtration rate (eGFR) thresholds to determine the eligibility of donors. The aim of our study was to evaluate whether pre-transplant donor eGFR was associated with kidney function in the recipient. **Methods:** We retrospectively studied LDKT recipients who received a kidney graft between September 1, 2005, and June 30, 2016 in the same transplant center in France and that had eGFR data available at 3, 12, 24, and 36 months posttransplant. **Results:** We studied 90 donor-recipient pairs. The average age at time of transplant was  $51.47 \pm 10.95$  for donors and  $43.04 \pm 13.52$  years for recipients. Donors' average eGFR was  $91.99 \pm 15.37$  mL/min/1.73 m<sup>2</sup>. Donor's age and eGFR were significantly correlated ( $p < 0.0001$ ,  $r^2 0.023$ ). Donor's age and eGFR significantly correlated with recipient's eGFR at 3, 12, and 24 months posttransplant (age:  $p < 0.001$  at all intervals; eGFR  $p = 0.001$ ,  $0.003$ , and  $0.016$ ,

respectively); at 36 months, only donor's age significantly correlated with recipient's eGFR. BMI, gender match, and year of kidney transplant did not correlate with graft function. In the multivariable analyses, donor's eGFR and donor's age were found to be associated with graft function; correlation with eGFR was lost at 36 months; and donor's age retained a strong correlation with graft function at all intervals ( $p < 0.001$ ). **Conclusions:** Donor's eGFR and age are strong predictors of recipient's kidney function at 3 years. We suggest that donor's eGFR should be clinically balanced with other determinants of kidney function and in particular with age.

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## Introduction

Since the first successful kidney transplant, living donor kidney transplant (LDKT) has been considered the best therapeutic option for end-stage kidney disease (ESKD) [1–5]. One of the most important premises of a

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**Table 1.** Donor eligibility according to different guidelines

Guideline	Year	Acceptable eGFR, mL/min/1.73 m <sup>2</sup>	Age limit	BMI limit	Gender match	Kidney size
British transplantation society [16]	2018	≥49 according to age and gender	No	No (caution if >30 kg/m <sup>2</sup> )	na	na
KDIGO [15]	2017	≥90 (caution between 60 and 89)	No	No (caution if >30 kg/m <sup>2</sup> )	na	na
ERBP [14]	2015	≥80 if older than 50	No	>35 kg/m <sup>2</sup> (caution if ≥30 kg/m <sup>2</sup> )	na	na

eGFR, estimated glomerular filtration rate.

successful transplant is careful selection of the donor: age, kidney function, gender match, and body weight have all been associated with increased rates of graft survival [6–8].

Overall, kidney donation is safe [9–11] although a few studies suggest a small but significant increase in the risk of ESKD among kidney donors [12, 13]. While the risk remains very low, it has been associated with the occurrence of de novo kidney diseases [12] or secondary to obesity, diabetes, and hypertension, all of which have increased in the general population in the last 2 decades [13].

The glomerular filtration rate (GFR) threshold for allowing kidney donation is not univocally defined and ranges in the current guidelines go from 50 to 90 mL/min/1.73 m<sup>2</sup> (Table 1) [14–16]. KDIGO guidelines indicate a GFR of 90 mL/min per 1.73 m<sup>2</sup> or greater as acceptable for donation and suggest, in case of GFR between 60 and 89 mL/min per 1.73 m<sup>2</sup>, that the decision be based on demographic and health profile; a GFR lower than 60 mL/min per 1.73 m<sup>2</sup> is considered a contraindication for donation [15]. However, after the release of the guidelines, some authors advised for caution when evaluating donors with an estimated GFR (eGFR) between 60 and 89 mL/min per 1.73 m<sup>2</sup> [17]. According to the British Transplantation Society guidelines for living kidney donor transplantation, the safe threshold of pre-donation kidney function is one that leaves sufficient function after donation to maintain the donor in normal health (or minimal absolute reduction of health) without affecting lifespan [16]; this threshold is modulated according to age and gender.

The shortage of organs and the decrease in LDKT in some countries are valid reasons to try to expand selection criteria for donors. In 2006, the term “complex living donors” was introduced to define donors that did not fit into the profile suggested by guidelines but that could still be eligible for donation in the absence of clear contraindications [18]. Occasional reports indicate that kidney

donation may be performed without complications with complex living donors, even with eGFR below 45 mL/min [19, 20]. However, most transplant centers consider 80 mL/min/1.73 m<sup>2</sup> as the threshold for donor eligibility, and this choice increased from 67 to 74% between 2005 and 2017 in the USA, while the prevalence of centers accepting as their lower limit 2 standard deviations below the expected-for-age eGFR decreased from 25 to 22% [21]. It has been suggested that donor’s kidney function should be evaluated considering age and expected survival of both donor and recipient, as older donors with mildly reduced kidney function could be a resource to answer the growing demand for kidney transplant in elderly patients [22, 23].

Almost intuitively, a donor with low GFR has been associated with a higher risk of graft loss [24] or reduced graft function at 1 year [25], but a large study in the USA found no differences dichotomizing donor’s eGFR at 80 mL/min [26]. In fact, the long-term effect of donor’s kidney function, in the current accepted ranges on the recipient’s kidney function, is still debated and few studies assessed this issue (Table 2). In this context, we aimed to review the characteristics of living kidney donors at a single referral kidney transplant center with significant LKDT activity, in order to test the effect of donor’s eGFR and to identify other variables that could contribute to modulating selection criteria.

## Methods

### Study Population

We retrospectively evaluated all consecutive adult living kidney transplant donor-recipient pairs that had undergone transplantation between September 1, 2005, and July 30, 2016, at the Centre Hospitalier Universitaire in Grenoble, the third largest LDKT center in France. The immunosuppression protocol at the center consists in thymoglobulin-based induction therapy and maintenance therapy with calcineurin inhibitors (mainly tacrolimus) plus mycophenolate mofetil, in the context of an early steroid withdrawal policy, within 3 months from transplantation. Follow-up data up to 3

**Table 2.** Studies assessing the effect of donor's kidney function on recipient's graft function [24–26, 52–54]

Study	Donor-recipient pairs	Donor's GFR	Method	Correlation between donor's and recipient's kidney function	Notes
Norden et al. [24]	344	Measured	<sup>51</sup> Crom-EDTA	Yes	Donor's mGFR <80 mL/min/1.73 m <sup>2</sup> increase the risk of graft loss
Poggio [52]	119	Measured	<sup>125</sup> I-iothalamate urinary clearance	Yes	Transplanted kidney GFR >55 mL/min/1.73 m <sup>2</sup> associated with better recipient's kidney function at 2 years
Issa [53]	248	Measured	<sup>125</sup> I-iothalamate urinary clearance	Yes	Donor's iGFR >110 mL/min was associated with a better recipient's renal function at 2 years
Chang [54]	83	Estimated	MDRD equation	No	
Young et al. [26]	2,057	Estimated	CKD-EPI equation	No	No differences in graft survival between donor's with eGFR > or <80 mL/min/1.73 m <sup>2</sup>
Godinho et al. [25]	48	Estimated	CKD-EPI equation	Yes	

mGFR, measured glomerular filtration rate; iGFR, glomerular filtration rate measured by <sup>125</sup>I-iothalamate urinary clearance; eGFR, estimated glomerular filtration rate.

years after kidney transplant were assessed on June 30, 2019. Pairs with incomplete data on recipient's kidney function were excluded.

#### Outcome Measures

For donors, we collected demographic data, serum Cr, eGFR calculated according to the CKD-EPI equation [27], bipolar kidney length, as measured by ultrasound and BMI at the time of donation. For recipients, we collected demographic data and serum Cr and eGFR calculated according to the CKD-EPI equation at 3, 12, 24, and 36 months posttransplant with a tolerance of ±1 month at each time point.

#### Statistical Analysis

Statistical analysis was performed using GraphPad Prism software v7.0 (GraphPad Software, La Jolla, CA, USA) and SPSS v23.0 (IBM Corp., Foster city, CA, USA). Parametric data are presented as mean ± standard deviation, while categorical variables are given as percentages or absolute numbers. Quantitative variables were compared using the one- or two-way ANOVA followed by Tukey's multiple comparisons test, while qualitative variables were compared by means of Fisher's exact test. Linear regression was assessed between recipient's eGFR and donor's eGFR, age, BMI, and kidney size at each time point (i.e., 3, 12, 24, and 36 months). Logistic regression was assessed between recipient's eGFR (used as a continuous variable) and gender match (yes or no) and year of transplant (dichotomized at the median which was 2012) at each time point. Noncollinear, statistically, or clinically significant covariates were analyzed by multiple variable regression analysis. Correlation of the explanatory variables was tested by means of the Pearson correlation test and the multivariable regression model and verified using residual analysis (available as online suppl. material; for all online suppl. material, see [www.karger.com/doi/10.1159/000512177](http://www.karger.com/doi/10.1159/000512177)). A  $p < 0.05$  was considered statistically significant.

## Results

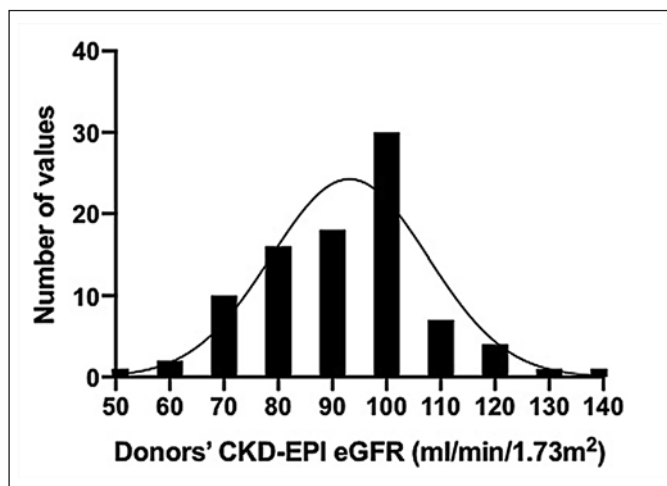
### Baseline Data

From September 1, 2005, to June 30, 2016, 136 living donor kidney transplantations were performed in the study center. Kidney function data at baseline (donor and recipient) and recipient data at all intervals were available in 90 cases. The mean age at transplantation was  $51.47 \pm 10.95$  for donors and  $43.04 \pm 13.52$  for recipients. Of the 58 recipients, 26 were men. Donors' mean CKD-EPI eGFR was  $91.99 \pm 15.37$  mL/min/1.73 m<sup>2</sup> (Table 3; Fig. 1).

### Descriptive Analysis

The 90 donor-recipient pairs were divided into tertiles according to donor's eGFR: (i) <85.33 mL/min/1.73 m<sup>2</sup>, (ii) between 85.33 and 98.30 mL/min/1.73 m<sup>2</sup>, and (iii) >98.30 mL/min/1.73 m<sup>2</sup> (Table 4). All subjects were Caucasians except 1 donor-recipient couple in the third tertile that was of African descent. For 6 recipients, this was the second kidney transplant (1 in the first, 2 in the second, and 3 in the third tertile).

One patient in the first tertile experienced an acute cellular rejection at month 12, 2 patients in the second tertile experienced a relapse of baseline disease (sarcoidosis and focal segmental glomerulosclerosis), and 1 patient in the third tertile had a relapse of baseline disease (focal segmental glomerulosclerosis). No donor or recipient died or required dialysis during the period studied. Overall,



**Fig. 1.** Donors' eGFR distribution in our cohort. eGFR, estimated glomerular filtration rate.

**Table 3.** Baseline characteristics of donors and recipients

	Donors, <i>n</i> = 90	Recipients, <i>n</i> = 90
Age at transplant, years	51.47±10.95	43.04±13.52
Gender (male), <i>n</i> (%)	26 (28.9)	58 (64.4)
CKD-EPI eGFR, mL/min/1.73 m <sup>2</sup>	91.99±15.37	na
Kidney size, mm	108.89±10.33	na
BMI, kg/m <sup>2</sup>	24.28±3.57	na

eGFR, estimated glomerular filtration rate.

recipients in the third tertile had better renal function during the entire follow-up compared to patients in the first tertile ( $p < 0.05$ ) (Fig. 2).

#### Univariate Regression Analysis

Donor's kidney function positively correlated with graft function at 3, 12, and 24 months ( $p = 0.001, 0.03,$  and  $0.016,$  respectively) but not at 36 months (Table 5). Donor's age and donor's kidney function were significantly and inversely correlated ( $p < 0.0001, r^2 0.323$ ).

Moreover, donor's age showed an inverse correlation with recipient's kidney function at all time points (Table 5). Figure 3 shows recipient's kidney function dichotomized according to median age of donors. Donor's kidney size showed a direct correlation with recipient's graft function, reaching statistical significance at 12 and 24 months ( $p = 0.034$  and  $0.014,$  respectively) (Table 5). Do-

nor's BMI, donor-recipient gender match, and the year of transplant were not significantly correlated with recipient's kidney function (Table 5).

#### Multiple Variable Linear Regression Analysis

Since donor's eGFR and donor's age displayed collinearity, we tested them separately in 2 multivariate models: model 1 – donor's eGFR, BMI, and kidney size and model 2 – donor's age, BMI, and kidney size. BMI was included in the model due to its clinical relevance [28].

No collinearity was detected between donor's BMI, eGFR, and kidney size. Donor's eGFR was significantly associated with recipient's eGFR up to month 24 of follow-up (Table 6). Donor's age was independently associated with recipient's kidney function at each time point (Table 7). Donor's BMI was significantly correlated with graft function up to 24 months in the second multiple variable regression model (Table 7).

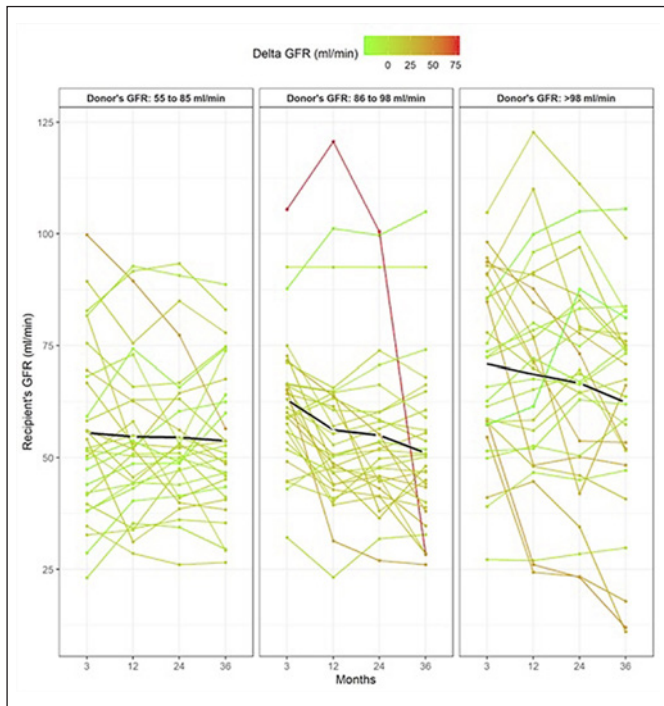
A third model was subsequently designed to adjust for the effect of donor's age and eGFR together. In this model, donor's BMI was significantly correlated with graft function for up to 24 months (Table 8). The appropriateness of each model was verified using residual analysis (available as see online suppl. material).

## Discussion

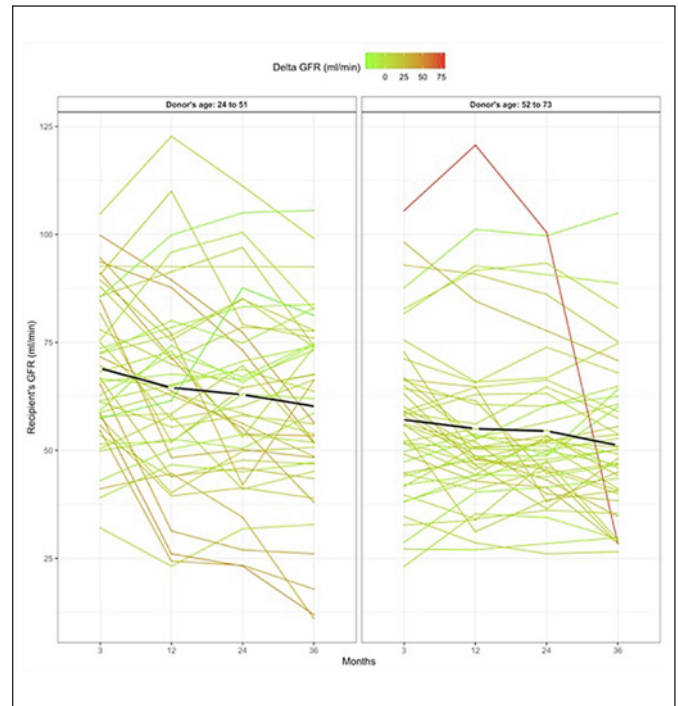
Living kidney graft, whose results depend upon a careful selection of donor and recipient, has proved to be an optimal treatment option for ESKD [29]. Different guidelines suggest different eGFR thresholds for donation, and it is still not known whether mildly reduced renal function affects graft function (Table 2). The aim of our study was to gather information that could contribute to answering this question. For this purpose, we decided to study 90 donor-recipient pairs with complete data on recipients over their 3-year post-transplant follow-up period. As expected, higher donor eGFR was generally associated with better eGFR in the recipient.

However, this is the main finding of the study, the effect on donor's kidney function progressively decreased during time and significance was lost at 36 months post-transplant. Conversely, relationship with donor's age is significant at all time points. Since age and eGFR show a strong inverse correlation, this suggests that donor's age is a leading element in determining the effect on recipient's eGFR. Of note, however, is the fact that the slope of the eGFR curve in recipients is similar, even when the





Color version available online



Color version available online

**Fig. 2.** Individual recipients' eGFR evolution during follow-up according to tertile of donor's kidney function. Black lines represent the recipient's average eGFR trend inside the tertile group during follow-up ( $p < 0.05$  tertile III vs. I). eGFR, estimated glomerular filtration rate.

**Fig. 3.** Individual recipients' eGFR evolution during follow-up according to median donor's age. Black lines represent the recipients' average eGFR trend inside the group during follow-up. eGFR, estimated glomerular filtration rate.

**Table 4.** Recipients' baseline characteristics divided into tertiles according to donor's renal function

	I tertile ( $n = 30$ )	II tertile ( $n = 30$ )	III tertile ( $n = 30$ )	$p$ value
Donor age at transplant, years	58.10±8.04	53.50±8.95	42.80±9.30	<0.001 I versus III and II versus III
Recipient age at transplant, years	44.20±14.82	44.87±12.20	40.07±13.36	ns
Donor gender (male)	5	10	11	ns
Recipient gender (male)	18	18	22	ns
Donor-recipient age difference, years	13.90±14.98	8.63±13.90	2.73±10.10	<0.01 I versus III
Donor-recipient gender match (f > m)	16	16	16	–
Donor-recipient gender match (f > f)	9	4	3	–
Donor-recipient gender match (m > f)	3	8	5	–
Donor-recipient gender match (m > m)	2	2	6	–
Donor CKD-EPI eGFR, mL/min/1.73 m <sup>2</sup>	74.95±8.04	93.44±3.73	107.58±11.36	<0.001
Donor kidney size, mm	107.50±11.45	109.14±7.64	110.12±11.36	ns
Donor BMI	24.38±3.58	24.11±3.44	24.36±3.79	ns
Year of transplant ≤2012	16	20	15	–

eGFR, estimated glomerular filtration rate.

**Table 5.** Univariate regression analysis between different donor characteristics and recipients' kidney function over follow-up

	<i>B</i>	CI 95%		Odds ratio	CI 95%		<i>p</i> value
		lower	higher		lower	higher	
<i>Donor's eGFR</i>							
3 months	0.419	0.176	0.662	1.520	1.192	1.939	<b>0.001</b>
12 months	0.426	0.147	0.705	1.531	1.158	2.024	<b>0.003</b>
24 months	0.331	0.064	0.597	1.392	1.066	1.817	<b>0.016</b>
36 months	0.250	-0.017	0.517	1.284	0.983	1.677	0.066
<i>Donor's age</i>							
3 months	-0.254	-0.365	-0.143	0.776	0.694	0.867	<b>&lt;0.001</b>
12 months	-0.208	-0.307	-0.108	0.812	0.736	0.898	<b>&lt;0.001</b>
24 months	-0.22	-0.327	-0.114	0.803	0.721	0.892	<b>&lt;0.001</b>
36 months	-0.214	-0.322	-0.105	0.807	0.725	0.9	<b>&lt;0.001</b>
<i>Kidney size</i>							
3 months	0.102	-0.021	0.225	1.107	0.979	1.252	0.102
12 months	0.119	0.009	0.229	1.126	1.009	1.257	<b>0.034</b>
24 months	0.145	0.03	0.26	1.156	1.03	1.297	<b>0.014</b>
36 months	0.071	-0.056	0.198	1.074	0.946	1.219	0.271
<i>Donor's BMI</i>							
3 months	0.025	-0.014	0.065	1.025	0.986	1.067	0.208
12 months	0.033	-0.002	0.068	1.034	0.998	1.07	0.063
24 months	0.034	-0.003	0.071	1.035	0.997	1.074	0.074
36 months	0.022	-0.017	0.06	1.022	0.983	1.062	0.264
<i>Gender match</i>							
3 months	-0.015	-0.017	0.004	0.986	0.962	1.01	0.247
12 months	-0.019	-0.018	0.001	0.981	0.96	1.002	0.082
24 months	-0.01	-0.014	0.005	0.99	0.968	1.012	0.373
36 months	-0.018	-0.018	0.003	0.982	0.959	1.006	0.136
<i>Year of transplant</i>							
3 months	-0.009	-0.014	0.006	0.991	0.969	1.014	0.431
12 months	0.000	-0.008	0.009	1.000	0.981	1.020	0.999
24 months	0.004	-0.007	0.011	1.004	0.983	1.026	0.702
36 months	0.010	-0.005	0.014	1.010	0.989	1.032	0.354

eGFR, estimated glomerular filtration rate. Values in bold are statistically significant.

starting point is different, when dichotomizing for donor's age at the median of 51 years (Fig. 3). Likewise, recipients of kidneys from donors in the lowest eGFR tertile do not display a steeper decrease in eGFR compared to those grafted from a donor in a higher tertile. Our data are in keeping with the observations of Young and colleagues [26] who did not find differences in graft function in recipients from donors with an eGFR lower or >80 mL/min/1.73 m<sup>2</sup>.

Aging is associated with loss of kidney function, and thus, age and glomerular filtration rate are closely related [30, 31]. There is no general agreement on whether the

definition of CKD should be changed to account for the changes observed in the elderly [32–34]. Nevertheless, elderly people have a reduced functional reserve even when GFR has been preserved [35]. Guidelines do not set an upper limit for donor age [15], but some do recommend caution when potential donors are older than 50 [14] or 60 [16]. Clinical studies have yielded conflicting results: Pena De La Vega and colleagues [36] found no difference in transplant outcomes between donors older or younger than 50, while Veroux and colleagues [6] observed that donor's age had a significant impact on graft outcomes, independently of recipient's age.

**Table 6.** Multiple regression analysis: model 1

Model 1	B	CI 95%		Odds ratio	CI 95%		p value
		lower	higher		lower	higher	
<i>3 months</i>							
Donor's eGFR	0.501	0.205	0.797	1.650	1.228	2.219	<b>0.001</b>
BMI	1.125	-0.089	2.338	3.080	0.915	10.360	0.069
Kidney size	0.226	-0.192	0.644	1.254	0.825	1.904	0.285
<i>12 months</i>							
Donor's eGFR	0.543	0.223	0.863	1.721	1.250	2.370	<b>0.001</b>
BMI	1.363	0.051	2.675	3.908	1.052	14.512	<b>0.042</b>
Kidney size	0.365	-0.087	0.817	1.441	0.917	2.264	0.112
<i>24 months</i>							
Donor's eGFR	0.420	0.110	0.730	1.522	1.116	2.075	<b>0.009</b>
BMI	1.036	-0.235	2.306	2.818	0.791	10.034	0.108
Kidney size	0.464	0.026	0.901	1.590	1.026	2.462	<b>0.038</b>
<i>36 months</i>							
Donor's eGFR	0.290	-0.021	0.602	1.336	0.979	1.826	0.067
BMI	0.644	-0.631	1.920	1.904	0.532	6.821	0.317
Kidney size	0.148	-0.292	0.587	1.160	0.747	1.799	0.504

Donor's eGFR, donor's BMI, and kidney size were tested as independent variables to assess their effect on recipient's eGFR at different time points (dependent variable). Values in bold are statistically significant. eGFR, estimated glomerular filtration rate.

**Table 7.** Multiple regression analysis: model 2

Model 2	B	CI 95%		Odds ratio	CI 95%		p values
		lower	higher		lower	higher	
<i>3 months</i>							
Donor's age	-0.813	-1.165	-0.462	0.444	0.312	0.630	<b>&lt;0.001</b>
BMI	1.483	0.325	2.641	4.406	1.384	14.027	<b>0.013</b>
Kidney size	0.157	-0.240	0.553	1.170	0.787	1.738	0.434
<i>12 months</i>							
Donor's age	-0.869	-1.251	-0.487	0.419	0.286	0.614	<b>&lt;0.001</b>
BMI	1.745	0.488	3.002	5.726	1.629	20.126	<b>0.007</b>
Kidney size	0.293	-0.138	0.724	1.340	0.871	2.063	0.179
<i>24 months</i>							
Donor's age	-0.856	-1.210	-0.501	0.425	0.298	0.606	<b>&lt;0.001</b>
BMI	1.428	0.260	2.595	4.170	1.297	13.397	<b>0.017</b>
Kidney size	0.367	-0.033	0.767	1.443	0.968	2.153	0.072
<i>36 months</i>							
Donor's age	-0.771	-1.127	-0.415	0.463	0.324	0.660	<b>&lt;0.001</b>
BMI	1.010	-0.161	2.181	2.746	0.851	8.855	0.090
Kidney size	0.041	-0.360	0.442	1.042	0.698	1.556	0.839

Donor's age, donor's BMI, and kidney size were tested as independent variables to assess their effect on recipient's eGFR at different time points (dependent variable). Values in bold are statistically significant. eGFR, estimated glomerular filtration rate.

**Table 8.** Multiple regression analysis: model 3

Model 3	B	CI 95%		Odds ratio	CI 95%		p value
		lower	higher		lower	higher	
<i>3 months</i>							
BMI	1.318	0.151	2.486	3.738	1.163	12.010	<b>0.028</b>
Kidney size	0.168	-0.228	0.564	1.183	0.796	1.757	0.401
Donor's eGFR	-0.652	-1.897	0.592	0.521	0.150	1.808	0.299
Age	-2.198	-4.440	0.043	0.111	0.012	1.044	0.054
Donor's eGFR × age	0.016	-0.007	0.040	1.017	0.993	1.041	0.173
<i>12 months</i>							
BMI	1.714	0.429	2.998	5.549	1.536	20.044	<b>0.010</b>
Kidney size	0.279	-0.157	0.715	1.322	0.855	2.044	0.205
Donor's eGFR	0.336	-1.033	1.705	1.399	0.356	5.504	0.626
Age	-0.461	-2.927	2.005	0.631	0.054	7.429	0.710
Donor's eGFR × age	-0.003	-0.029	0.023	0.997	0.972	1.024	0.832
<i>24 months</i>							
BMI	1.419	0.217	2.622	4.135	1.242	13.764	<b>0.021</b>
Kidney size	0.368	-0.040	0.775	1.444	0.960	2.171	0.077
Donor's eGFR	-0.029	-1.311	1.254	0.972	0.270	3.503	0.965
Age	-0.919	-3.228	1.390	0.399	0.040	4.015	0.430
Donor's eGFR × age	0.001	-0.024	0.025	1.001	0.977	1.026	0.950
<i>36 months</i>							
BMI	1.019	-0.182	2.220	2.771	0.834	9.210	0.095
Kidney size	0.052	-0.355	0.460	1.054	0.701	1.584	0.798
Donor's eGFR	-0.308	-1.588	0.973	0.735	0.204	2.646	0.633
Age	-1.197	-3.503	1.109	0.302	0.030	3.033	0.304
Donor's eGFR × age	0.004	-0.021	0.028	1.004	0.979	1.028	0.775

Donor's BMI and kidney size were tested as independent variables to assess their effect on recipient's eGFR at different time points (dependent variable), adjusted for donor's eGFR and age. Values in bold are statistically significant. eGFR, estimated glomerular filtration rate.

A recent survey describing the attitude of US transplant centers toward living kidney donor candidates showed that, starting in 2005, less strict criteria on age were applied. Between 2005 and 2017, the proportion of centers with no defined upper age limit for donation increased from 59 to 68%. Of the centers which still applied an absolute upper age limit, the most common threshold was set at 70 years, as opposed to 65 in 2005 [21]. A similar trend in accepting older donors has been seen in France [37].

Obesity is a growing concern in the Western world, and the number of obese kidney donors is likely to increase in the future [38–40]. Once more, the literature is discordant: some studies have shown good perioperative outcomes for obese donors [41] and their kidney recipients [42], while others found that donor obesity is a risk factor for graft outcomes [28]. Our data are in keeping

with this observation possibly because of the relatively small and homogeneous sample involved in the study and showed that the effect of kidney size or donor's BMI was negligible. The association between recipient's kidney function and BMI was only significant up to 24 months in the model considering donor's age, as well as in the model that combined the effect of donor's age and eGFR. This pattern highlights the need for larger prospective studies capable of further exploring these variables. Of note, however, is the fact that in our study average BMI of the donors was 24.28 kg/m<sup>2</sup> and only 6 donors had a BMI >30 kg/m<sup>2</sup>, previously identified as a risk threshold [28]; thus, our results should be interpreted with caution.

Likewise, previous studies found an association with donor's kidney size at ultrasounds or kidney volume at the CT scan or at the time of surgery and recipient's renal



function [43–47]. Our data do not support a close correlation between donor’s kidney size and recipient’s kidney function, possibly because of the use of a less sensitive technique [48].

Gender match is an important factor in LDKT, especially because there is a disproportion between female and male donors [49]: our study did not support the controversial topic of a role of gender matching independently of other factors [8, 50, 51]. Our study suffers from several limitations. First of all, it is monocentric and complete data were not available for all donor-recipient pairs; furthermore, we did not adjust for immunosuppressive therapy; finally, due to the size of our cohort, we preferred to perform a regression model at each time point rather than fitting regression models for repeated measurements. These limitations may be partially offset by the homogeneity of the treatment and surgical policies followed at the transplant center and by the low incidence of acute rejection (1/90 cases) and primary disease recurrence (3/90 cases). Furthermore, we relied on available eGFR in the absence of more sophisticated data at all intervals. However, our study is addressed to a clinical audience, and the use of eGFR is the common practice of most transplant centers [21] and is in agreement with international guidelines [15]. Finally, the retrospective nature of this study does not allow for a cause-effect analysis of the parameters investigated.

## Conclusions

Our study suggests the presence of a minor, albeit significant effect of donor’s kidney function at time of transplantation on recipient’s renal function during a 3-year follow-up period. However, this modest effect is compatible with a stable graft eGFR over follow-up even for recipients from donors with suboptimal renal function.

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Nevertheless, when considering several donor characteristics, age seems to be a stronger predictor of future graft function than eGFR. We suggest that eGFR should be clinically balanced with other clinical and demographic determinants of kidney function, in particular age.

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## Statement of Ethics

The results presented in this paper have not been published previously in whole or part, except in abstract format. Written consent was obtained from each patient. Medical data were collected from the database at Université Grenoble Alpes (CNIL [French national committee for data protection] approval number 1987785v0).

## Conflict of Interest Statement

No author has a conflict of interest.

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## Author Contributions

Research idea and study design: M.T., C.E., G.B.P., and P.M.; data acquisition: E.M. and T.J.; data analysis/interpretation: M.T., C.E., L.R., G.B.P., and P.M.; bibliographic search: M.C., E.P., V.E., and G.S.; statistical analysis: M.T., A.C., and G.B.P.; drafting: M.T., G.B.P., and P.M.; and final version: all authors.

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