Research paper

US deceased kidney transplantation: Estimated GFR, donor age and KDPI association with graft survival

Timothy L. Pruett, Gabriel R. Vecce, Robert J. Carrico, David K. Klassen

Abstract

Background: Despite a significant shortage of kidneys for transplantation in the US, kidneys from older deceased donors are infrequently transplanted. This is primarily over concern of graft quality and transplant durability.

Methods: The US national transplant database (2000–2018) was assessed for deceased donor kidney transplant patient and graft survival, graft durability and stratified by donor age (< 65 years), Kidney Donor Profile Index (KDPI) and estimated glomerual filtration rate (GFR) one year post-transplantation (eGFR-1) were calculated.

Findings: Recipients of kidneys transplanted from deceased donors > 65 years had a lower eGFR-1, (median 39 ml/min) than recipients of younger donor kidneys (median 54 ml/min). However, death-censored graft survival, stratified by eGFR-1, demonstrated similar survival, irrespective of donor age or KDPI. The durability of kidney survival decreases as the achieved eGFR-1 declines. KDPI has a poor association with eGFR-1 and lesser for graft durability. While recipients of kidneys > 65 years had a higher one year mortality than younger kidney recipients, recipients of kidneys > 65 years and an eGFR-1 < 30 ml/min, had a lower survival than an untransplanted waitlist cohort (p < 0.001).

Interpretation: The durability of graft survival after transplantation was associated with the amount of kidney function gained through the transplant (eGFR-1) and the rate of graft loss (return to dialysis) was not significantly associated with donor age. 24.9% of recipients of older donor kidneys failed to achieve sufficient eGFR-1 providing a transplant survival benefit. While there is significant benefit from transplanting older kidneys, better decision-making tools are required to avoid transplanting kidneys that provide insufficient renal function.

Funding: None.

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1. Introduction

Kidney transplantation is the optimal treatment for many people with renal failure. In 2019, the greatest number of deceased organ donations were performed in the US (11,870) resulting in 16,534 deceased kidney transplants [1]. However, when juxtaposed against the 500,000 people requiring dialysis [2] and 93,000 on the national kidney transplant waitlist [1], the need for kidneys is striking. The HRSA sponsored, Deceased Donor Potential study suggested that 38,000 deceased donors was feasible, but an expanded use of older donors would be required [3]. While older donor kidneys are frequently transplanted in Europe [4,5], it is less frequent in the US. The US transplant and recipient community has concern about the quality and durability of kidneys from older donors, in part due to the known decline of glomerular filtration and kidney damage with increasing age [6–9]. Presently, over 50% of kidneys retrieved from donors over 65 years are not transplanted [1]. In 2019, only 646 of 11,152 US deceased kidney donors were > 65 years (5.8%) and fewer than half of the kidneys (298) were transplanted.

Kidney transplantation intends to provide durable relief from dialysis. From a multinational, > 13,000 transplant study, the amount of renal function (estimated glomerular filtration rate at a year post-
Research in Context

Evidence before this study

Despite is a global shortage of kidneys for transplantation, the use of older deceased donor kidneys is heterogeneous. European countries frequently transplant kidneys from deceased donors over 60–65 years of age (NHS, Eurotransplant, CNT and OPTN annual reports), whereas the US has a much lower use (OPTN annual report). This is predominantly thought to be due to uncertain kidney quality and durability of graft function.

Added value of this study

Analysis of the US donor and transplant database demonstrated that the durability of kidney transplants from deceased donors > 65 years was similar to younger donor kidneys when stratified by estimated glomerular filtration rate after one year (eGFR-1) and that durability decreases as eGFR-1 decreases. Importantly, the recipient survival benefit was lost when the older kidney failed to supply an eGFR-1 > 30 ml/min.

Implications of all the available evidence

A kidney transplant should provide sufficient function to provide the recipient a survival benefit. This analysis suggests an eGFR-1 > 30 ml/min is required (in the US), but global applicability needs to be assessed. The loss of GFR with age is known to occur and its impact upon transplanting older kidneys is substantial for risk assessment.

transplantation, eGFR-1 was associated with 10-year kidney survival [10]. Lesser eGFR-1 had increasing rates of graft failure, but did not specifically address the impact of deceased donor age upon graft survival. Do older kidneys fail quicker? This analysis focuses upon deceased donor age, estimated graft function after one year and long-term graft failure.

2. Methods

2.1. Data and construction of cohorts

This study used the Organ Procurement and Transplantation Network (OPTN) database that includes information on donors, waitlisted candidates, and transplant recipients in the U.S., and has been described elsewhere [1]. The Health Resources and Services Administration (HRSA), U.S. Department of Health and Human Services provides oversight to the activities of the OPTN contractor. IRB exemption was obtained from the US Department of Health and Human Services Health Resources and Services Administration (HRSA) under the Public Benefit and Service program exemption of the Common Rule. The de-identified database was queried for the outcomes of adult deceased donor kidney transplants in first kidney-alone transplants occurring between 01/01/2000 and 12/31/2018 (Table 1). 139,363 kidney transplants met this criteria; a small number were excluded (N = 1006, 0.7%) for one or more missing data elements. Kidney graft failure is recorded when the recipient either returned to dialysis, the graft was removed or at recipient death. As the study intent is the assessment of age upon graft durability, recipients with grafts surviving one year had the eGFR calculated using the CKD_EPI equation [11]. The current assessment of kidney quality, the Kidney Donor Risk Index [12] was calculated, with a subsequent conversion to KDPI (Kidney Donor Profile Index, with higher percentiles predicting worse function). The eGFR-1 calculation was made from the closest data point, within a 90 day window, of the actual "one year transplant anniversary". 20,561 records (14.8%) did not have a creatinine measurement within 90 days of the "one-year transplant anniversary", but within this group were 97% of one-year graft failures. While eGFR-1 after transplant is a continuous outcome; for outcome comparisons, the eGFR-1 were categorized by the 2012 KDIGO Chronic Kidney Disease criteria [13]: eGFR-1 > 45 ml/min (CKD 3a), eGFR-1 30–44 ml/min (CKD 3b) and eGFR-1 < 30 ml/min (CKD 4/5). An eGFR-1 >60 ml/min (CKD 2 and CKD 1) from older donor kidneys were few and are included in the > 45 ml/min group.

To assess transplant survival benefit of recipients with a kidney from a deceased donor >65 years, patients with a functioning kidney at one year were compared to the survival of a matched cohort of waitlisted, but not transplanted candidates. This used propensity-matching procedures developed by Ho et al. [14] including candidate sex, age, race, diagnosis, CPRA, BMI, height, and ESRD time of the kidney recipients and waitlist candidates (details in Supplement).

2.2. Statistical analysis

Outcomes of deceased donor (>65 years) kidney recipients with a functioning graft at one year were stratified by demographics and grouped by the recipients’ eGFR-1. Kruskal-Wallis (for continuous data elements) and Chi-Squared tests (for categorical data elements) were used to determine significance of differences between transplant groups. 5 and 10 year Kaplan-Meier (95% confidence intervals) graft survival, with and without death censoring, was performed: using donor age (18–64 and 65+), donor KDPI (0–85, 86+), and eGFR-1 (>30, 31–44 and >45 ml/min). As death and graft loss during the first year precluded the eGFR-1 calculation, a separate analysis of recipients with first-year graft failure was performed. A logistic regression model was used to assess donor/recipient variables associated with eGFR-1 greater or less than 45 ml/min. Multiple imputation—using 37 separate imputations to predict missing values (common among earlier transplants)—was necessary as OPTN data elements and collection policies changed over time (details in Supplement). Continuous predictors were parametrized using restricted cubic splines each, having three knots at the 10th, 50th (i.e., the median) and 90th percentiles of the respective data. Starting from a “full model” involving all of the imputed modelling data elements, a backwards variable selection procedure was used to remove predictors from the model until the Akaike Information Criteria (AIC) could not be further reduced. All analyses were performed using the R statistical software and associated packages [15,16].

2.3. Role of funding source

There was no funding source for this study. GV had access to the full dataset and all the authors decided to submit the manuscript for publication.

3. Results

3.1. Demographics of donors and recipients of kidneys from deceased donors greater or less than 65 years

Deceased donors over the age of 65 had a median KDPI of 92% (86%–96%; KDRI 1.90–2.36) compared to 41% (19%–63%; KDRI 0.94–1.45) for those under 65 years (Table 2). Donors >65 were more likely to be female, with fewer donations after circulatory death (DCD). Allocation policy intends to match organ potential with recipient need, so recipients of older kidneys were expected to differ from recipients of younger kidneys. The recipients of kidneys >65 years were older, median age of 65 (vs 54) years and had a higher prevalence of diabetes as the cause for ESRD. There was a higher use of dual kidney transplants with donors >65.
3.2. Spectrum of deceased kidney transplant function stratified by donor age, KDPI and eGFR-1

Deceased kidney recipients demonstrated the expected decline in eGFR-1, as donor age increased (Fig. 1). The median recipient eGFR-1 after <45 year donor kidney transplant was 60 ml/min with 80% of recipients obtaining at least CKD 3a (eGFR-1 >45 ml/min) and 95% of recipients better than CKD 3b (>30 ml/min). Kidney recipients from donors 46–64 years had a median eGFR-1 of 46 ml/min with 55% of obtaining at least CKD 3a and an additional 31.5% CKD 3b. However, recipients of kidneys from deceased donors >65 years had a median eGFR-1 of only 39 ml/min, with 35.6% of recipients gaining CKD 3a, 39.4% CKD 3b and 24.9% CKD 4 or 5 (>45, 30–44 and <30 ml/min, respectively). There were minimal KDPI/KDPI clinical differences between the three eGFR-1 ranges for recipients of >65 year kidneys (Table 3). The KDPI was 92% for recipients with one year eGFR-1 >45 ml/min (CKD3a), 93% for 30–44 ml/min (CKD 3b) and 94% for <30 ml/min (CKD 4/5). Recipients with the lower eGFR-1 (< 30 ml/min); trended towards being female and more frequently black.

Asians and Hispanics were more common with the higher eGFR-1. Diabetes-related ESRD and a longer duration of dialysis was more common in the higher eGFR groups. While statistically significant as categorical features, there were few clinical distinctions between these groups.

As recipient comorbidities affect patient survival, death censoring was used to discern the impact of eGFR-1 upon the duration of graft survival. Death-censored 5 and 10-year graft survival (95% CI) for recipients of >65 year donor kidneys (KDPI 92%) and an eGFR-1 >45 ml/min was 94% (92.2%–94.9%) and 77% (73.4%–80.4%). This was nearly identical to the 5 and 10-year survival (93% [93.2%–93.6%] and 80% [79.9%–80.8%]) observed in recipients of younger kidneys (KDPI 41%) (Fig. 2a). These outcomes are striking as the older donor group includes the younger kidneys (KDPI 41%) (Fig. 2a).

### Table 1
Data from the OPTN database: criteria and exclusions.

| Cohort | Inclusion Criteria | Number of Records |
|--------|-------------------|-------------------|
| All kidney transplants during 2000–2018 | Adult deceased donor (18+ y.o.) | 298,394 |
| Initial Cohort | Kidney-alone transplant | 134,104 |
| Reduced Cohort | No previous transplant | 139,363 |
| Reduced Cohort with eGFR-1 | Donated within 90 days of 1-year post transplant | 118,802 |
| Reduced Cohort with eGFR-1 and Received Elderly-Donor Kidney | Donor age 65+ | 4015 |
| Final Cohort | Must not have experienced graft failure or death within 1 year post transplant | 4545 |

* Among 19,556 patients excluded for not having a 1-year eGFR (+/- 90 days), nearly half (9248, 47.3%) could not contribute a measured eGFR because the patient experienced death or graft failure during the first year. An additional 1348 patients did not die or experience graft loss, but were otherwise lost to follow-up before they could contribute a measured creatinine within the 90-day period. The remaining 8960 had creatinine measurements taken at times that were too distant from the 1-year anniversary to be included in the study (e.g., 7127 measurements recorded at the 1-year follow-up visit were measured during the first 9 months after transplant).

### Table 2
Demographic comparison of adult, deceased-donor, kidney-only, first transplants occurring between 01/01/2000 and 12/31/2018 by donor age >65 years.

| N (Transplants) | Donor Age 0–64 | Donor Age >65 | p-value |
|-----------------|----------------|---------------|---------|
| Donor KDPI (median, IQR) | 133,502 | 5881 | – |
| Donor KDPI (median, IQR) | 41% (19% – 63%) | 92% (86% – 96%) | < 0.0001 |
| Donor KDPI (median, IQR) | 1.17 (0.94 – 1.45) | 2.11 (1.90 – 2.36) | < 0.0001 |
| Donor Sex: Female | 53,023 (39.7%) | 3104 (53.0%) | < 0.0001 |
| Donor Creatinine (mg/dL; median, IQR) | 1.00 (0.70 – 1.30) | 0.90 (0.70 – 1.20) | < 0.0001 |
| Donor Type: DCD | 18,260 (11.7%) | 142 (2.4%) | < 0.0001 |
| Donor Cigarette Use: Yes | 39,059 (29.3%) | 1796 (30.6%) | 0.023 |
| Share Type: Local Donor | 100,320 (75.1%) | 4122 (70.3%) | < 0.0001 |
| Candidate Race: Black | 44,298 (33.2%) | 1779 (30.4%) | < 0.0001 |
| Candidate Race: Hispanic | 21,238 (15.9%) | 770 (13.1%) | < 0.0001 |
| Candidate Race: Asian | 8060 (6.0%) | 446 (7.6%) | 0.0040 |
| Candidate Race: Hispanic | 3076 (2.3%) | 107 (1.8%) | < 0.0001 |
| Candidate Race: Hispanic | 56,829 (42.6%) | 2759 (47.1%) | 0.0011 |
| Candidate Race: Hispanic | 43,005 (31.8%) | 1179 (20.4%) | 0.0001 |
| Candidate Race: Hispanic | 21,238 (15.9%) | 770 (13.1%) | < 0.0001 |
| Candidate Race: Hispanic | 8060 (6.0%) | 446 (7.6%) | 0.0040 |
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| Candidate Race: Hispanic | 3076 (2.3%) | 107 (1.8%) | < 0.0001 |
respectively. For recipients with eGFR-1 <30 ml/min (CKD 4/5), the 5 and 10 year death-censored kidney function was lower, 62% (59.3% - 65.8%) and 36% (31.5% - 40.3%), from >65 year kidneys, but still similar to younger kidneys. The donor KDPI had a poor correlation with 5 and 10-year graft survival contrasted to eGFR-1 (Fig. 3), only kidneys with a KDPI >95% had statistically significant lower graft survival.

3.3. Long-term graft survival, including patient death

The median recipient age of >65 year deceased kidneys was 65 (IQR = 58 – 70) years, over a decade older than the median age (54 years, IQR = 43 – 62) of recipients of younger grafts. It is expected that older recipients would die more frequently than younger recipients. When recipient death is included as a cause of graft loss, the graft survival was lower in the recipients of kidneys >65 years. Graft survival that includes recipient death with deceased donors aged less or greater than 65 years was; 86% (85.6% - 86.1%) vs 78% (75.3% - 79.7%), 76% (75.6% - 76.8%) vs 74% (71.6% - 76.0%) and 51 (50.4% - 52.5%) vs 48% (45.3% - 51.5%); if the eGFR-1 was >45, 30 – 44 or <30 ml/min. (Fig. 2b).

3.4. One year patient and graft survival

eGFR-1 calculations can only be made when the patient and graft survive for a year. Younger recipients (< 65 years, median age 54

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**Table 3**

Demographics of > 65 year Deceased Donor kidney transplants surviving one year and stratified by eGFR-1.

| Recipient eGFR-1 | p-value | Number | 31 - 44 ml/min | > 45 ml/min |
|------------------|---------|--------|----------------|------------|
| <30 ml/min       |         | 1133   | 1792           | 1620       |
| Donor KDPI (median, IQR) | 94% (88% - 97%) | 93% (87% - 96%) | 92% (86% - 96%) | < 0.0001 |
| Donor KDRI (median, IQR) | 2.16 (1.93 - 2.43) | 2.11 (1.90 - 2.33) | 2.07 (1.86 - 2.30) | < 0.0001 |
| Donor Sex: Female | 598 (52.8%) | 977 (54.5%) | 842 (52.0%) | 0.26 |
| Donor Creatinine (mg/dL; median, IQR) | 1.00 (0.80 - 1.29) | 0.90 (0.70 - 1.20) | 0.90 (0.70 - 1.20) | < 0.0001 |
| Donor Type: DCD | 42 (3.7%) | 39 (2.2%) | 25 (1.5%) | 0.0020 |
| Donor Cigarette Use: >20 Pack-Years | 42 (3.7%) | 39 (2.2%) | 25 (1.5%) | 0.063 |
| Share Type: Local Donor | 801 (70.7%) | 1274 (71.1%) | 1138 (70.2%) | 0.87 |
| Candidate Sex: Female | 487 (43.0%) | 686 (49.4%) | 572 (35.3%) | < 0.0001 |
| Candidate Race: White | 486 (42.9%) | 885 (40.4%) | 755 (46.6%) | < 0.0001 |
| Candidate Race: Hispanic | 90 (7.9%) | 223 (12.4%) | 298 (18.4%) | |
| Candidate Race: Asian | 53 (4.7%) | 123 (6.9%) | 177 (10.9%) | |
| Candidate DX at Listing: Diabetes | 377 (33.3%) | 653 (36.4%) | 637 (39.3%) | 0.024 |
| Candidate DX at Listing: Glomerular Diseases | 138 (12.2%) | 236 (13.2%) | 194 (12.0%) | |
| Candidate DX at Listing: Hypertensive Nephrosclerosis | 363 (32.0%) | 478 (26.7%) | 427 (26.4%) | |
| Candidate DX at Listing: Polycystic Kidneys | 94 (8.3%) | 140 (7.6%) | 123 (7.6%) | |
| Candidate PVD: Yes | 72 (6.4%) | 123 (6.9%) | 123 (7.6%) | 0.49 |
| Delayed Graft Function: Yes | 400 (35.1%) | 454 (25.3%) | 304 (18.8%) | < 0.0001 |
| Candidate Total Serum Albumin at Listing (g/dL; median, IQR) | 3.9 (3.6 - 4.3) | 4.0 (3.7 - 4.3) | 4.0 (3.6 - 4.3) | 0.21 |
| Candidate ESRD Time (days; median, IQR) | 744 (383 - 1268) | 791 (356 - 1355) | 825 (418 - 1361) | 0.0080 |
| Transplant Type: Dual/En-Bloc | 99 (8.7%) | 183 (10.2%) | 349 (21.5%) | < 0.0001 |
| Cold Ischemic Time (hours; median, IQR) | 18.0 (13.0 - 24.0) | 18.0 (13.1 - 23.7) | 17.6 (12.8 - 24.0) | 0.15 |
| Recipient Age at TX (years; median, IQR) | 64 (58 - 69) | 65 (58 - 70) | 65 (59 - 70) | 0.041 |
years) receiving a kidney from a deceased donor <65 years had an aggregate one-year graft survival rate of 93.0%, with a 3.34% one year mortality. All but 0.8% of the deaths occurred with a functioning graft (Table 4). In contrast, the older recipients of kidneys >65 years were over a decade older with a one-year graft survival of 84.4% and a 10.7% one-year mortality (7.08% died with a functioning graft and 3.6% died after the kidney failed).

There were no clinically relevant differences of measured organ quality (KDPI 93 vs 92, \(p < 0.001\)) or recipient characteristics between the older recipients that died or survived (Table 5). A higher rate of delayed graft function was observed in non-survivors, 48.3 vs 28.5%. The vast majority of deaths were attributed to cardiac events, stroke or infection. There were the expected statistical associations with death (slight increase in age, slightly higher KDRI), but clinical predictions of survival or death within first year was not possible from the OPTN data.

### 3.5. Survival benefit stratified by eGFR-1

A successful kidney transplant should confer some form of (survival) benefit compared to remaining on the waitlist. To determine long-term benefit of eGFR-1, the survival curves were superimposed upon the survival point when eGFR-1 was calculated. Kidney recipients from a deceased donor >65 years (older, median age 65) had a 91.1% graft survival and 95.9% of recipients of <65 year kidneys were alive after one year with a surviving graft. The recipients of a >65 year kidney achieving an eGFR-1 of >45, 30–44 and <30 ml/min had a 5-year survival of 72.5% (70.5–74.3%), 71.9% (70.0–73.7%) and 58.8% (56.0–61.4%) (Fig. 3) after transplantation. The cohort of similar candidates remaining on the waitlist had a 68.4% (66.0–71.0%) 5-year survival (Fig. 4). The recipients of a >65 year old kidneys achieving an eGFR-1 of 30–44 or >45 ml/min demonstrated no significant survival benefit after Bonferroni correction at 5 or 10 years post-transplant (statistical comparisons for each eGFR-1 group at each time point used Bonferroni-adjusted \(a\)-levels of 0.05/6 = 0.008), although the overall survival trended better than the waitlist cohort (Supplement). Recipients with an eGFR-1 <30 ml/min, never achieved survival equivalence (\(p < 0.001\)).

### 3.6. Logistic regression predicting achievement of eGFR-1 > 45

A logistic regression model was used to determine, among recipients of donor kidneys 65 or older, which factors best predicted achievement of eGFR-1 > 45 ml/min. A final model considering donor
type, KDPI, BMI, diagnosis, ESRD time, transplant type, insurance type, and clinical infections resulted in only a moderate-to-weak ability to discriminate those with eGFR-1 > 45 from those who did not reach this threshold (AUC = 0.649). Although the overall model performance was lacking, recipients of dual transplants had over 3 times (3.63, 3.01 - 4.38) greater odds of achieving eGFR-1 compared to single-KI recipients.

4. Discussion

This analysis reconfirms the association between the amount of transplant kidney function after a year (eGFR-1) and ten-year kidney allograft survival. Importantly, kidneys from deceased donors over 65 years did not have accelerated graft loss when stratified by eGFR-1. The recipient of a donor kidney > 65 years and obtaining an eGFR-
1 > 45 ml/min had 5 and 10-year graft survival (barring death of the recipient) similar to younger recipients receiving younger kidneys and obtaining a similar eGFR-1. Dual transplants more often provided an eGFR-1 > 45 ml/min. However, differences in death or graft failure were not observed with the only significant stratification being amount of eGFR provided.

Kidney transplantation is a superior therapy for ESRD contrasted to dialysis [2,17]. Transplanting lower quality kidneys using the “extended criteria donor” [18] definition or the “high KDPI” kidney [19] has demonstrated a consistent survival benefit after the risks of the peri-operative period have passed. The iBOX score reliably predicts outcomes, but is dependent upon information not within the OPTN database (post-transplant biopsy results and alloantibodies) [20]. The first year risks to recipients of greater > 65 year kidneys (“older” kidneys go to older recipients, mimicking the “old to old” European program) is substantial, with a lower 1-year survival than remaining on the waitlist (89.3 vs 97%), consistent with prior reports [21–25]. If the transplanted kidney provided at least 30 ml/min eGFR-1 (better than CKD3b), the five-year survival was similar and trended better than the waitlist cohort. However, recipients of older kidneys and an eGFR-1 < 30 ml/min, never achieved similar survival observed in the cohort group.

Young adult deceased donor kidneys have long been the “standard”, providing predictable transplant outcomes. Accordingly, over 60% of US adult deceased kidney transplants use kidneys from deceased donors under 45 years [2], but more (quality) kidneys are needed. In 2018, there were > 2.8 million deaths in the US and fewer than 170,000 deaths occurred in adults < 45 years. Over 900,000 deaths were in people 55–75 years [26]. Despite greater than fivefold more deaths, kidneys from this older age group accounts for only 16% of kidney transplants. Additionally, over 40% of the kidneys retrieved from older donors were not transplanted (discarded). 543,778 deaths occurred in individuals 65–74 years, yet only 298 kidneys were transplanted. From this analysis, it is likely that many of these deaths could have provided kidneys with excellent long-term dialysis relief.

Analysis of the US transplant experience from almost 20 years of OPTN data has inherent limitations. While most data are very reliable (patient and graft survival, age and gender, KDPI), there are issues with completeness and timing of data entry (of 138,358 recipients, 6% did not have data for an eGFR-1 calculation within the ninety-day window), historical and added/differing medical elements can produce variance. The large transplant numbers mitigate the inherent internal data vagaries. Medical care, donor/recipient characteristics and immunosuppression have gradually changed over time, but have not created “transplant eras”. Center criteria for organ and recipient selection are highly individualistic, and not available. All these add to outcomes variability.

Despite these uncertainties, the large number of transplants minimizes the vagaries and permits the basic questions to be addressed: is the duration of kidney graft function significantly impacted by donor age and can eGFR-1 serve as a metric to supplement (not replace) one-year graft survival? In the absence of recipient death, kidney donor age is not associated with accelerated graft loss and eGFR-1 was a good surrogate for 5 and 10-year graft function, independent of donor age. This analysis reinforces that death within the first year remains a major barrier to survival benefit for older candidates. As the > 65 year recipient of a live donor kidney only has a 2.7% one mortality [27], there should be an expectation that the risk/benefit relationship could be modified. Failure to reach a specified degree of kidney function is deleterious and should be candidate specific. This analysis focused upon graft survival from older kidneys (usually put into older recipients) and didn’t address the quality of life issues for all recipients; when poor graft function results in repeated hospitalizations, biopsies, immunosuppression modifications and infections. Achieving sufficient kidney function is an important outcome.

Tools to predict perioperative survival and subsequent durability of graft survival need attention. This analysis confirms the benefit and the uncertainty of transplanting older donor kidneys. The benefit is real, over three quarters of recipients achieved survival equivalence and many more would have survival benefit, if one year mortality was similar to age-matched live donor recipients. However, almost a quarter of older donor kidney transplant recipients had a survival outcome that was worse than the waitlist cohort. The differential use of “older” kidneys between the US and Europe appears to center upon acceptance of perceived risk vs. probable benefit. There should...
be methods to clarify the risk/benefit decisions necessary for acceptance of older donor kidneys for transplantation. Others have used kidney volumes [28,29], histology [30,31], deceased donor ICU management [32,33] or pumping characteristics [34,35] to aid quality assessment. While each may have marginal univariate predictability, it is probable that machine-learning algorithms could improve reliability.

This analysis puts quantitative measures onto outcomes that are clinically obvious to clinicians. Older donor kidneys can provide excellent long-term outcomes, but are presently unpredictable. The OPTN definition of one-year graft survival does predict long-term function, but the data includes the ability to calculate eGFR-1, which is a good surrogate for 10-year graft survival (off dialysis). Transplantation is a predictable ESRD treatment, but increasing demand requires more kidneys that provide similar outcomes as seen with kidneys from younger donors. Older donor kidneys can provide excellent long-term function (eGFR-1 > 45 ml/min) and should be available in larger numbers. However, better predictive tools are required to assess renal function.

**Declaration of Competing Interest**

TP is a Board member of an Organ Procurement Organization (Lifesource). All the other authors declare no conflicts of interest.

**Funding**

There was no outside funder for this analysis. The database is supported through a contract with HRSA.

**Data sharing**

This study used the Organ Procurement and Transplantation Network (OPTN) database that includes information on donors, wait-
listed candidates, and transplant recipients in the U.S., and has been described at [https://optn.transplant.hrsa.gov/data/about-data/](https://optn.transplant.hrsa.gov/data/about-data/). The Health Resources and Services Administration (HRSA), U.S. Department of Health and Human Services provides oversight to the activities of the OPTN contractor. All data used in this study are publicly available from the OPTN. Processes to obtain the data are enunciated on the OPTN website, found here: [https://optn.transplant.hrsa.gov/data/request-data/data-request-instructions/](https://optn.transplant.hrsa.gov/data/request-data/data-request-instructions/).

**Contributors**

TP and GV developed the initial hypothesis, GV and RC collected, organized and performed final statistical analysis of data. TP, GV, RC and DK analyzed data and generated conclusions. TP was primary author of manuscript and incorporated edits and suggestions from GV, RC and DK. There is agreement amongst all authors about the content and interpretation.

**Supplementary materials**

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/eclinm.2021.100980](https://doi.org/10.1016/eclinm.2021.100980).

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