National Trends in Utilization and 1-Year Outcomes with Transplantation of HCV-Viremic Kidneys

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ABSTRACT
Background Recent pilot trials have demonstrated the safety of transplanting HCV-viremic kidneys into HCV-seronegative recipients. However, it remains unclear if allograft function is impacted by donor HCV-viremia or recipient HCV-serostatus.

Methods We used national United States registry data to examine trends in HCV-viremic kidney use between 4/1/2015 and 3/31/2019. We applied advanced matching methods to compare eGFR for similar kidneys transplanted into highly similar recipients of kidney transplants.

Results Over time, HCV-seronegative recipients received a rising proportion of HCV-viremic kidneys. During the first quarter of 2019, 200 HCV-viremic kidneys were transplanted into HCV-seronegative recipients, versus 69 into HCV-seropositive recipients, while 105 HCV-viremic kidneys were discarded. The probability of HCV-viremic kidney discard has declined over time. Kidney transplant candidates willing to accept a HCV-seropositive kidney increased from 2936 to 16,809 from during this time period. When transplanted into HCV-seronegative recipients, HCV-viremic kidneys matched to HCV-non-viremic kidneys on predictors of organ quality, except HCV, had similar 1-year eGFR (66.3 versus 67.1 ml/min per 1.73 m², P=0.86). This was despite the much worse kidney donor profile index scores assigned to the HCV-viremic kidneys. Recipient HCV-serostatus was not associated with a clinically meaningful difference in 1-year eGFR (66.5 versus 71.1 ml/min per 1.73 m², P=0.056) after transplantation of HCV-viremic kidneys.

Conclusions By 2019, HCV-seronegative patients received the majority of kidneys transplanted from HCV-viremic donors. Widely used organ quality scores underestimated the quality of HCV-viremic kidneys based on 1-year allograft function. Recipient HCV-serostatus was also not associated with worse short-term allograft function using HCV-viremic kidneys.
outcomes, it has never been unequivocally established whether these inferior allograft outcomes using HCV-viremic kidneys resulted from donor organ quality or recipient HCV-associated morbidity.5 The kidney donor profile index (KDPI)—a measure of allograft quality that is deeply integrated into United States organ allocation—assigns a substantially worse score to kidneys from HCV-seropositive donors, which may also encourage organ discard.6,7 Our group and others have questioned whether these kidney quality scores accurately reflect the transplant outcomes with HCV-viremic kidneys in contemporary practice.8–11 An excessive KDPI “penalty” for kidneys from donors with evidence of active or prior HCV viremia may inappropriately discourage centers from transplanting these organs.

New and effective treatment options for HCV may lead to better transplant outcomes for recipients of HCV-viremic kidneys.12,13 Until 2014, HCV treatment strategies were on the basis of IFN, which had cure rates as low as 40%, required multiple injections, and caused severe side effects.14 When administered after transplantation, IFN promoted allograft rejection.15 The development of DAA therapy for HCV has prompted single-center trials of transplanting HCV-viremic kidneys into seronegative recipients, including THINKER and EXPANDER, which reported 100% HCV cure rates and good allograft outcomes at 12 months.8,16 These trials—and promising data in thoracic transplantation—have prompted cautious interest in using HCV-viremic kidneys in the United States and abroad, although the effect of HCV viremia on contemporary kidney discard rates is not well understood.3,17–20

Greater clarity about outcomes using HCV-viremic kidneys may also have major implications for the management of waitlisted patients with preexisting chronic HCV infection. Because accepting HCV-viremic kidneys reduced waiting time to transplantation in the past, particularly in regions with long wait times, kidney transplant candidates with chronic HCV infection have often been advised to forego antiviral treatment until after transplantation.21 However, the success of this strategy relies on readily available HCV-viremic kidneys for patients with preexisting infection. Because many recent studies of HCV-viremic organs involved single-center trials,8,16,18,20 we took advantage of national registry data and meticulous matching methods. We aimed to (1) describe temporal trends in the allocation and discard for HCV-viremic kidneys, (2) determine if recipients of kidneys from HCV-viremic donors experience worse 12-month allograft eGFR compared with matched recipients of HCV-nonviremic kidneys, and (3) determine if recipient HCV serostatus is associated with 12-month allograft eGFR after transplantation with donor HCV-viremic kidneys.

**METHODS**

**Overview**

On the basis of the Organ Procurement and Transplantation Network (OPTN) data as of March 19, 2019, we assembled a retrospective cohort of adult (≥18 years old) recipients of a deceased donor kidney transplant in the United States. The OPTN data system includes data on all donor, waitlisted candidates, and transplant recipients in the United States submitted by the members of the OPTN, and it has been described elsewhere.22,23 The Health Resources and Services Administration, US Department of Health and Human Services provides oversight to the activities of the OPTN contractor.

Donor HCV viremia was defined as an HCV nucleic acid test (NAT)—positive result reported to the OPTN by organ procurement organizations. Donors who were HCV NAT negative were labeled as HCV nonviremic. We characterized kidney transplant recipients as either HCV seropositive or seronegative defined as testing positive or negative for HCV antibody, respectively. Notably, HCV NAT testing of kidney transplant recipients was not required by the OPTN and rarely reported during the study period.

Transplants performed between April 1, 2015 (the date that the OPTN started requiring testing of all deceased donors in the United States using HCV NAT) and March 31, 2019 were included for the description of trends in organ utilization (Aim 1). Transplants performed from April 1, 2015 through December 31, 2017 were included for analyses of 12-month allograft outcomes (Aims 2 and 3) to make sure that these recipients had the opportunity for 12-month data to be reported to the United Network for Organ Sharing (UNOS). Recipients with a history of HIV infection, recipients of a multiorgan transplant, and those transplanted at centers that did not perform any kidney transplants from donors with HCV viremia or anti-HCV antibody (Ab) during the study period were excluded.24

Waitlisted patients must opt in to receive offers of kidneys from HCV Ab or HCV NAT-positive (viremic) kidneys. We examined temporal trends in this HCV-seropositive kidney eligibility defined as willingness to receive HCV Ab or HCV-viremic kidney offers or both.

The study was approved by the University of Pennsylvania Institutional Review Board (no. 822070).
Outcomes
We described the allocation of HCV-viremic kidneys to HCV-seronegative and HCV-seropositive recipients over time. We also evaluated the change in rates of HCV-viremic deceased donor kidney allocation and changes in the quality of accepted and discarded HCV-viremic kidneys over time. Finally, we evaluated sociodemographic characteristics of recipients of HCV-viremic kidneys and analyzed patterns of discard for HCV-viremic kidneys.

The primary outcome for analyses of allograft function was eGFR measured at 12 months post-transplantation and calculated using the Chronic Kidney Disease Epidemiology Collaboration equation.25,26 The OPTN requires that transplant centers report 100% of 12-month forms by 18 months post-transplant.27 The accuracy of serum creatinine reported in these forms has been previously validated by our group.28 To account for the fact that centers may submit these forms at different times (likely related to when patients have clinical encounters), we accepted serum creatinine measures reported between 9 and 15 months post-transplant.8 We also examined data on delayed graft function, acute rejection, graft failure, and death within 15 months post-transplant.

Multivariable Matching
For Aims 2 and 3, we generated highly similar matched sets in a 1:2 ratio by leveraging advances in statistical theory and analysis.29–31 Many traditional approaches, such as propensity score matching, generate a comparator group with similar distributions of characteristics to those of the focal group (here, recipients of HCV NAT-positive kidneys) but allow individuals in the pool to be matched to comparators who may differ in key characteristics.32 For instance, with propensity score matching, an individual patient who is a man can be matched to a patient who is a woman. Instead, we used an iterative process of optimal subset and cardinality matching, which has previously been shown to improve both distance between matched pairs and reduce systematic biases.31 We prioritized the most important donor and recipient characteristics and used tools, such as exact matching, distance matrices (which includes propensity score), and fine balance, to select pairs that were extremely similar to focal patients at the level of an individual recipient. We used the R package “designmatch.”33 For each match, a Mahalanobis distance matrix was built using important covariates. Additionally, for each match, a propensity score was constructed as the propensity of transplanting an HCV-viremic kidney into a seronegative recipient.34 For Aim 3 (a comparison of HCV-seropositive versus -seronegative recipients of HCV-viremic kidneys), because there were fewer comparators, we performed matching on the KDPI rather than the individual elements of the KDPI. For Aim 3, we performed exact matching on recipient race, cause of ESKD (diabetes and hypertension), preemptive kidney transplantation, and private insurance. To ensure exact balance between categorical variables that were not exactly matched, we performed fine balance.29 Finally, penalties were applied to continuous variables to ensure that the matching algorithm first prioritized donor variables (donor creatinine, age, weight, and height for Aim 2 and KDPI for Aim 3) followed by recipient age at transplant and then, panel reactive antibody at allocation.

Covariate balance for all variables was assessed by comparing the standardized difference between pairs and by visual inspection of the distributions pre- and postmatch. A standardized difference <0.10 was chosen as the cutoff point to determine if the groups were well balanced.31 The R package “Cobalt” was used to assess covariate balance.33 Finally, as recommended by Rubin and Thomas,36 outcomes were analyzed only after matching was completed and covariate balance was reviewed by the principal investigators (V.S.P. and P.P.R.).

Sensitivity and Secondary Analyses
To ensure reproducibility of the results and detect potential unmeasured bias, we performed several additional analyses. First, we analyzed 1-year allograft function using m statistics available in the R package “sensitivitym.”37 This process excluded matched pairs even if one of the comparators had missing follow-up data; these results are presented in Supplemental Table 1.

Finally, we fit a linear regression model on the eGFR outcome using the cohort of kidney recipients transplanted from April 1, 2015 through December 31, 2017. We included the individual elements of KDPI (donor age, height, weight, race, cause of death, history of hypertension and diabetes, terminal creatinine, donation after cardiac death, and HCV serostatus) as well as the recipient variables at the time of transplant that could affect 12-month eGFR (cause of ESKD, recipient HCV serostatus, history of diabetes, history of prior transplant, dialysis vintage, cytomegalovirus status, HIV infection, and panel reactive antibody at organ allocation). We excluded recipient age, sex, race, height, and weight, because they are included in the equation for eGFR. We also performed a linear regression on 12-month eGFR with only donor covariates with clustering at the level of the organ donor, because some donors provided kidneys to two recipients included in our study. The results of the linear regression are presented in Supplemental Tables 2 and 3.

Statistical Analyses
To predict organ discard, we performed logistic regression accounting for donor KDPI and HCV viremia status and used postestimation to obtain probabilities. To compare eGFR and serum creatinine between matched groups, we used the stratified Wilcoxon rank sum test available in the STATA package “VANELTEREN.”38 These analyses exclude matched pairs that did not have follow-up information for the patient group, but they were retained if at least one of the comparators had follow-up data. To compare outcomes of delayed graft function and acute rejection, we used conditional logistic regression. Because we anticipated low event
Deceased Donor Kidney Transplants Between 04/01/2015 & 3/31/2019
N = 59,452

Include for Analysis of Transplant Trends
N = 49,423

Include for Comparing HCV Viremic Kidney Transplant Outcomes
N = 28,711

Exclude:
Age <18 at Listing (N = 2,467)
Listed for Multiorgan Transplant (N = 7,561)
Erroneous Dialysis Duration (N = 1)

Transplants Performed After 12/31/2017 to allow for 15 months of follow-up (N = 16,716)

Centers that did not perform any HCV-seropositive deceased donor kidney transplant (N = 3,996)

HIV Seropositive Recipients (N = 465)

N = 28,256

Compare Outcomes for Aim 2: Final Cohort for Match After Excluding Missing Variables

Donor HCV-Viremic Kidney Transplanted Into HCV-seronegative Recipient
(HCV NAT D+/R-)
N = 103

Donor HCV-non-viremic Kidney Transplanted Into HCV-seronegative Recipient
(HCV NAT D-/R-)
N = 21,914

Compare Outcomes for Aim 3: Final Cohort for Match After Excluding Missing Variables

Donor HCV-Viremic Kidney Transplanted Into HCV-seronegative Recipient
(HCV NAT D+/R-)
N = 103

Donor HCV-Viremic Kidney Transplanted Into HCV-seropositive Recipient
(HCV NAT D+/R+)
N = 701

Figure 1. Flow chart for cohort generation. HCV, hepatitis C virus; NAT, nucleic acid test.
rates for the outcomes of death and graft failure within 1 year after transplant, we only reported descriptive data and did not perform statistical comparison. Analyses were completed using the statistical package R (version 3.4.3, R Foundation for Statistical Computing) and STATA (version 15.1, StataCorp).

Missing Data
After applying our inclusion and exclusion criteria, no recipients of HCV-viremic kidneys had missing data on KDPI, clinical, or demographic characteristics necessary for the match. Less than 0.1% of potential comparators had missing data on KDPI or any independent recipient characteristic; these recipients were not selected for the final matched pairs. Less than 0.1% of the entire cohort had missing data on any independent variable included in the multivariable analysis.

RESULTS
Temporal Trends (Aim 1)
Figure 1 shows the generation of cohorts. Figure 2 demonstrates a progressive increase in the pool of potentially transplantable HCV-viremic deceased donor kidneys from April 1, 2015 to March 31, 2019. During this timeframe, 1862 HCV-viremic kidneys were transplanted, 1199 kidneys were discarded, and 892 were not recovered. There was a striking temporal trend in which greater numbers of HCV-viremic kidneys were transplanted over time, and a smaller proportion of these kidneys was not recovered. During the first quarter of the year 2019, a total of 105 kidneys from HCV-viremic donors were discarded; in the same time period, the median KDPIs of HCV-viremic transplanted kidneys, discarded kidneys, and nonrecovered kidneys were 54%, 84%, and 95%, respectively. Supplemental Figure 1 shows the wide variation in the number of HCV-viremic kidneys that were discarded across UNOS regions. Compared with HCV-nonviremic kidneys that were discarded, discarded HCV-viremic kidneys were from donors with a younger median age (38 versus 54 years old, \( P < 0.001 \)) and lower KDPI (median KDPI 63% versus 82%, \( P = 0.001 \)) (Supplemental Table 4). HCV viremia remains a risk factor for discard, but Figure 3 shows that the probability of HCV-viremic kidney discard for the same allocation KDPI has declined in the study period.

Figure 4 reveals that transplantation of HCV-viremic kidneys into HCV-seronegative recipients became much more common than transplantation into HCV-seropositive recipients. By the first 3 months of the 2019, 200 HCV-viremic kidneys were transplanted into HCV-seronegative recipients, nearly triple the number transplanted into HCV-seropositive recipients (\( n = 69 \)). We also find that the majority of HCV-viremic transplants into HCV-seronegative recipients were performed in UNOS regions 2, 3, 9, and 11 (Figure 5). Among HCV-seronegative recipients of HCV-viremic kidneys, 28.2% were women, 40.6% were black, 26% had private insurance, and 36.4% had a bachelor’s degree or higher education level (Supplemental Table 5).

We also detected much greater willingness of centers and candidates to ever accept offers of kidneys from donors that were HCV viremic, HCV Ab positive, or both. On December 31, 2015, the number of candidates listed as willing to accept such kidneys was 2936, and it increased to 16,809 by March 31, 2019. The number of candidates ever listed as willing to accept an HCV-viremic kidney specifically was 1487 at the end of
December 31, 2015, and it increased to 2852 on March 31, 2019. The number of transplant centers using HCV-viremic kidneys into HCV-seronegative recipients has increased from 11 in 2015 to 33 in 2018, and in the first 3 months of 2019, 39 centers performed these transplants (Supplemental Figure 2).

The 12-Month Allograft Function among HCV-Seronegative Recipients of HCV-Viremic Kidneys Versus HCV-Nonviremic Kidneys (Aim 2)

Table 1 shows the demographic and clinical characteristics of the 103 HCV-seronegative recipients of HCV-viremic kidneys—the focal group. Through an iterative matching process and using a 1:2 ratio of focal patients to comparators, we generated highly similar matched sets of HCV-seronegative recipients of HCV-nonviremic kidneys and HCV-seronegative recipients of HCV-viremic kidneys. As expected, the HCV-viremic kidneys had a higher KDPI compared with HCV-nonviremic kidneys (47 versus 26), despite nearly identical donor qualities other than HCV serostatus. Table 2 shows 12-month allograft outcomes for the matched pairs; none of the HCV-viremic kidney allografts failed, and six (2.9%) HCV-nonviremic kidney allografts failed by 12 months. As expected, the median time to transplant for recipients of HCV-viremic versus HCV-nonviremic allografts was shorter (239 versus 619 days), even after we matched on dialysis vintage. HCV-viremic kidney allograft recipients had similar organ function with mean eGFR of 66.8 versus 66.5 ml/min per 1.73 m² for matched recipients of HCV-nonviremic kidneys (P=0.80). Supplemental Figure 3A shows the similar distribution of eGFR.

Figure 3. HCV (hepatitis C virus)-viremic kidneys have a higher probability of discard compared to HCV-non-viremic kidneys with similar KDPI (kidney donor profile index). However, the probability of discard for HCV-viremic kidneys has declined over time.

Figure 4. Dramatic increase in the allocation of HCV (hepatitis C virus)-viremic kidneys into HCV-seronegative recipients during the study period. NAT, nucleic acid test.
A total of 20 (19.6%) uninfected recipients of HCV-viremic kidneys had delayed graft function, and the cumulative prevalence of acute rejection reported by centers was similar between the matched recipients of HCV-viremic versus HCV-nonviremic kidneys (3.9% versus 5.4%, \( P =0.57 \)).

### Secondary and Sensitivity Analyses

Results of supplemental and sensitivity analyses of outcomes for the matched cohorts were similar to the primary results, and they are shown in Supplemental Table 1.

Using data on kidney transplants performed between April 1, 2015 and December 31, 2017 (n=28,711), we fit a multivariable linear regression model clustering on the kidney donor to assess the effect of individual elements of donor characteristics included in the KDPI after accounting for recipient variables that might predict kidney transplant outcome at the end of 12 months post-transplant; these results are presented in Supplemental Tables 2 and 3. Donor age, history of hypertension, diabetes, and donation after cardiac death status were strongly associated with post-transplant function at 12 months. However, donor HCV status was not significantly associated with allograft function. The model had modest predictive ability with \( R^2=20 \).

### DISCUSSION

This national study during the era of DAA treatments for HCV revealed a rising number of kidney transplants from HCV-viremic donors, with a large majority now transplanted into HCV-seronegative recipients. Recipients of HCV-viremic kidneys had 1-year allograft function that was similar to that of recipients of HCV-nonviremic kidneys who were meticulously matched on donor and recipient characteristics. These striking results provide important additional evidence that the KDPI, with its current negative weightage for HCV status, does not accurately assess the quality of kidneys from HCV-viremic donors. Additionally, 1-year allograft outcomes for HCV-viremic kidneys were not meaningfully different if transplanted into HCV-seropositive versus HCV-seronegative recipients. Taken together, these findings suggest that the benefits of transplantation using HCV-viremic kidneys will be similar if allocated to HCV-seropositive or HCV-seronegative recipients.

The opioid epidemic has driven a rapid rise in the number of potential deceased donors who died from drug overdoses, many of whom have HCV viremia.\(^{39,40}\) Given that many of these donors are young, the higher utilization of HCV-viremic kidneys is an important development for the transplant field, and it may help some families of donors in their...
Although we show that the discard rate of HCV-viremic kidneys has declined over time, the 39% discard rate for HCV-viremic kidneys donated between January 2018 and March 2019 suggests that a substantial opportunity remains to increase access to kidney transplantation in the future by maximizing the use of these organs.

This study calls attention to a major change in center practice—that centers are increasingly transplanting
HCV-viremic kidneys into HCV-seronegative recipients. This trend is driven by promising early publications showing 100% HCV cure rates in pilot trials. The competition for HCV-viremic kidneys, however, will over time likely lead to decreased availability of those organs for waitlisted patients with chronic HCV infection. If true, then this information should be considered by HCV-viremic patients with ESKD and their clinicians considering HCV treatment before transplantation. This decision about whether to treat an HCV-infected waitlisted patient may be driven by concerns about HCV morbidities, patient preferences, costs, and in the dialysis setting, the possibility of disease transmission. The decline in transplantation of HCV-seropositive recipients with kidneys from HCV-viremic donors over the duration of this study also raises the possibility that HCV-viremic United States patients on dialysis have increasingly been cured of their infection. As use of HCV-viremic kidneys becomes mainstream, the use of these organs in individuals with previously treated HCV infection is a new clinical scenario that transplant centers and referring nephrologists may have to confront.

In this national sample, we found that HCV-viremic kidneys transplanted into HCV-seronegative recipients have similar 12-month allograft function compared with HCV-nonviremic kidneys matched on individual elements of KDPI (except HCV). Our findings also show that donor HCV viremia did not lead to poor allograft function or reveal evidence of greater risk for acute rejection within the first year of transplant, even after accounting for recipient characteristics. However, data on acute rejection should be interpreted cautiously, because we do not know the type or severity of rejection; moreover, our prior work has shown that acute rejection may be under-reported to the OPTN. A recent study using national registry data also has shown excellent short-term allograft function for HCV-viremic kidneys, although they used less precise matching methods. Taken together, these findings have two implications for clinical practice. First, this finding suggests that the KDPI does not accurately represent kidney quality for HCV-viremic donors. A similar concern about the accuracy of the KDPI was raised by Sibulesky et al. with kidneys from donors that were HCV antibody positive but HCV nonviremic. Second, in the current era of DAA treatments, kidneys from donors with HCV viremia function just as well as those without HCV viremia. Rescaling the KDPI to reflect outcomes for HCV-viremic kidneys might lead clinicians to offer these kidneys to younger patients with longer life expectancy. We acknowledge that the KDPI is calculated on the basis of allograft failure events, not allograft function, but allograft function is very meaningful to patients and transplant professionals. To date, there is insufficient follow-up time for HCV-viremic kidney transplants into seronegative recipients to have sufficient power to examine this outcome.

This study also provides important insights into the effect of recipient HCV serostatus on allograft function after transplantation using HCV-viremic kidneys. Surprisingly, recipient HCV serostatus was not associated with any meaningful difference in 12-month allograft outcomes.

We acknowledge limitations, which include lack of information on donor HCV characteristics, such as genotype,
treatment regimens, and outcomes of treatment. However, by assembling a national cohort, this manuscript complements prior single-center work. The HCV-viremic kidneys used for transplantation between 2015 and 2019 may have been carefully selected by centers, and therefore, future wider use of these kidneys may not lead to outcomes as positive as those reported here. Like other observational studies, the findings may be limited by unmeasured confounding. For example, HCV-seronegative recipients of HCV-viremic kidneys could have been better informed or otherwise healthier than recipients of HCV-nonviremic kidneys. Although we matched on patient insurance status, education level, and duration on dialysis before transplantation, it is still possible that uninfected recipients of HCV-viremic kidneys in our matched cohort were either enrolled in clinical trials or had greater access to transplantation, because copays for hepatitis C therapy can be a significant financial barrier.44,45 Finally, because of limitations in the dataset, we are unable to examine the effect of timing of HCV antiviral therapy on allograft function.

In conclusion, transplant centers and candidates are increasingly willing to accept HCV-viremic kidneys. During the first quarter of 2019, 74% of HCV-viremic kidneys were transplanted into seronegative recipients—a major change from how HCV-viremic kidneys were allocated a few years ago. We also find that HCV-viremic kidneys had similar

Table 3. Characteristics of matched pairs of hepatitis C virus (HCV)—seronegative recipients versus HCV-seropositive recipients of HCV-viremic kidneys

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<tr>
<td>Recipient variables</td>
<td></td>
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<tr>
<td>Age at transplant, yr, mean (SD)</td>
<td>58.8 (8.8)</td>
<td>58.9 (8.2)</td>
<td>59.9 (7.9)</td>
<td>−0.1303</td>
<td>−0.0084</td>
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<tr>
<td>Sex (women)</td>
<td>24 (23.5%)</td>
<td>48 (23.5%)</td>
<td>162 (23.1%)</td>
<td>0.0016</td>
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<tr>
<td>Race (black)</td>
<td>47 (46.1%)</td>
<td>94 (46.1%)</td>
<td>413 (58.9%)</td>
<td>−0.1323</td>
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<tr>
<td>Cause of ESKD</td>
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<tr>
<td>Diabetes</td>
<td>43 (42.1%)</td>
<td>86 (42.1%)</td>
<td>291 (41.5%)</td>
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<tr>
<td>Hypertension</td>
<td>16 (15.7%)</td>
<td>32 (15.7%)</td>
<td>222 (31.6%)</td>
<td>−0.1604</td>
<td>0</td>
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<tr>
<td>GN</td>
<td>11 (10.8%)</td>
<td>22 (10.8%)</td>
<td>27 (3.9%)</td>
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<td>0</td>
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<tr>
<td>Cystic</td>
<td>10 (9.8%)</td>
<td>20 (9.8%)</td>
<td>21 (3%)</td>
<td>0.0768</td>
<td>0</td>
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<tr>
<td>Other</td>
<td>22 (21.6%)</td>
<td>44 (21.6%)</td>
<td>140 (20%)</td>
<td>0.0136</td>
<td>0</td>
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<tr>
<td>Prior transplant</td>
<td>14 (13.7%)</td>
<td>28 (13.7%)</td>
<td>139 (19.8%)</td>
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<td>Prior malignancy</td>
<td>5 (4.9%)</td>
<td>10 (4.9%)</td>
<td>83 (11.8%)</td>
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<td>Blood type</td>
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<tr>
<td>A</td>
<td>27 (26.5%)</td>
<td>54 (26.5%)</td>
<td>205 (29.2%)</td>
<td>−0.0196</td>
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<tr>
<td>B</td>
<td>17 (16.7%)</td>
<td>34 (16.7%)</td>
<td>113 (16.1%)</td>
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<td>O</td>
<td>56 (54.9%)</td>
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<td>360 (51.4%)</td>
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<td>AB</td>
<td>2 (1.9%)</td>
<td>4 (1.9%)</td>
<td>23 (3.3%)</td>
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<td>Duration on dialysis</td>
<td></td>
<td></td>
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<tr>
<td>Preemptive</td>
<td>16 (15.7%)</td>
<td>32 (15.7%)</td>
<td>87 (12.4%)</td>
<td>0.0311</td>
<td>0</td>
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<tr>
<td>&lt;1 yr</td>
<td>27 (26.5%)</td>
<td>54 (26.5%)</td>
<td>102 (14.6%)</td>
<td>0.1261</td>
<td>0</td>
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<tr>
<td>1–5 yr</td>
<td>49 (48%)</td>
<td>98 (48%)</td>
<td>397 (56.7%)</td>
<td>−0.0914</td>
<td>0</td>
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<tr>
<td>&gt;5 yr</td>
<td>10 (9.8%)</td>
<td>20 (9.8%)</td>
<td>114 (16.3%)</td>
<td>−0.0658</td>
<td>0</td>
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<td>Insurance type</td>
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</tr>
<tr>
<td>Private</td>
<td>36 (35.3%)</td>
<td>72 (35.3%)</td>
<td>185 (26.4%)</td>
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<td>Medicaid</td>
<td>9 (8.8%)</td>
<td>18 (8.8%)</td>
<td>58 (8.3%)</td>
<td>0.0142</td>
<td>0</td>
</tr>
<tr>
<td>Medicare/other</td>
<td>57 (55.9%)</td>
<td>114 (55.9%)</td>
<td>458 (65.3%)</td>
<td>−0.0995</td>
<td>0</td>
</tr>
<tr>
<td>PRA (mean)</td>
<td>9.4 (23.4)</td>
<td>9.4 (23.5)</td>
<td>15.2 (28.5)</td>
<td>−0.2276</td>
<td>−0.0011</td>
</tr>
<tr>
<td>Education level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>1 (1%)</td>
<td>2 (1%)</td>
<td>36 (5.1%)</td>
<td>−0.0417</td>
<td>0</td>
</tr>
<tr>
<td>High school and college</td>
<td>67 (65.7%)</td>
<td>134 (65.7%)</td>
<td>515 (73.5%)</td>
<td>−0.0755</td>
<td>0</td>
</tr>
<tr>
<td>Bachelor and higher</td>
<td>32 (31.4%)</td>
<td>64 (31.4%)</td>
<td>134 (19.1%)</td>
<td>0.1193</td>
<td>0</td>
</tr>
<tr>
<td>Unknown</td>
<td>2 (1.9%)</td>
<td>4 (1.9%)</td>
<td>16 (2.3%)</td>
<td>−0.002</td>
<td>0</td>
</tr>
<tr>
<td>Donor variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allocation KDPI %, mean (SD)c</td>
<td>47 (14.6%)</td>
<td>47 (16.3)</td>
<td>48 (16.7)</td>
<td>−0.0155</td>
<td>0</td>
</tr>
</tbody>
</table>

PRA, panel reactive antibody; KDPI, kidney donor profile index.

*We were unable to find optimal matches for one of 103 patients.

*bDonors with a history of diabetes were excluded from the match, because none of the HCV-viremic kidney transplant recipients received a kidney from a donor with history of diabetes.

*Postmatch characteristics of the individual elements of KDPI are presented in Supplemental Table 6.

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function compared with HCV-nonviremic kidneys matched on the donor elements included in the KDPI (except HCV). HCV-viremic kidneys also functioned similarly when transplanted into recipients who were seropositive or seronegative for HCV. These findings provide strong evidence that HCV-viremic kidneys are a valuable resource for transplantation. Disincentives for accepting these organs should be addressed by the transplant community.

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Dr. Potluri, Dr. Goldberg, Dr. Mohan, and Dr. Reese designed the study. Dr. Potluri, Dr. Goldberg, Dr. Mohan, Dr. Sharpe, and Dr. Reese were involved in analyzing the data. Dr. Potluri and Dr. Reese drafted and revised the manuscript. All authors were involved in the interpretation of the results and approved the final version of the manuscript.

Preliminary findings of this research were presented by Dr. Potluri at the National Kidney Foundation Spring Clinical Meeting Young Investigators Forum on May 8, 2019, Boston, MA, and by Dr. Reese at the American Transplant Congress on June 5, 2019, Boston, MA.

The data reported here have been supplied by the United Network for Organ Sharing as the contractor for the Organ Procurement and Transplantation Network (OPTN). The interpretation and reporting of these data are the responsibility of the author(s) and in no way should be seen as an official policy of or interpretation by the OPTN or the US Government. The content is the responsibility of the authors alone and does not necessarily reflect the views or policies of the Department of Health and Human Services nor does mention of trade names, commercial products, or organizations imply endorsements by the US Government.

DISCLOSURES

Dr. Blumberg has received research funds from Merck for research related to cytomegalovirus infection. Dr. Goldberg has received investigator-initiated grants from Merck and AbbVie awarded to the University of Pennsylvania for trials of hepatitis C virus (HCV)–viremic kidney transplants into HCV-seronegative recipients followed by antiviral treatment. Dr. Mohan is supported by research funds from the National Institutes of Health (the National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK], the National Institute of Allergy and Infectious Diseases, the National Institute of Minority Health and Health Disparities, and the National Institute of Biomedical Imaging and Bioengineering). He is also the deputy editor for Kidney International Reports and is a consultant for Bravado Health, Jazz Pharma, and Angion. Dr. Molnar served as an advisor for Merck and AbbVie. Dr. Parikh is supported by NIDDK grant R01DK93770. He also receives consulting fees from Renalynx and is on the Data Safety and Monitoring Board for Genfit and Abbott. The work of Dr. Potluri was supported by a Ben J. Lipps grant from the American Society of Nephrology. Dr. Reddy served as an ad hoc advisor to Merck, Gilead, AbbVie, Spark Therapeutics, Shionogi, and Dova. Dr. Reddy received research support (paid to the University of Pennsylvania) from Merck, Gilead, AbbVie, Mallinckrodt, Intercept, Conatus, and Exact Sciences. Dr. Reese has received investigator-initiated grants from Merck and AbbVie awarded to the University of Pennsylvania for trials of hepatitis C virus (HCV)–viremic kidney transplants into HCV-seronegative recipients followed by antiviral treatment. Dr. Sise is supported by NIDDK grant K23 DK117014 and has received investigator-initiated grants from Merck and AbbVie awarded to the Massachusetts General Hospital for trials of HCV-viremic kidney transplants into HCV-seronegative recipients followed by antiviral treatment. Dr. Sise has served as an advisory board member to Merck, AbbVie, and Gilead.

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SUPPLEMENTAL MATERIAL

This article contains the following supplemental material online at http://jasn.asnjournals.org/lookup/suppl/doi:10.1681/ASN.2019050462/-/DCSupplemental.

Supplemental Figure 1. Total number of HCV-viremic kidney discards in the 15-month period between January 1, 2018 and March 31, 2019 by UNOS region.

Supplemental Figure 2. Number of transplant centers using a kidney from a deceased donor who was either HCV viremic or HCV seropositive.

Supplemental Figure 3. A. Distribution of estimated glomerular filtration rate at 12 months after kidney transplantation between highly similar pairs of HCV-seronegative recipients of HCV-viremic kidneys versus HCV-non-viremic kidneys. B. Distribution of estimated glomerular filtration rate at 12 months after transplantation with HCV-viremic kidneys into highly similar pairs of HCV-seropositive recipients versus HCV-seronegative recipients.

Supplemental Table 1. Secondary analysis—comparison of outcomes using M statistics (matched sets are excluded where any creatinine value at the follow up time point for the HCV-viremic kidney recipient or either comparator was missing).

Supplemental Table 2. Multivariable linear regression on the outcome of post-transplant 12-month allograft eGFR (milliliters per minute per 1.73 m²) for transplants performed between April 1, 2015 and December 31, 2017 (N=28,711).

Supplemental Table 3. Linear regression evaluating only the effect of donor variables on the outcome of post-transplant 12-month allograft eGFR (milliliters per minute per 1.73 m²) for transplants performed between April 1, 2015 and December 31, 2017 (N=28,711).

Supplemental Table 4. Donor characteristics where at least one kidney was discarded or not recovered by donor HCV NAT status between April 1, 2015 and March 31, 2019 and characteristics of HCV-viremic donors where at least one kidney was discarded or not recovered by year of organ donation.

Supplemental Table 5. Sociodemographic characteristics of all recipients of HCV-viremic compared with HCV-nonviremic deceased donor kidneys between April 1, 2015 and March 31, 2019.

Supplemental Table 6. Characteristics of HCV-viremic deceased donors of kidneys transplanted into HCV-seropositive and HCV-seronegative recipients after matching on the KDPI.
Supplemental Table 7. Regional variation in the utilization of HCV-viremic kidneys in uninfected recipients by year.

REFERENCES

27. Organ Procurement and Transplantation Network: OPTN Policy 18.4: Data Submission Requirements-Data Submission Standards. Available at: https://optn.transplant.hrsa.gov/governance/policies. Accessed May 2, 2019
38. Coveney J: VANELTEREN: Stata Module to Perform van Elteren’s Test (Generalized Wilcoxon-Mann-Whitney Ranksum Test), Statistical Software Components S439101, Boston, Boston College Department of Economics, 2004
42. Zhong Y, Schaubel DE, Kalbfleisch JD, Ashby VB, Rao PS, Sung RS: Reevaluation of the Kidney Donor Risk Index (KDRI). Transplantation 103: 1714–1721, 2019


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