Published in final edited form as:

Clin Transplant. 2018 April ; 32(4): e13212. doi:10.1111/ctr.13212.

Increasing kidney donor profile index sequence does not adversely affect medium-term health-related quality of life after kidney transplantation

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Abstract

Background—The United Network for Organ Sharing system allocates deceased donor kidneys based on the kidney donor profile index (KDPI), stratified as sequences (A = 20%, B = 20–< 35%, C = 35– 85%, and D > 85%), with increasing KDPI associated with decreased graft survival. While health-related quality of life (HRQOL) may improve after transplantation, the effect of donor kidney quality, reflected by KDPI sequence, on post-transplant HRQOL has not been reported.

Methods—Health-related quality of life was measured using the eight scales and physical and mental component summaries (PCS, MCS) of the SF-36[®] Health Survey. Multivariable mixed effects models that adjusted for age, gender, rejection, and previous transplant and analysis of variance methods tested the effects of time and KDPI sequence on post-transplant HRQOL.

Results—A total of 141 waitlisted adults and 505 recipients (>1700 observations) were included. Pretransplant PCS and MCS averaged, respectively, slightly below and within general population

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CONFLICT OF INTEREST

None.

AUTHORS' CONTRIBUTIONS

Rachel C. Forbes: Conceived and designed the study, collected the data, drafted the article, critically revised the article, and approved the article. Irene D. Feurer: Conceived and designed the study, analyzed and interpreted the data, drafted the article, critically revised the article, and approved the article. David LaNeve: Collected the data, managed the database, and approved the article. Beatrice P. Concepcion: Collected the data, critically revised the article, and approved the article. Christianna Gamble: Collected the data, managed the database, and approved the article. Scott A. Rega: Managed the database, carried out statistics, and approved the article. C. Wright Pinson: Critically revised the article, approved the article, and contributed to other processes. David Shaffer: Conceived and designed the study, collected the data, drafted the article, critically revised the article, and approved the article.

norms (GPN; 40–60). At 31 ± 26 months post-transplant, average PCS (41 ± 11) and MCS (51 ± 11), overall and within each KDPI sequence, were within GPN. KDPI sequence was not related to post-transplant HRQOL ($P > .134$) or its trajectory (interaction $P > .163$).

Conclusion—Increasing KDPI does not adversely affect the medium-term values and trajectories of HRQOL after kidney transplantation. This may reassure patients and centers when considering using high KDPI kidneys.

Keywords

health-related quality of life; KDPI; kidney allocation system; kidney transplantation; organutilization

1 | INTRODUCTION

In December 2014, the United Network for Organ Sharing (UNOS) introduced a novel kidney allocation system (KAS), which allocates deceased donor kidneys via four sequences based on donor quality calculated as the kidney donor profile index (KDPI).¹ The KDPI incorporates 10 variables in the calculation of a score ranging from 0% to 100%: donor age, height, weight, ethnicity, history of hypertension and diabetes, cerebral vascular accident as cause of death, serum creatinine level, hepatitis C status, and donation after cardiac death status. The KDPI approach replaced the prior designations of donor quality, standard criteria donor, and extended criteria donor (ECD). Lower KDPI correlates with a better quality donor kidney, and estimated graft survival decreases as KDPI increases.² The four KDPI strata and their associated score ranges are sequences: A ($< 20\%$), B (>20 but $<35\%$), C (35 but $< 85\%$), or D ($>85\%$). In an effort to optimize resource allocation by longevity matching, KAS allocates kidneys within the lowest KDPI stratum, sequence A, to patients with the highest estimated post-transplant survival, with the latter based on age, duration of dialysis, prior organ transplant, and diabetes status. To increase utilization of more marginal kidneys and improve access through broader geographic sharing, kidneys within the highest KDPI stratum, sequence D (KDPI > 85), are allocated both locally and regionally from a single match run. However, recent data suggest that utilization of these organs actually decreased after the initial year of KAS implementation.³ This finding may be attributable not only to decreased KDPI-based organ quality but also to increased cold ischemia time when organs are transported regionally as opposed to locally, with a subsequent decreased willingness of transplant programs to use them.

As KDPI is a relatively new concept, the literature evaluating this metric's relationship to long-term outcomes is sparse compared to the prior ECD designation. Although ECD kidneys have been associated with a 70% higher risk of graft failure, it has been proposed that the transplant-related increase in patient survival may be advantageous, especially for candidates over age 40 with longer wait times and diabetes.⁴ Another study found no relative survival benefit for elderly recipients who received medium-quality versus lower quality kidneys.⁵ Markov modeling estimates indicate that the KDPI-based allocation policy promotes increased quality-adjusted life years at lower lifetime costs of care through improved age and quality matching between recipients and donor organs.⁶

While kidney transplantation is associated with significantly improved patient survival,⁷ studies of its effect on patient-reported health-related quality of life (HRQOL) have varied. Kidney transplant recipients have been reported to have generally better HRQOL, as measured by the “generic” Short Form 36 Health Survey (SF-36), compared to transplant candidates⁸ and to dialysis patients.^{9,10} Condition-specific norms for version 1 of the SF-36 indicate that physical component summary scores of persons with kidney disease average more than a standard deviation below that of the US general population, with the specific impact being in the physical functioning and general health scales.¹¹ However, Liem et al’s meta-analysis found that kidney transplant recipients’ scores did not differ from hemodialysis patients on six of eight SF-36 scales after adjusting for age and the prevalence of diabetes.¹⁰ Pinson et al reported no difference in SF-36 scale and summary component scores between kidney transplant candidates and recipients, which was related to the kidney candidates’ HRQOL being substantively less impaired and closer to general population norms than other solid organ transplant candidates.¹² Others have described SF-36 scale-specific effects,¹³ the relevance of kidney disease-specific HRQOL measures,^{13,14} and the absence of clinically relevant change in SF-36 scales after kidney transplantation.¹⁵

Previous reports have evaluated the effects of age, gender, duration of dialysis, retransplantation, obesity, steroid-based immunosuppression, employment, muscle weakness, and diabetes on the magnitude and trajectory of HRQOL scores after kidney transplantation.^{8,10,13,16–19} However, despite significant attention to survival outcomes for lower quality kidneys, whether measured by ECD or KDPI criteria, and multiple studies assessing HRQOL after renal transplantation, there are no longitudinal data specifically evaluating the effect of donor kidney quality on patient-reported HRQOL. With the recent KAS changes and the apparent decreased utilization of high KDPI kidneys, the primary aim of our study was to assess whether deceased donor kidney quality, as reflected by KDPI sequence, is related to post-transplant HRQOL and its trajectory. Our secondary aim was to compare the HRQOL of high KDPI recipients to those whose KDPI scores were less than or equal to 85 and to persons listed for kidney transplantation.

2 | MATERIALS AND METHODS

2.1 | Design and sample

Patient-reported longitudinal HRQOL data were collected at Vanderbilt University Medical Center in adult kidney transplant candidates and recipients under an IRB-approved protocol. A previously described survey battery was employed using a rolling enrollment process that maximizes the number of participants and follow-up duration by allowing persons to complete surveys at any monitoring point (pretransplant, at 1, 3, and 6 months, and annually after transplantation) regardless of whether they participated previously.²⁰

The recipient cohort included patients at least 18 years of age who underwent deceased donor kidney transplantation without an extrarenal simultaneous organ transplant and completed at least one post-transplant HRQOL survey data point. Kidney donor profile index scores were extracted from UNOS records or retrospectively determined from clinical records. Recipients were characterized based on the KDPI sequence of their donor organ: A (< 20%), B (>20–< 35%), C (35– 85%), and D (>85%). Additional clinical and

demographic variables included age at HRQOL (years), gender, history of previous kidney transplantation, whether there was an episode of biopsy-proven acute rejection within 6 months prior to a given HRQOL assessment, and post-transplant follow-up time (months) at each HRQOL assessment. A separate pretransplant cohort included adults who were waitlisted for kidney transplant.

2.2 | HRQOL measures

Health-related quality of life was measured using version 1 of the SF-36.²¹ This extensively validated instrument, which is widely used in kidney transplant research,²² is scored as 8 scales: physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional, and mental health. Physical and mental component summary scores (PCS and MCS) that are calculated from the 8 individual scales as differentially weighted composites are normed to the general population at a mean of 50 and standard deviation of 10. Higher scores represent better HRQOL. Data were interpreted in relation to SF-36 general population and kidney disease-specific norms,¹¹ and from the perspective of the half standard deviation effect size threshold for meaningful change or difference in HRQOL.²³

2.3 | Statistical methods

Multivariable linear mixed effects models were used to test the effects of KDPI sequence on the value and temporal trajectory of post-transplant HRQOL after adjusting for gender, age, previous kidney transplant, and whether acute rejection occurred within 6 months prior to a given HRQOL assessment. Ten separate outcomes, scores on the 8 SF-36 scales and the PCS and MCS, were tested using these prespecified models. Under this approach, which maximizes the number of longitudinal data points and does not require uniform data collection, the time by KDPI sequence interaction effect specifically evaluates whether the trajectories of post-transplant HRQOL differ on the basis of the quality of the deceased donor kidney.

Secondary cross-sectional analyses utilized all mixed effects model-estimated post-transplant scores by weighting them to determine a single post-transplant value per scale or summary component per recipient. Nonparametric median tests were used to: (i) compare the post-transplant HRQOL of KDPI sequence D recipients to those receiving sequence A through C kidneys (combined) and (ii) evaluate whether post-transplant PCS and MCS scores differed between the 4 KDPI sequences and from a kidney transplant candidate cohort. Nonparametric correlation coefficients and repeated measures analysis of variance evaluated the relationships between KDPI sequence and graft function, reflected by serum creatinine (SCr), at post-transplant years 1 and 3.

Some study data were collected and managed using Research Electronic Data Capture (REDCap) tools hosted at Vanderbilt University Medical Center. REDCap is a secure, web-based application designed to support data capture for research studies.²⁴ Analyses were performed using IBM SPSS (version 24, Armonk, NY, USA) statistical software, and statistical significance was interpreted if a nondirectional *P*-value was <.05.

3 | RESULTS

The sample included 505 kidney transplant recipients transplanted between January 2006 and June 2014 and a cohort of 141 wait-listed candidates (Table 1). There were a total of 1580 discrete post-transplant HRQOL measurements (range: 1–10 per patient). Participants' post-transplant follow-up at their last HRQOL measurement averaged 42 ± 28 months (range: <1–111).

Multivariable model-based estimates of the effects of KDPI sequence, age, gender, history of previous kidney transplantation, recent acute rejection, and time post-transplant at HRQOL measurement on post-transplant PCS and MCS are reported in Table 2. After adjusting for the negative relationship between age and PCS ($P < .001$), overall post-transplant PCS scores were stable (main effect of time $P = .212$) and *within general population norms* over the monitoring period and did not differ between the sequences (main effect of sequence $P = .400$). The temporal trajectories of post-transplant PCS scores did not differ between the KDPI sequences (time by sequence interaction $P = .472$) (Figure 1, Panel A). After adjusting for the negative effect on MCS of a recent rejection episode ($P = .019$), overall post-transplant MCS scores declined *while remaining within general population norms* over the monitoring period (main effect of time $P = .009$) and did not differ between the sequences (main effect of sequence $P = .789$). The temporal trajectories of post-transplant MCS scores did not differ between the KDPI sequences (time by sequence interaction $P = .548$) (Figure 1, Panel B). While the trend lines indicate that PCS and MCS scores of KDPI sequence D recipients may fall substantively below general population norms after year 5, the temporal trajectories of post-transplant scores did not differ statistically between the KDPI sequences. These findings were upheld in each of the scale-specific models in that there was no effect of KDPI sequence on post-transplant HRQOL (all KDPI sequence main effect $P > .134$) or its trajectory (all time by sequence interaction $P > .163$).

Secondary cross-sectional analyses weighted all multivariable model-based estimates of HRQOL to reflect 1 post-transplant point per recipient at an average follow-up time of 27 ± 24 months. Median tests demonstrated no effect of high KDPI (>85, sequence D) compared to sequences A through C (combined) on any SF-36 measure (all $P > .440$) (Figure 2). Based on box plot depictions of frequency distributions, wherein 75% of observations are represented within and below the box, kidney transplant recipients' post-transplant HRQOL was predominantly higher than SF-36 averages for US population kidney disease norms, with the most consistently higher scores being in the physical functioning, bodily pain, general health, and vitality scales. Consistent with the longitudinal analyses, subject-level estimated post-transplant PCS and MCS scores were predominantly within general population norms (40–60). Cross-sectional comparisons of weighted, model-estimated post-transplant and candidates' observed PCS and MCS scores demonstrated no difference between candidates' and KDPI-stratified recipients' scores (all $P = .060$) (Figure 3).

KDPI, stratified as the 4 sequences A through D, was positively associated with SCr at post-transplant years 1 and 3 (both $\rho = 0.35$, $P < .001$). Repeated measures model-estimated SCr values are depicted by KDPI sequence for the 455 recipients (90% of sample) having

longitudinal 1- and 3-year renal function data (Figure 4). Paired tests indicate no change in SCr for sequences A and B and that SCr increased significantly among sequence C recipients. The apparent increase among sequence D recipients did not reach statistical significance due to the limited sample size.

4 | DISCUSSION

Although kidney transplantation has been shown to be superior to dialysis in terms of survival and long-term costs of care, recent trends have shown increases in the number of waitlisted candidates while the organ supply remains unchanged. This imbalance has resulted in increased wait times and an increased number of patients removed from the waitlist due to death or a deteriorating medical condition. Additionally, the number of waitlist candidates aged 65 years or older has risen from 13.8% in 2004 to 21.2% in 2014.²⁵ One proposed solution for this disparity has been to maximally utilize available organs, even those deemed of lower quality. In an effort to promote lower quality kidney utilization, the recently implemented KAS calculates organ quality based on KDPI, with lower quality having a higher number, and allocates them regionally initially in an effort to have more centers consider them for their patients.

Despite this goal to increase use of high KDPI kidneys, recent 1-year data after the KAS implementation report a 7.9% decrease in utilization of these organs from 939 organs to 904 in the year prior and the year following implementation,³ and the reasons for this are likely multifactorial. Centers must now also accept a lower quality kidney as well as an increase in cold ischemia time for those organs transported regionally or nationally. Furthermore, cross-matches for compatibility often cannot be performed prior to the organ arrival, which increases the cold ischemia time of what is already considered a marginal organ. These organs are often being allocated to patients who would accept an organ of lower quality, such as the elderly or diabetics. Transplantation in these individuals has to be carefully weighed as cardiovascular events, infections, and malignancy occur disproportionately in elderly transplant recipients.^{26,27} In consideration of these negative outcomes, some transplanting physicians may choose not to utilize marginal organs under the assumption that the patient may not gain a substantial increase in survival or quality of life or that detriment to these may occur.

This is the first study to specifically evaluate the effect of donor organ quality, as reflected by KDPI sequence, on HRQOL after deceased donor kidney transplantation. We found that (i) increasing KDPI sequence does not adversely affect medium-term post-transplant HRQOL or its trajectory; (ii) the post-transplant HRQOL of high KDPI (>85%) recipients is statistically comparable to those recipients of kidneys with KDPI ≤85%; (iii) the post-transplant HRQOL of kidney transplant recipients is predominantly better than average SF-36 norms for persons with kidney disease; (iv) potentially substantive reductions in high KDPI recipients' HRQOL do not likely occur until after post-transplant year 5; and (v) high KDPI is associated with worse allograft function as measured by model-estimated SCr (Figure 4). Consistent with several previous reports, we did not find any statistically significant difference between kidney transplant candidates' and recipients' HRQOL. These

collective findings may reassure patients and centers when assessing the risks and benefits of accepting high KDPI kidney offers.

Strengths of this study include large sample sizes in two respects: that patient-reported HRQOL data were collected in over 500 recipients over up to 9 years and that these data encompassed over 5000 post-transplant time points. Additionally, the multivariable modeling methods accounted for factors that have previously been demonstrated to affect physical or mental HRQOL after solid organ transplantation including age,^{16,28,29} gender,¹⁶ rejection, and retransplantation.²⁹ Importantly, we interpret our data with respect to general population and clinical standards, which provide valuable reference points that augment statistical tests.

Limitations of our study include the limited sample size of the high KDPI (>85%) cohort, which included 16 patients, or 3% of the recipient sample. Although this is small, the overall national utilization of high KDPI kidneys was only 7.9% in the first year following KAS implementation³ and our statistical methods were designed to mitigate sample size imbalances. It is notable that although there are no statistically significant differences in HRQOL or its temporal trajectory between the 4 KDPI sequences, the graphical depictions of the data indicate that the sequence D observations begin to decrease for both the PCS and MCS scores (Figure 1A,B, respectively), falling below the indicator for clinically significant impairment from the norm for PCS and MCS at approximately 5.5 years, which is the estimated survival of sequence D organs.³⁰ These findings suggest there is clinical concordance to this dataset in that with deteriorating function, which is expected to occur earlier in sequence D allografts, patients may begin to experience deterioration in their HRQOL. This study, however, did not follow patients after graft failures occurred, and an evaluation of HRQOL postallograft failure would be a worthwhile exploration in future studies.

Analyzing graft function at and between post-transplant years 1 and 3 by sequence confirmed, in our dataset, that higher KDPI sequence was associated with worse allograft function (Figure 4). Despite overall worse allograft function, patients receiving sequence D kidneys reported HRQOL that was well within general population norms and statistically comparable to those in other sequences for several years post-transplant. They certainly did not do notably worse in terms of their HRQOL, which has been a concern for marginal organ acceptance.

During the first several years post-transplant, or medium-term, the values and temporal trajectories of HRQOL do not differ, and this has been consistent with other published reports on HRQOL after kidney transplantation.^{10–15} It may be postulated that patients on dialysis who go on to receive a kidney transplant likely have a HRQOL that is higher and within general population norms compared to those on dialysis who do not. Additionally, a patient receiving a high KDPI kidney should expect similar HRQOL post-transplant when compared to those receiving lower KDPI kidneys.

Our secondary analysis, which addressed whether a patient might do worse receiving a high KDPI kidney versus continuing to wait on dialysis for a better quality organ, suggests that

there is no difference in the HRQOL of the waitlisted cohort compared to any of the transplanted sequences A–D (Figure 3). This further confirms that those individuals receiving high KDPI kidneys are not disadvantaged when compared to either remaining on the waitlist or receiving a higher quality kidney. Again, this finding is likely related to the fact that pre-transplant patients' SF-36 HRQOL generally approximates general population norms and remains within these norms post-transplant for sustained periods of time.^{10–15} We recognize that the evaluation of HRQOL in our waitlisted patients is limited, and understanding the trajectory of HRQOL in patients during the waitlist period represents a worthwhile area for future investigation. In conclusion, although health-related quality of life may only have modest changes postkidney transplant, with most improvements being reported using kidney disease-specific scales, our findings indicate that even those who receive lower quality kidneys as represented by higher KDPI will experience no difference in their HRQOL or its trajectory post-transplantation compared to individuals who receive a lower KDPI or better quality organ. This may be reassuring to transplant programs and patients when making decisions regarding utilization of deceased donor kidneys with KDPI > 85%.

Acknowledgments

The project described was supported by CTSA award No. UL1TR000445 from the National Center for Advancing Translational Sciences. Its contents are solely the responsibility of the authors and do not necessarily represent official views of the National Center for Advancing Translational Sciences or the National Institutes of Health.

References

1. [Accessed August 15, 2017] http://optn.transplant.hrsa.gov/ContentDocuments/OPTN_Policies.pdf
2. [Accessed August 15, 2017] https://optn.transplant.hrsa.gov/media/1512/guide_to_calculating_interpreting_kdpi.pdf.
3. Stewart DE, Kucheryavaya AY, Klassen DK, Turgeon NA, Formica RN, Aeder MI. Changes in deceased donor kidney transplantation one year after KAS implementation. *Am J Transplant*. 2016; 16:1834–1847. [PubMed: 26932731]
4. Merion RM, Ashby VB, Wolfe RA, et al. Deceased-donor characteristics and the survival benefit of kidney transplantation. *JAMA*. 2005; 293:2726–2733.
5. Hernandez RA, Malek SK, Milford EL, Finlayson SR, Tullius SG. The combined risk of donor quality and recipient age: higher-quality kidneys may not always improve patient and graft survival. *Transplantation*. 2014; 98:1069–1076. [PubMed: 24918617]
6. Smith JM, Schnitzler MA, Gustafson SK, et al. Cost implications of new national allocation policy for deceased donor kidneys in the United States. *Transplantation*. 2016; 100:879–885. [PubMed: 26784114]
7. Wolfe RA, Ashby VB, Milford EL, et al. Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant. *N Engl J Med*. 1999; 341:725–1730. [PubMed: 10471458]
8. Overbeck I, Bartels M, Decker O, Harms J, Hauss J, Fangmann J. Changes in quality of life after renal transplantation. *Transplant Proc*. 2005; 37:1618–1621. [PubMed: 15866689]
9. Ogutmen B, Yildirim A, Sever MS, et al. Health-related quality of life after kidney transplantation in comparison intermittent hemodialysis, peritoneal dialysis and normal controls. *Transplant Proc*. 2006; 38:419–421. [PubMed: 16549136]
10. Liem YS, Bosch JL, Arends LR, Heijenbrok-Kal MH, Hunink MG. Quality of life assessed with the medical outcomes study short form 36-item health survey of patients on renal replacement therapy: a systemic review and meta-analysis. *Value Health*. 2007; 10:390–397. [PubMed: 17888104]

11. Ware, JE., Jr, Kosinski, M. SF-36® Physical & Mental Health Summary Scales: A Manual for Users of Version 1. 2. Lincoln, RI: QualityMetric Incorporated; 2001. p. 104
12. Pinson CW, Feurer ID, Payne JL, Wise P, Shockley S, Speroff T. Health-related quality of life after different types of solid organ transplantation. *Ann Surg.* 2000; 232:597–607. [PubMed: 10998658]
13. Neipp M, Karavul B, Jackobs S, et al. Quality of life in adult recipients more than 15 years after kidney transplantation. *Transplantation.* 2006; 81:1640–1644. [PubMed: 16794528]
14. Von der Lippe N, Waldun-Grevbo B, Reisaeter AV, Os I. Is HRQOL in dialysis associated with patient survival or graft function after kidney transplantation. *BMC Nephrol.* 2016; 17:94–103. [PubMed: 27456506]
15. Von der Lippe N, Waldun B, Brekke FB, Amro AAG, Reisaeter AV, Os I. From dialysis to transplantation: a 5-year longitudinal study on self-reported quality of life. *BMC Nephrol.* 2014; 15:191–199. [PubMed: 25465066]
16. Liu H, Feurer ID, Dwyer K, Speroff T, Shaffer D, Pinson CW. The effects of gender and age on health-related quality of life following kidney transplantation. *J Clin Nurs.* 2008; 17:82–89. [PubMed: 18088260]
17. Zaydfudim V, Feurer ID, Moore DR, Moore DE, Pinson CW, Shaffer D. Pre-transplant overweight and obesity do not affect physical quality of life after kidney transplantation. *J Am Coll Surg.* 2010; 3:336–344.
18. Villeneuve C, Laroche M-L, Essig M, et al. Evolution of determinants of health-related quality-of-life in kidney transplant patients over the first 3 years after transplantation. *Transplantation.* 2016; 100:640–647. [PubMed: 26569063]
19. Dukes JL, Seelam S, Lentine KL, Schnitzler MA, Neri L. Health-related quality of life in kidney transplant patients with diabetes. *Clin Transplant.* 2013; 27:E554–E562. [PubMed: 23902276]
20. Feurer ID, Russell RT, Pinson CW. Incorporating quality of life and patient satisfaction measures into a transplant outcomes assessment program: technical and practical considerations. *Prog Transplant.* 2007; 17:121–128. [PubMed: 17624134]
21. Ware, JE., Jr, Kosinski, M., Gandek, B. SF-36® Health Survey: Manual & Interpretation Guide. Lincoln, RI: QualityMetric Incorporated; 1993.
22. Butt Z, Yount SE, Caicedo JC, Abecassis MM, Cella D. Quality of life assessment in renal transplant: review and future directions. *Clin Transplant.* 2008; 22:292–303. [PubMed: 18482050]
23. Norman GR, Sloan JA, Wyrwich KW. Interpretation of changes in health-related quality of life. The remarkable universality of half a standard deviation. *Med Care.* 2003; 41:582–592. [PubMed: 12719681]
24. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) – A meta-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009; 42:377–381. [PubMed: 18929686]
25. Hart A, Smith JM, Skearns MA, et al. OPTN/SRTR 2014 Annual Report, Kidney. 2014
26. Martins PN, Pratschke J, Pascher A, et al. Age and immune response in organ transplantation. *Transplantation.* 2005; 79:127–132. [PubMed: 15665758]
27. Kappes U, Schanz G, Gerhardt U, Matzkies F, Suwelack B, Hohage H. Influence of age on the prognosis of renal transplant recipient. *Am J Nephrol.* 2001; 21:259–263. [PubMed: 11509796]
28. Neri L, Dukes J, Brennan DC, et al. Impaired renal function is associated with worse self-reported outcomes after kidney transplantation. *Qual Life Res.* 2011; 20:1689–1698. [PubMed: 21479956]
29. Kensinger CD, Feurer ID, O'Dell HW, et al. Patient-reported outcomes in liver transplant recipients with hepatocellular carcinoma. *Clin Transplant.* 2016; 30:1036–1045. [PubMed: 27291713]
30. [Accessed August 15, 2017] http://optn.transplant.hrsa.gov/ContentDocuments/KDPI_Guide_Clinicians.pdf.

FIGURE 1.

All post-transplant SF-36 physical component summary (PCS) and mental component summary (MCS) scores are plotted over time, stratified by KDPI sequence, and temporal trajectories are compared via the time by sequence interaction effect. The solid horizontal reference lines indicate the lower and upper values for observations that are within 1 standard deviation of the general population average (50 ± 10). The dashed red reference line at 35 indicates the threshold for scores that are substantively (ie, greater than a half standard deviation) below the general population norm. Panel A, average post-transplant PCS scores (41 ± 11) were within general population norms, and their temporal trajectory did not differ on the basis of KDPI sequence. Panel B, average post-transplant MCS scores (51 ± 11) remained within general population norms over the monitoring period, and their temporal trajectories did not differ on the basis of KDPI sequence.

FIGURE 2.

Box plots of model-estimated, post-transplant SF-36 scale and summary component scores by whether KDPI sequence D (KDPI $> 85\%$) or sequences A through C combined (KDPI $\leq 85\%$) and median tests demonstrated no effect of high KDPI on post-transplant HRQOL. Solid square markers between box pairs indicate average scores for SF-36 version 1 US general population norms, and the solid oblong markers represent average scores derived from kidney disease norms. Scale and component abbreviations are as follows: PF, physical functioning; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, role emotional; MH, mental health; PCS, physical component summary; MCS, mental component summary

FIGURE 3.

Box plots of observed waitlisted candidates' PCS and MCS scores and model-estimated, post-transplant scores stratified by KDPI sequence and median tests demonstrate no difference between candidates' and KDPI-stratified recipients' scores. The solid horizontal reference lines reflect general population norm ranges, and the dashed reference line indicates the threshold for scores being substantively (more than a half standard deviation) below the general population

FIGURE 4.

Model-estimated serum creatinine values at 1 and 3 y post-transplant for KDPI sequences AD. Consistent with the 1- and 3-y univariate correlation coefficients indicating that KDPI sequence is positively associated with SCr, within-subjects average post-transplant SCr values confirm that sequence D recipients have reduced graft functioning compared to sequences A, B, and C (all Dunnett's test P -values $\leq .011$)

TABLE 1

Patient sample and HRQOL observations by cohort

Cohort	Patient-level data	HRQOL observations
Waitlisted candidates	141	141
Age at listing HRQOL (y)	49 (12)	n/a
Male gender	80 (56.7)	n/a
Transplant recipients	505	1580
Age at transplant (y)	51 (12)	n/a
Male gender	277 (54.9)	n/a
KDPI sequence		
A (20%)	139 (27.5)	438 (27.7)
B (21%–34%)	98 (19.4)	288 (18.2)
C (35%–85%)	252 (49.9)	805 (50.9)
D (>85%)	16 (3.2)	49 (3.1)
Previous kidney transplant	25 (0.05)	67 (0.04)
Rejection within 6 mo prior to post-transplant HRQOL	15 (0.03) ^a	16 (0.01) ^b
Follow-up time (mo)	42 (28) ^a	31 (26) ^b

Table entries are frequencies (percent) or mean (SD).

^aPatient-level characteristic.

^bTime-varying covariate, computed over all post-transplant observations.

n/a = not applicable.

TABLE 2

Multivariable models of post-transplant PCS and MCS

Effect	PCS			MCS		
	Estimate	95% CI	P-value	Estimate	95% CI	P-value
Male (ref: female)	1.44	-0.32, 3.20	.109	0.87	-0.82, 2.56	.314
Age (y)	-0.06	-0.09, -0.03	<.001	-0.02	-0.05, 0.01	.188
No rejection proximal to HRQOL (ref: rejection)	-1.10	-5.48, 3.28	.623	5.15	0.86, 9.45	.019
No retransplant prior to HRQOL (ref: retransplant)	0.23	-3.70, 4.16	.908	-0.01	-3.79, 3.76	.994
Time post-transplant at HRQOL (mo)	-0.02	-0.06, 0.01	.212	-0.04	-0.08, -0.01	.009
KDPI sequence			.400			.789
Sequence B (ref: A)	-0.91	-3.91, 2.10	.554	-1.44	-4.34, 1.46	.330
Sequence C (ref: A)	1.96	-0.39, 4.30	.102	-0.79	-3.05, 1.47	.494
Sequence D (ref: A)	1.22	-4.71, 7.16	.686	-1.28	-7.01, 4.45	.661
Time by KDPI sequence interaction			.472			.548
Intercept	43.75	37.50, 50.00	<.001	48.35	42.28, 54.42	<.001