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Association of Karnofsky Performance Status with waitlist mortality among older and younger adults awaiting kidney transplantation

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Abstract

Patients with end-stage renal disease (ESRD) have impaired functional status compared with the general population. We sought to explore the association between Karnofsky Performance Status (KPS) and death/delisting from the kidney transplantation waitlist and whether this association differed by age. Patients listed for single-organ kidney transplantation in the United Network for Organ Sharing/Organ Procurement and Transplantation Network from January 1, 2015, to January 1, 2018, were included. We performed competing-risk regression analyses to determine the association between KPS ("Severely impaired", "Moderately impaired", "Non-impaired") and death/delisting, with deceased-donor kidney transplantation as a competing risk. We tested for interactions between age and KPS on death/delisting. Of the 89,819 patients analyzed, 39% were impaired (KPS < 80) and 20% were aged ≥ 65 years. Older age and lower KPS were independently associated with higher risk of death/delisting (age 45–64 years, HR 1.97 [95% CI 1.73–2.24]; age ≥ 65 years, HR 3.62 [95% CI 3.33–3.92] compared with age < 45 years; moderately impaired, HR 1.68 [95% CI 1.45–1.95]; severely impaired, HR 4.80 [95% CI 3.71–6.21] compared with non-impaired). Lower KPS was associated with higher risk of death/delisting

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AUTHORS' CONTRIBUTIONS

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CONFLIC T OF INTEREST

The authors declare no conflicts of interest.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

among all ages, but this effect was slightly less pronounced among individuals aged ≥ 65 years. Performance status should be used when counseling patients with ESRD on their risks for death/delisting.

Keywords

age; delisting; end-stage renal disease; Karnofsky Performance Status; waitlist

1 | INTRODUCTION

The prevalence of ESRD in the United States is rising particularly steeply among older adults. From 2006–2016, the prevalence of ESRD rose by 21% in individuals aged ≥ 65 years compared with 16% for younger persons.[1] Patients with ESRD have impairments in functional status and quality of life[2–4] that are similar to those found in adults without chronic kidney disease who are 65 years or older,[5–8] and older patients treated with dialysis are more likely than younger ones to have substantial functional impairment. Indeed, in one study, nearly two-thirds of dialysis patients over 50 years of age and more than 75% of those older than 60 years had substantial impairment.[6] Given that an increasing proportion of older adults are seeking kidney transplantation, a better understanding of how functional status is related to waitlist outcomes and whether this association varies by age is greatly needed.

Prior research in patients awaiting kidney transplantation has shown that frailty[9] and impaired physical function[10] are associated with a higher risk of death or delisting. Specifically, frailty (as measured by three or more of the following criteria: unintentional weight loss of more than 10 lbs. in the past year, self-reported exhaustion, low grip strength, slow walking speed, or low physical activity)[5] has been shown to be associated with a 119% higher risk of death while on the waitlist[9] and a 32% decreased likelihood of successful transplantation compared with non-frail candidates.[11] Moreover, those with the lowest physical function (as measured by the physical component scale of the Short Form 36 health survey [SF-36]) experienced a 36% lower transplantation rate than those with the highest level of function.[10] However, these studies utilized tools that require either in-person testing, which can be cumbersome due to the length of time required to administer the tests, or candidate self-reporting. For these reasons, these tools have not achieved widespread adoption at transplant centers. In addition, though there has been a call to standardize measurement and application of frailty or other objective measures of physical function or performance across kidney transplantation, this has not yet reached clinical practice.[1,12]

On the other hand, the Karnofsky Performance Status (KPS) scale is a tool that originated in the field of oncology to capture functional status for the purposes of predicting response to more intense and tumor-specific vs symptomatic treatment of tumors.[13,14] It has been validated in patients receiving dialysis[15,16] and has the advantage of being quick and easy to administer in clinical practice by the clinician or transplant coordinator. Furthermore, as a requirement of listing for kidney transplantation in the United Network for Organ Sharing (UNOS)/Organ Procurement and Transplantation Network (OPTN), all kidney transplant candidates must have their performance status—as measured by the KPS—recorded in the

national registry at listing. In fact, KPS is the only surrogate for physical function that is currently nationally mandated for reporting.[17] Prior studies have evaluated the association of KPS with post-transplant outcomes[18] but not with death or delisting.

Therefore, we sought to leverage KPS data available on all kidney transplant candidates in the US to evaluate the relationship between age, functional status, and death or delisting. We hypothesized that age and functional impairment would be independently associated with higher risk of death or delisting among transplant candidates. We further hypothesized that functional impairment would be more strongly associated with risk of death or delisting among older compared with younger kidney transplant candidates.

2 | METHODS

2.1 | Participants

All patients listed for primary single-organ kidney transplantation in the United Network for Organ Sharing/Organ Procurement and Transplantation Network (UNOS/OPTN) registry from January 1, 2015, to January 1, 2018, were evaluated for inclusion in this study. Data were obtained from the UNOS/OPTN registry as of April 06, 2018. This timeframe was chosen such that all included patients would be listed under the new Kidney Allocation System (effective December 4, 2014). We excluded patients who were <18 years of age (N = 3123), had a previous organ transplantation (N = 12 163), were listed for simultaneous kidney-pancreas transplantation (N = 3575), lacked KPS data at the time of listing (N = 1777), or were listed in error or were duplicates listed simultaneously at multiple centers (N = 3614).

2.2 | Independent variables

The primary independent variables were KPS and age. KPS at the time of listing was categorized into three strata based on previously established cutoffs from studies of hospitalized patients with ESRD,[19] elderly patients on maintenance hemodialysis,[20] and other abdominal transplant patients[21–23]:10–40 (“Severely Impaired”), 50–70 (“Moderately Impaired”), or 80–100 (“Non-Impaired”). To facilitate clinical interpretation of our analyses, age was categorized as <45, 45–64, and ≥65 years based on mortality data for patients with ESRD.[24]

2.3 | Covariates

Potential covariates included date of listing, sex, age at the time of listing, race or ethnicity, BMI at the time of listing, ABO group, initial Calculated Panel Reactive Antibodies (CPRA) at the time of listing, UNOS region, center volume of transplantation (calculated from UNOS data), cause of kidney disease, and time on dialysis (“dialysis vintage”). Volume of transplantation was categorized as low, medium, or high based on tertiles of transplantations performed per year. Causes of kidney disease were grouped into the following diagnostic categories: glomerular disease (including IgA nephropathy, membranous glomerulonephritis, focal segmental glomerulosclerosis, lupus nephritis, and other glomerulonephritis), diabetes, hypertension, cystic disease (including polycystic kidney disease and medullary cystic disease), and other causes of end-stage renal disease.

2.4 | Statistical analysis

Patients' baseline characteristics at the time of listing for transplantation were summarized as median [interquartile range (IQR)] for continuous variables or frequency and percentage for categorical variables. We performed non-parametric tests for baseline characteristics at the time of listing across age categories and across KPS categories.

The primary outcome was death or delisting for being "medically unsuitable" or "too sick for transplant" (removal codes 5 and 13, respectively). Patients who remained alive on the waitlist at the end of follow-up were conventionally censored at the date of last follow-up (4/6/18). We performed competing-risk regression under the Fine-Gray model[25] to examine the association of KPS with death or delisting in univariable and multivariable analysis. Deceased-donor kidney transplantation (DDKT) was treated as a competing risk. Patients who underwent living donor kidney transplantation were censored at the time of their transplantation, as living donor transplantation is often a function of having a living donor available and not necessarily correlated with other factors predictive of survival on the waitlist. We also performed sensitivity analyses treating living donor kidney transplantation as a competing risk, as well as analyses examining the association of KPS without further categorization (ie, 10–100 inclusive) with death or delisting. We also performed sensitivity analyses with categories of KPS but excluding patients who were not on dialysis at time of listing as well as excluding living donor transplantation in order to examine the association between KPS and death or delisting in a more homogenous population. Finally, to examine whether or not there was a possible bolus of patients with greater degrees of impairment undergoing transplantation after the implementation of the Kidney Allocation System, we compared the cumulative incidences of delisting, deceased-donor transplantation, and living donor transplantation at 6 months from listing for patients in the primary analysis who were listed from January 1, 2015, to December 31, 2015, with those who were listed from January 1, 2016, to December 31, 2016.

Unadjusted models were used to assess the association of all listed covariates with the outcome. All covariates with *P*-values < .2 in univariate analysis were considered for inclusion in multivariable models. Those not reaching significance of $P < .05$ were sequentially eliminated. Center volume of transplantation did not meet the threshold of $P < .2$, but we retained this covariate as a surrogate for experience in transplantation that might influence the chance of delisting for patients with low KPS or of higher age. Therefore, our final models for multivariable analyses were adjusted for sex, race and ethnicity, blood type, cause of ESRD, UNOS region, and dialysis vintage, similar to models in prior literature.[10,18] Center volume of transplantation was included in the model as a group-level variable. We used multiple imputation techniques to impute values for any covariate with >1% missingness. We estimated adjusted subhazard ratios and cumulative incidence of death or delisting at 6 months from listing based on the competing-risk model for each stratum of KPS and age. Finally, to evaluate whether the association between functional status and death or delisting differed by age, we tested for an interaction between age and KPS on the primary outcome.

Two-sided *P*-values < .05 were considered statistically significant. Statistical analyses were performed using Stata, version 14 (StataCorp).

2.5 | Ethics

This study was considered exempt by the Institutional Review Board at the University of California, San Francisco.

3 | RESULTS

3.1 | Baseline patient characteristics by KPS category

A total of 114 521 patients were listed for kidney transplantation during the study period, and 89 819 patients included in this study after exclusion criteria were applied (Table 1). Of these, 61% were not impaired, 35% had moderate impairment, and 4% had severe impairment (Figure 1). Among those who were not impaired, there was a higher proportion of patients aged < 45 years than among patients with moderate or severe impairment. When examining patients by age category, among patients < 45 years of age, 65% were non-impaired, 32% moderately impaired, and 3% severely impaired. For patients aged 45–64, 59% were non-impaired, 37% moderately impaired, and 4% severely impaired, and for those ≥65 years of age, 58% were non-impaired, 39% moderately impaired, and 3% severely impaired.

Fifty-seven percent of non-impaired patients were on dialysis at time of listing, compared to 80% of patients with moderate impairment and 64% of severely impaired patients. Being in a higher stratum of KPS was also associated with being on dialysis for a greater number of years at the time of listing (*P*-value for trend < .01). Finally, participants with lower levels of KPS were less often still working for an income at time of listing, with only 5% of those with severe impairment still working at time of listing.

3.2 | Cumulative incidence of outcome events by degree of functional impairment

During follow-up, patients with better functional status were less likely to die or be delisted for being too stick for kidney transplantation (2% for non-impaired, 3% for moderately impaired, and 6% for severely impaired; *P*-value < .01). The likelihood of receiving a DDKT also differed across performance status categories: At censored time, 8% of those without impairment had a DDKT, compared with 12% of those with moderate impairment and 30% of those with severe impairment ($P < .01$). Conversely, 8% of non-impaired patients received a living donor kidney transplant, compared with 4% of patients with moderate impairment, and 2% of patients with severe impairment ($P < .01$).

3.3 | Association between age, KPS, and death or delisting

In univariable analysis, compared with those without impairment, patients with moderate impairment had a 63% higher risk of death or delisting (HR 1.63; 95% CI 1.55–1.72), and patients with severe impairment had a 299% higher risk of death or delisting (HR 3.99; 95% CI 3.64–4.39) (Table 2). Age was also strongly associated with death or delisting in univariable analysis (HR 2.16 [95% CI 1.99–2.34] for age 45–64 years and 3.79 [95% CI 3.48–4.12] for age ≥ 65 years compared with patients < 45 years).

In multivariable analysis, after adjusting for sex, race and ethnicity, blood type, cause of ESRD, UNOS region, center volume of transplantation, and dialysis vintage, level of KPS

(moderately impaired, HR 1.68 [95% CI: 1.45–1.95]; severely impaired, HR 4.80 [95% CI 3.71–6.21]) and category of age (45–64 years, HR 1.97 [95% CI: 1.73–2.24]; ≥65 years, HR 3.62 [95% CI 3.33–3.92]) remained important predictors of death or delisting.

Next, we investigated the *combined* effect of performance status and age on death or delisting. In univariable analysis among patients of each age category, being moderately or severely impaired was associated with a higher risk of death or delisting regardless of age category (Table 3). In multivariable analyses, the associations between level of impairment and death or delisting remained significant at each category of age (Figure 2).

3.4 | Interaction between age, KPS, and death or delisting

For the youngest patients (<45 years), and compared to non-impaired patients, moderate impairment was associated with an adjusted HR of 1.58 (95% CI 1.43–1.76) and severe impairment an adjusted HR of 4.93 (95% CI 3.46–7.02). However, among the oldest patients (aged ≥ 65 years), the associations of level of KPS with death or delisting were HR 1.34 (95% CI 1.29–1.39) for moderate impairment and HR 2.83 (95% CI 2.47–3.23) for severe impairment, compared with non-impaired patients. Therefore, when examining combinations of age category and KPS, we found that for the oldest patients (≥65 years) the magnitude of effect for the association between KPS and death or delisting for moderately and severely impaired patients was less than the magnitude of effect for the same associations between KPS and death or delisting for younger patients. When formally testing for interaction, the *P*-value for the test of interaction for patients ≥ 65 years with moderate impairment was .01 and the *P*-value for interaction for patients ≥ 65 years with severe impairment was < .01.

3.5 | Sensitivity Analyses

We found no significant differences in associations or interactions when treating both DDKT and living donor kidney transplantation as competing risks (data not shown). When examining the association between the entire spectrum of KPS (ie, no additional categorization) and death or delisting, each level of KPS remained predictive of death or delisting with worse KPS within each category of age associated with a higher likelihood of death or delisting. This association was significant at every KPS level within every category of age except when comparing patients with KPS of 90 to those with KPS of 100 for waitlisted patients less than 45 years of age (Table S1). A sensitivity analysis excluding patients who were not on dialysis at time of listing and those who went on to undergo living donor transplantation had similar results to the primary analysis except that there was no significantly higher hazard for death or delisting when comparing moderate impairment to no impairment in patients aged 65 years or older. Patients with severe impairment still had an increased risk for death or delisting (HR 1.71; 95% CI 1.29–2.28) (Table S2). Finally, there was a similar trend in cumulative incidences of death or delisting, deceased-donor transplantation, and living donor transplantation when comparing patients listed from January 1, 2015 to December 31, 2015 with those listed from January 1, 2016 – December 31, 2016 (Table S3).

3.6 | Missing data

There were no missing observations for any covariates under analysis with the exception of 5 entries with a missing diagnosis of ESRD. Because of the very small percentage of missing data, no further imputation was performed.

4 | DISCUSSION

Using national registry data from patients listed for kidney transplantation in the United States from 2015–2018, we observed high rates of functional impairment as assessed by the KPS; nearly 40% displayed moderate (KPS 50%−70%) or severe (KPS ≤ 40%) functional impairment at the time of listing. Patients with functional impairment (KPS < 80%) tended to be older, female, were more often black or Hispanic, were more likely to be on dialysis at the time of listing for transplantation, and had spent more time on dialysis. Compared with those with higher performance status, patients with lower KPS also had higher proportions of ESRD related to diabetes and were less likely to still be working at time of transplantation. KPS was strongly associated with death or delisting within each age category. Patients with moderate impairment (KPS 50–70) or severe (KPS ≤ 40) impairment in performance status at the time of listing for kidney transplant had a 68% and 380% higher risk of death or delisting for being too sick for kidney transplant, respectively. Patients aged 65 years or older with severe impairment had the single highest risk of death or delisting overall. Interestingly, despite the overall association between category of age and death or delisting, we found that the magnitude of the association between functional status and death or delisting among those with functional impairment (defined by KPS ≤ 70) was relatively *smaller* (but still substantial) in kidney transplant candidates aged ≥ 65 years than in those aged < 65 years.

These analyses offer meaningful data to inform our conversations with patients with ESRD considering or awaiting kidney transplantation. Severe functional impairment (KPS < 50) was associated with higher risk of death or delisting for all patients, but especially among younger patients. Even if these patients survive to kidney transplantation, prior data have demonstrated that severe functional impairment is associated with changes in health-related quality of life independent of age even post–kidney transplantation.[26] Given the substantially higher risk of death or delisting associated with impaired performance status, assessment of KPS in the clinical setting may be best utilized as a rapid assessment tool to trigger a more objective, performance-based assessment of physical function—such as the Short Physical Performance Battery (SPPB)[27]—which can then be used for timely referral to physical therapy or structured exercise for even younger adults with functional impairment, who might otherwise not be considered for referral (given their chronologic youth). It is possible that younger patients with a KPS < 50 have qualitatively different severity or types of disease than older patients in this same category. However, if it were possible to improve functional impairment from severe to non-impaired in this group, their risk would be theoretically decreased almost fivefold (compared to threefold for patients aged 45–64 years and halved for patients older than 65 years). Younger patients with even moderate functional impairment may represent an important target population not only for intensive prehabilitation but also from additional resources to support an accelerated

path to transplant, including accepting a higher risk donor kidney or living donor kidney transplantation.[28]

Conversely, our analyses provide an important message for older patients as well. Severe and moderate impairment in the oldest patients carried the highest risks of death or delisting among the entire patient cohort. First, given that there is known disparity between information provided when presenting transplantation as a potential renal replacement therapy to older vs younger patients,[29] taking KPS into account may help providers present a more complete picture to patients. Older patients in particular may have particular psychosocial concerns about pursuing kidney transplantation[30] and such a conversation could take place without necessarily bringing up the concept of frailty, which can have negative connotations for some older patients.[31] Second, given that functional status is potentially modifiable in patients with ESRD,[3,32–34] prehabilitation should certainly still be considered for these patients. Intervening on functional impairment could potentially lower risk of death or delisting into the range of some younger patients. Indeed, although about 20% of adults ≥ 65 years who had preserved their functional status (as evidenced by KPS ≥ 80) met our primary outcome of death or delisting, the risk for these patients was less than adults aged < 45 years with severe impairment. Rather than being used solely as a tool for delisting, performance status can be used to identify older, non-impaired patients who have a lower risk of death or delisting than others of their chronological age and therefore should be referred for further risk stratification.

Patients and their caregivers should be counseled that although age is a risk factor for death or delisting, maintenance of functional status may represent a path to modifying that risk. We recognize that the KPS is subjective in nature which may affect the reliability and reproducibility of the KPS score. However, its advantage is that it is very easy and quick to use in clinical practice and may serve as a useful screening tool to rapidly identify younger, more impaired candidates or older, more robust patients for further risk stratification through the use of more objective measures of physical function, or more comprehensive geriatric assessment,[35] which in turn can be used to guide multidisciplinary interventions[34] on functional status prior to transplantation. Prehabilitation through use of outpatient physical therapy sessions has already been successfully piloted in kidney transplant,[36] and trials of other interventions should also be considered.[37]

We offer two main explanations as to why the results from our analyses differed from what we hypothesized. It is certainly possible that for younger patients to become severely or moderately impaired requires a greater overall burden of comorbidity or reflects severity of disease that results in higher death or delisting. That is, age and functional impairment may, to some extent, co-exist and, as a result, lower functional impairment may be more significant for a younger patient. An alternative explanation is selection bias; adults with ESRD who are older or who meet criteria for frailty[11] are less likely to be accepted for kidney transplantation than younger adults, and those who are accepted for waitlisting tend to be highly selected.[38,39] The higher rates of death or delisting among older adults in all KPS categories were largely driven by delisting for being too sick for transplant (rather than death on the waitlist), supporting the notion that functional status plays a greater role in providers' perceptions of suitability for transplant surgery in older vs younger candidates.

Of note, we found that a higher percentage of patients with more severe impairment obtained deceased-donor kidney transplantation when compared to patients with lower levels of impairment. A significant portion of this discrepancy can be explained by the very few living donor kidney transplantations in those with the most severe impairment. However, although the likelihood of death or delisting was much higher in this category, the overall rate of transplantation is still higher than expected. Our sensitivity analysis examining the cumulative incidence of death or delisting, deceased-donor transplantation, or living donor transplantation implies that this was not simply a bolus effect of patients with high degrees of impairment being transplanted after implementation of the Kidney Allocation System. It may be that this is because KPS takes into account impairment as a whole and not solely impairment that might be used to determine surgical risk, thereby providing a different perspective of a patients' overall health. Patients in the most severely impaired category may benefit the most from further risk stratification with objective measurements of functional status such as the SPPB.[27] It is also notable that the most severely impaired patients were not on dialysis for as long as patients with less impairment, which is counterintuitive. However, one study of the impact of risk factors on performance status in dialysis patients showed that older age with higher albumin or longer treatment years, or higher creatinine with longer treatment years significantly decreased odds of obtaining a low KPS score as conducted by trained assessors at in-person visits.[40] It may be that more robust patients are able to tolerate dialysis for longer periods of time before feeling that they need to seek transplantation or that more severely impaired patients are more highly motivated to seek transplantation as a way to improve quality of life. Unfortunately, the UNOS database does not include direct capture of dialysis modality (peritoneal dialysis [PD] vs hemodialysis [HD]), which may have influenced our findings on treatment years.

We acknowledge that the KPS carries with it a certain ambiguity and by itself is not an ideal test for physical function or frailty. However, as the only metric that offers insight into a patient's functional status available in the national registry, the KPS represents an important foundation to provide a general understanding of the association between functional status and transplant outcomes by age-groups. We also acknowledge that there are relatively few patients who fall into the most severely impaired category (4%). However, our sensitivity analysis using the entire spectrum of KPS (Table S1) showed similar results to our categorized analysis and indeed hazards for death or delisting followed a similar pattern as with categories of KPS. The fact that the UNOS database only includes patients who were approved for listing for kidney transplantation is another limitation of our study, as selection bias may have played a role in our findings on the differential impact of functional status on death or delisting among older adults (and is the most likely explanation for their being relatively few patients with KPS 10–40). For example, one study showed that compared with non-frail patients, frail patients had almost half the likelihood of being listed for transplantation.[11] There may also be factors such as differential social support or dialysis modality that are not captured by UNOS that lead to a smaller effect of impairment on older patients. However, in at least one observational study, choice of initial dialysis modality [PD vs HD] was associated with equivalent waitlist mortality.[41] It is also possible that older patients are subjected to more thorough testing by transplant centers and indeed possible that some patients in this analysis did go on to obtain physical therapy or exercise interventions

prior to transplantation. Another limitation of our study is that we categorized age rather than analyze age as a continuous variable. We did this to facilitate clinical interpretation of our analyses, although we recognize that a 64-year-old may not be substantially different physiologically from a 66-year-old.

Despite these limitations, our data demonstrate the added prognostic value of physical function in assessing waitlist mortality. Functional impairment and age are both risk factors for death and delisting. The effect of functional impairment is less profound for older patients than for younger patients, but the combination of older age and functional impairment is nevertheless associated with a very high risk of death or delisting. There is no definitive upper age limit for kidney transplantation, and there is a need for tools to better predict waitlist mortality for elderly patients.[42] A metric like KPS is appropriate to convey *risk* to patients and could be potentially useful in counseling patients about their likelihood of surviving to transplant. In addition, these data highlight the potential for interventions to maintain or improve functional status such that younger and older patients remain healthy enough to receive their transplant[12] and may affect clinical decision-making for younger impaired patients and robust older patients. Although KPS itself is not an ideal criterion, research could potentially follow a similar pathway to that of liver transplantation, leading from evaluation of KPS to formation of objective and standardized measures for use in clinical practice.[43] Further studies are needed to determine whether improving functional status ultimately reduces death or delisting, but our data provide further scientific premise for the development of interventions targeting functional status in patients awaiting kidney transplantation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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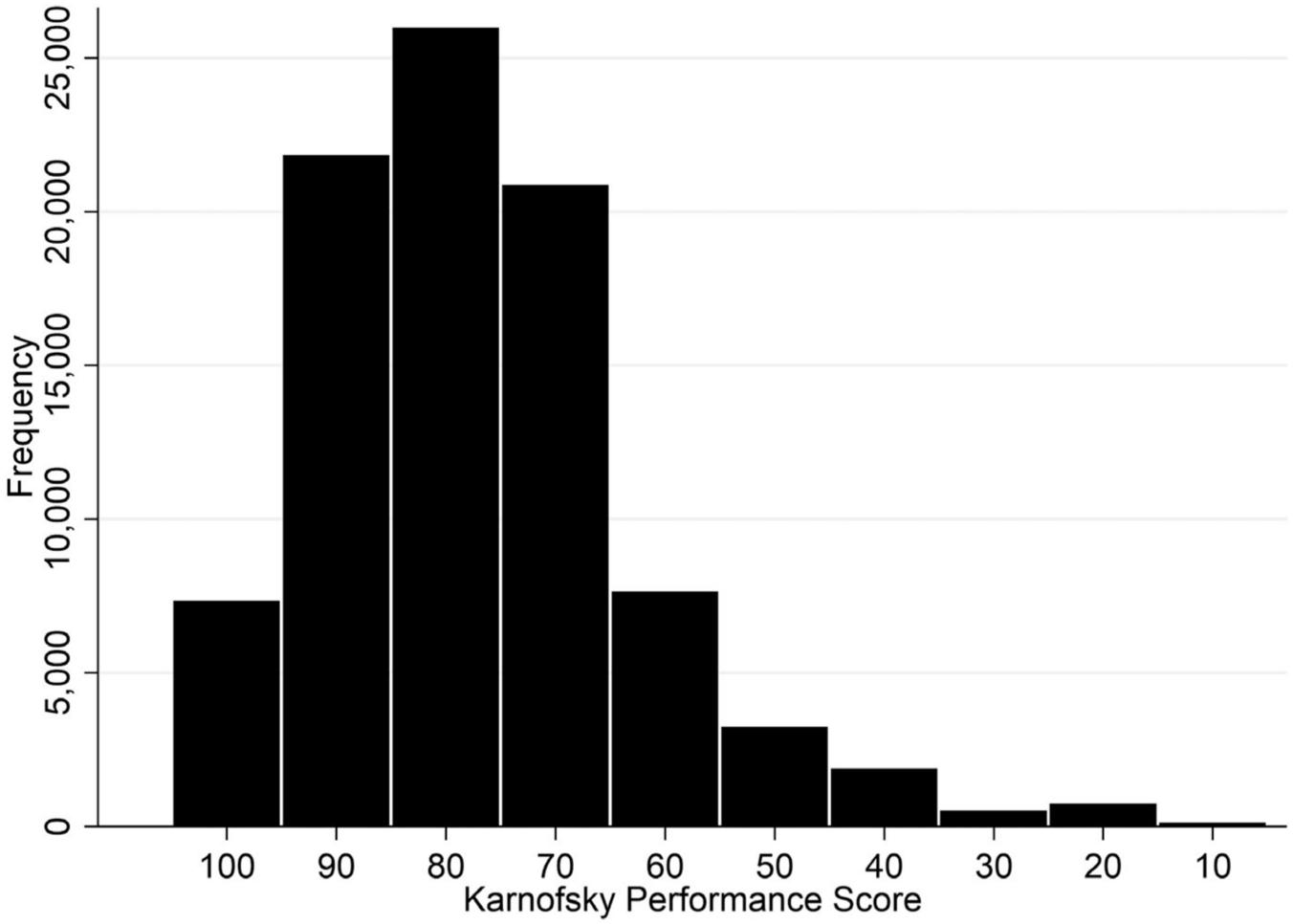

FIGURE 1.
Distribution of Karnofsky performance scores

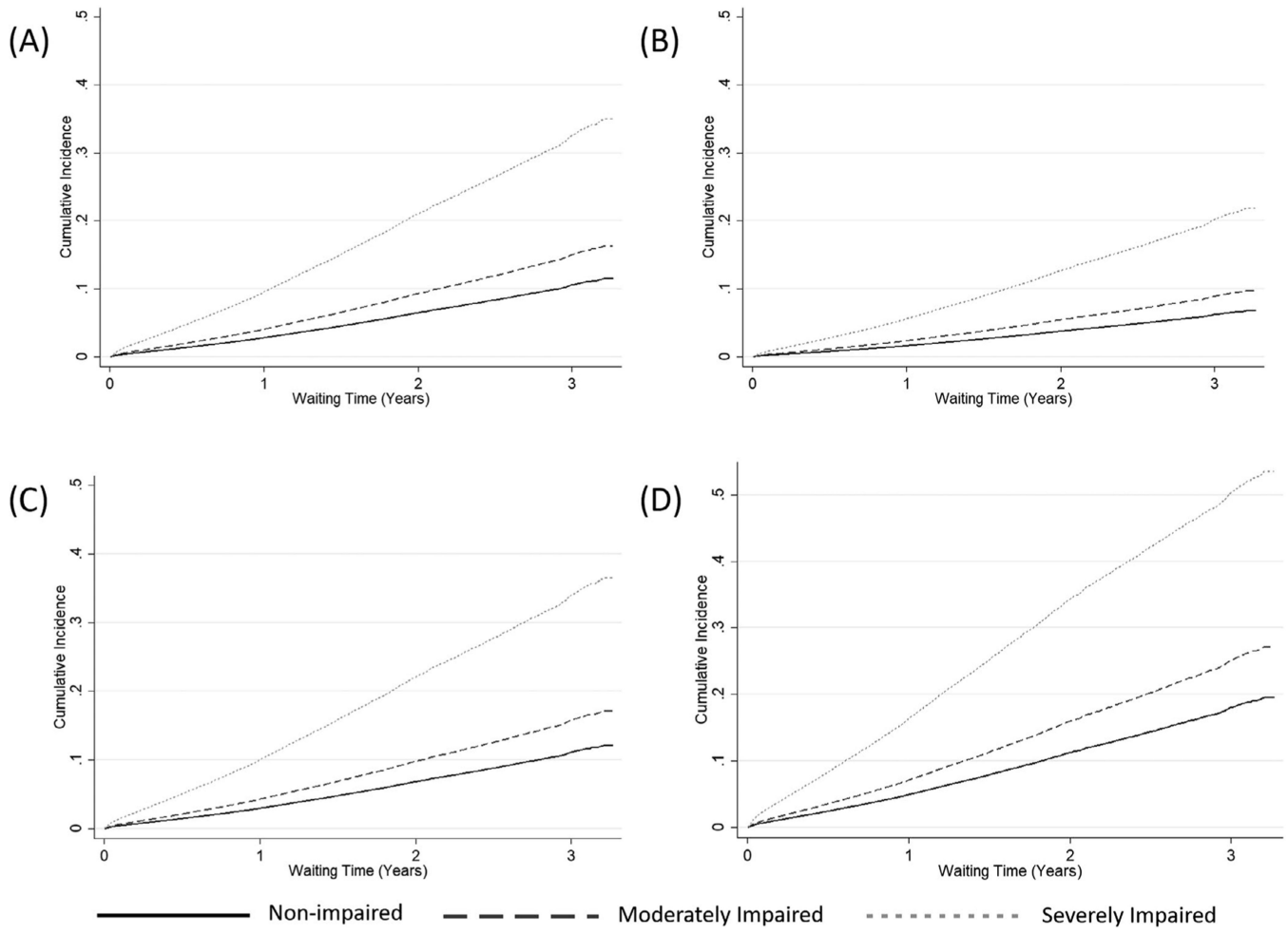

FIGURE 2.

Adjusted cumulative incidence for waitlist mortality by Karnofsky Performance Status at time of listing. A, all ages. B, ages 18–44 y. C, ages 45–64 y. D, ages 65 y and older

TABLE 1

Baseline characteristics[a] among 89 819 patients listed for kidney transplantation in the US from January 1, 2015, to January 1, 2018, by Karnofsky Performance Status[b]

	Non-impaired N = 55 072 (61%)	Moderately impaired N = 31 632 (35%)	Severely impaired N = 3115 (4%)
Characteristic			
Age at listing, years	54 (43–63)	56 (45–63)	56 (46–62)
Sex, % male	63%	62%	62%
Race/Ethnicity, %			
White	45%	38%	52%
Black	26%	33%	23%
Hispanic	18%	20%	18%
Asian	9%	6%	4%
Other	2%	2%	2%
BMI, kg/m^2	28.6 (24.9–32.7)	28.9 (25.1–33.0)	28.2 (24.4–32.7)
On dialysis at time of listing	57%	80%	64%
Dialysis vintage at listing, years	1.25 (0.62–2.60)	1.50 (0.78–3.07)	0.98 (0.17–2.39)
Etiology of ESRD			
Glomerular	18%	12%	8%
Diabetes	34%	45%	30%
HTN	21%	22%	12%
Cystic disease	10%	5%	3%
Other	17%	15%	47%
Working for income at time of listing	48%	15%	5%
Cumulative incidence of removal from waitlist[c]			
Death or medical delisting	2%	3%	6%
Deceased-donor kidney transplantation	8%	12%	30%
Living donor kidney transplantation	8%	4%	2%

[a] All continuous characteristics described as median (IQR).

[b] Non-parametric test of trend across categories of Karnofsky Performance Status. All $P < .01$ except for hypertension ($P = .02$) and other race/ethnicity ($P = .97$).

[c] Cumulative incidences at 6 mo from listing.

TABLE 2

Predictors of death or delisting among 89 819 patients listed for kidney transplantation in the US from January 1, 2015, to January 1, 2018

Predictor	Univariable Hazard ratio	95% CI	*P*-value	Multivariable[a] Hazard ratio	95% CI	*P*-value
KPS category						
Non-impaired	Ref			Ref		
Moderately impaired	1.63	(1.55–1.72)	<.01	1.68	(1.45–1.95)	<.01
Severely impaired	3.99	(3.64–4.39)	<.01	4.80	(3.71–6.21)	<.01
Age category						
<45	Ref			Ref		
45–64	2.16	(1.99–2.34)	<.01	1.97	(1.73–2.24)	<.01
≥65	3.79	(3.48–4.12)	<.01	3.62	(3.33–3.92)	<.01
Male sex	1.13	(1.07–1.19)	<.01	1.04	(0.97–1.13)	.26
Etiology of ESRD						
Glomerular	Ref			Ref		
Diabetes	2.87	(2.60–3.17)	<.01	2.20	(1.94–2.48)	<.01
HTN	1.59	(1.42–1.77)	<.01	1.29	(1.23–1.35)	<.01
Cystic	0.87	(0.74–1.03)	.10	0.72	(0.66–0.78)	<.01
Other	2.64	(2.37–2.94)	<.01	1.95	(1.58–2.41)	<.01
Dialysis vintage (per year)	1.02	(1.01–1.03)	<.01	1.04	(1.03–1.06)	<.01

[a]Adjusted for sex, race and ethnicity, blood type, cause of ESRD, UNOS region, center volume of transplantation, and dialysis vintage.

TABLE 3

Predictors of death or delisting and death or delisting among 89 819 patients listed for kidney transplantation in the US from January 1, 2015, to January 1, 2018, by age category

Age category	KPS category	N (%)[a]	Univariable Hazard ratio	95% CI	*P*-value	Multivariable[b] Hazard ratio	95% CI	*P*-value	3-y death or delisting (%)
<45 y	Non-impaired	15 227 (17)	Ref			Ref			5
	Moderately impaired	7316(8)	1.86	1.59–2.18	<.01	1.58	1.43–1.76	<.01	7
	Severely impaired	664 (1)	5.92	4.72–7.42	<.01	4.93	3.46–7.02	<.01	22
45–64y	Non-impaired	29 124 (32)	Ref			Ref			11
	Moderately impaired	17 694 (20)	1.68	1.64–1.72	<.01	1.50	1.43–1.56	<.01	15
	Severely impaired	1937(2)	4.27	3.65–5.01	<.01	3.50	2.98–4.11	<.01	32
>65 y	Non-impaired	10 721 (12)	Ref			Ref			20
	Moderately impaired[c]	6622 (7)	1.42	1.39–1.45	<.01	1.34	1.29–1.39	<.01	29
	Severely impaired[c]	514 (1)	3.03	2.65–3.47	<.01	2.83	2.47–3.23	<.01	51

[a] Percentage of total waitlisted population.

[b] Adjusted for sex, race and ethnicity, blood type, cause of ESRD, UNOS region, center volume of transplantation, and dialysis vintage.

[c] *P*-value for interaction term < .01; no other interaction terms for combination of KPS category and age category were significant.