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BRIEF COMMUNICATION

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Prevalence of frailty among kidney transplant candidates and recipients in the United States: Estimates from a National Registry and Multicenter Cohort Study

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Frailty, a measure of physiologic reserve, is associated with poor outcomes and mortality among kidney transplant (KT) candidates and recipients. There are no national estimates of frailty in this population, which may help patient counseling and resource allocation at transplant centers. We studied 4616 KT candidates and 1763 recipients in our multicenter prospective cohort of frailty from 2008-2018 with Fried frailty measurements. Using Scientific Registry of Transplant Recipients (SRTR) data (KT candidates = 560 143 and recipients = 243 508), we projected the national prevalence of frailty (for KT candidates and recipients separately) using standardization through inverse probability weighting, accounting for candidate/recipient, donor, and transplant factors. In our multicenter cohort, 13.3% of KT candidates were frail at evaluation; 8.2% of LDKT recipients and 17.8% of DDKT recipients were frail at transplantation. Projected nationally, our modeling strategy estimated 91 738 KT candidates or 16.4% (95% confidence interval [CI] 14.4%-18.4%) of all KT candidates during the study period were frail, and that 34 822 KT recipients or 14.3% (95% CI 12.3%-16.3%) of all KT recipients were frail (LDKT = 8.2%; DDKT = 17.8%). Given the estimated national prevalence of frailty, transplant programs should consider assessing the condition during KT evaluation to improve patient counseling and resource allocation along with identification of recipients at risk for poor outcomes.

KEYWORDS
clinical research/practice, kidney transplantation/nephrology, registry/registry analysis, Scientific Registry for Transplant Recipients (SRTR)

1 | INTRODUCTION

Frailty is characterized by decreased physiologic reserve and resistance when confronted with a stressor, such as transplantation. The Fried physical frailty phenotype, a common measurement of frailty, comprises unintentional weight loss, slowed walking speed, decreased grip strength, decreased physical activity, and exhaustion, and was initially identified in community-dwelling older adults.[1]

Abbreviations: AUC, area under the curve; DDKT, deceased donor kidney transplantation; DSA, donor service area; ESRD, end-stage renal disease; IPSW, inverse probability of selection weights; KDPI, kidney donor profile index; KT, kidney transplant; LDKT, living donor kidney transplantation; MICE, multiple imputation by chain equation; OPTN, Organ Procurement and Transplantation Network.

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Based on previous cohort studies, frailty is prevalent in 12%-20% of kidney transplant (KT) candidates and is associated with decreased listing for KT,[2] waitlist mortality,[2,3] decreased transplantation rates after listing,[2] and poor health-related quality of life.[4] Furthermore, frailty in KT recipients is associated with poor outcomes following KT such as delirium,[5] longer length of stay,[6] early hospital readmission,[7] immunosuppression intolerance,[8] poor health-related quality of life,[9] cognitive decline,[10] and mortality.[11] Yet these estimates are from multicenter cohort studies, and national prevalence estimates of frailty may vary from these studies due to differences in KT candidate and recipient populations across the United States. National frailty estimates may help centers with waitlist management, resource allocation, and planning at transplant centers, as well as with patient counseling regarding waiting time and outcomes prior to KT.

Frailty is not commonly assessed at the time of evaluation or transplant, or collected in national registries, despite its association with poor outcomes in KT candidates and recipients.[12] In 2018 in the United States, 94 970 adults were listed for KT and 21 167 underwent KT,[13] and likely a large percentage of those KT recipients were frail. In addition, frailty is more common in older (age ≥65) KT candidates[2,3] and KT recipients,[14] and the number of older adults undergoing KT is increasing over time, with more than 19% of KT recipients 65 and older (age ≥65).[13,15] Thus, national estimates of frailty across all states, donor service areas (DSAs), and transplant centers may help guide interventions to reduce or lessen the burden of frailty in the growing population of vulnerable KT candidates and recipients.

Understanding the prevalence of frailty among KT candidates and recipients can inform candidate expectations and waitlist management at centers across the United States. In this study, we estimated the prevalence of frailty in a prospective, longitudinal, multicenter cohort of KT candidates and recipients and developed a predictive statistical model using characteristics captured by the national transplant registry. Then, using a novel statistical approach, we estimated the national prevalence of frailty among transplant candidates and recipients in the United States over the two decades. Finally, we explored geographic difference in the prevalence of frailty across the United States.

2 | METHODS

2.1 | Prospective cohort data source: KT candidates

This study used data from a prospective, longitudinal multicenter cohort study at the Johns Hopkins Hospital (N = 2217), Baltimore, Maryland; the University of Michigan Hospital (N = 97), Ann Arbor, Michigan; and the Methodist Specialty and Transplant Hospital (N = 2217), San Antonio, Texas, and has been described elsewhere.[7,8,14,16] Briefly, study participants were enrolled prior to KT and consented to medical record abstraction to allow for the identification of demographics and comorbidities. KT candidates underwent a battery of exams to assess frailty (as described below) at KT evaluation in the clinic. The clinical and research activities being reported are consistent with the Declaration of Helsinki and Declaration of Istanbul. The institutional review boards of Johns Hopkins Hospital, the University of Michigan, and the Methodist Specialty and Transplant Hospital approved this study, and all participants provided written informed consent.

2.2 | Prospective cohort data source: KT recipients

The data for KT recipients was collected from the same longitudinal, prospective cohort studies at Johns Hopkins Hospital (n = 952), University of Michigan (n = 82), and the Methodist Specialty and Transplant Hospital (n = 729). At Johns Hopkins Hospital and the University of Michigan, study participants were enrolled at the time of KT and consented to medical record abstraction to allow for the identification of demographics and comorbidities. KT recipients underwent a battery of exams to assess frailty (as described below) at admission for KT. At the Methodist Specialty and Transplant Hospital, participants were enrolled at KT evaluation and frailty was assessed at every visit prior to KT; the measure of frailty prior to KT was used to estimate the prevalence of frailty among KT recipients.

2.3 | National registry data source

This study also used data from the Scientific Registry of Transplant Recipients (SRTR) external release made available in December 2018. The SRTR data system includes data on all donors, waitlist candidates, and transplant recipients in the United States (US), submitted by members of the Organ Procurement and Transplantation Network (OPTN), and has been described previously.[17] The Health Resources and Services Administration (HRSA), US Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors. Using SRTR, we identified 560 143 adult candidates (age ≥18) listed and 243 508 adult recipients who underwent KT between January 2000 and June 2018 to include the KT listing dates of candidates at the three prospective cohort centers.

2.4 | Frailty

We studied the Fried physical frailty phenotype as defined[1] in older adults as well as in end-stage renal disease and KT populations.[2-8,10,11,14,18-23] The Fried physical frailty phenotype was based on five components: shrinking (self-report of unintentional weight loss of more than 10 pounds in the past year based on dry weight); weakness (grip-strength below an established cutoff based on gender and BMI); exhaustion (self-report); low activity (kcals/week below an established cutoff); and slowed walking speed (walking time of 15 feet below an established cutoff by gender and height).[1] Each of the five components was scored as 0 or 1, representing the absence or presence of

that component. The aggregate frailty score was calculated as the sum of the component scores (range 0-5); frail was defined as a score of ≥3, prefrail as a score of 2, and nonfrail as a score of <2. The physicians at Johns Hopkins Hospital and University of Michigan were not aware of the frailty assessment results at time of evaluation, but the physicians at Methodist Specialty and Transplant Hospital were aware of the frailty assessments at the time of evaluation.

2.5 | Estimating national prevalence

To estimate the national prevalence of frailty, we mapped data from our prospective cohort to the national transplant population using variables captured by both databases. We used standardization using inverse probability of selection weights (IPSW). Standardization is a common approach in public health that uses known characteristics about a target population to inform estimation in a sampled population or vice versa. Weighting approaches to standardization allow for additional covariates to be considered.

We used a two-stage approach to estimate the national prevalence of frailty using IPSW. This method seeks to provide unbiased estimates by adjusting for variables that may have affected the selection of our study population relative to the general transplant population. The first stage calculated restricted IPSW using baseline characteristics. For candidates, we adjusted for female sex, African American race, Hispanic ethnicity, age at listing, time on dialysis, college education, BMI, hypertension status, history of previous transplantation, employment status, public insurance status, and panel reactive antibody (PRA) at listing. For recipients, we adjusted for female sex, African American race, Hispanic ethnicity, age at transplantation (splines with knots at 35 and 65), ≥2 years on dialysis, college education, BMI, hypertension status, history of previous transplantation, employment status, public insurance status, PRA at transplantation, and donor BMI. Potential variables were selected based on prior literature, and parsimonious models were built to maximize the Akaike information criterion (AIC) and Bayesian information criterion (BIC). These weights were then restricted to the range of 10% to 90% to avoid bias due to extreme weights[24] and converted to IPSW. The second stage used linear risk regression to examine the prevalence of frailty weighted by the IPSW.

2.6 | Frailty prediction model

We constructed a prediction model for frailty using data from our prospective cohort. The model building approach maximized area under the curve (AUC) and adjusted for recipient (age, sex, African American race, Hispanic ethnicity, diabetes, hypertension, history of transplantation, college education, PRA at transplantation, preemptive transplantation, years on dialysis, BMI, public insurance status, and employment status), donor (age, sex, African American race, Hispanic ethnicity, kidney donor profile index [KDPI] for deceased donors, BMI, and estimated GFR [eGFR]), transplantation (HLA mismatch, year of transplantation, cold ischemia time), and outcome (all-cause graft loss) characteristics. Separate models were used for KT candidates and recipients; donor and outcome variables were only included in the KT recipient model.

2.7 | Visualizing prevalence differences

Using the national prevalence estimates, we estimated the number of frail and prefrail candidates and transplant recipients across 58

TABLE 1 Characteristics of a prospective cohort of kidney transplant candidates listed from 2000-2018 by frailty status (n = 4616)

	Not frail	Prefrail	Frail	*P*
N (%)	2862 (62.0%)	1142 (24.7%)	612 (13.3%)	
Recipient characteristics				
Age at listing, y[a]	52.0 (42.0-60.0)	54.0 (44.0-62.0)	55.0 (45.0-63.0)	<.001
Female, %	39.1	41.1	41.3	.3
African American, %	25.8	31.3	41.2	<.001
Hispanic, %	37.5	30.8	22.4	<.001
BMI, kg/m^{2a}	29.1 (25.1-33.3)	29.6 (25.3-33.5)	29.5 (25.3-33.5)	.7
Dialysis vintage, y[a]	1.0 (0.4-2.4)	1.0 (0.5-2.4)	0.9 (0.4-2.2)	.2
College educated, %	55.8	52.9	53.8	.4
Employed, %	37.1	30.5	24.8	<.001
Public insurance, %	52.0	58.2	56.2	.05
Diabetes, %	35.9	38.4	41.3	<.01
Hypertension, %	23.6	23.4	24.7	.6
Previous transplant, %	15.1	17.8	19.8	<.01
PRA >80 at listing, %	1.4	1.2	2.3	.1

[a]Median (interquartile range).

DSAs and across 288 transplant centers. We estimated the ratio of the number of frail recipients divided by the number of frail candidates as a measure of access to transplantation for those that are frail (ratio >1 indicates greater access) for each DSA. We then compared the frail transplant recipient/candidate ratio in each DSA to the median frail transplant recipient/candidate ratio to demonstrate differences in access by geographic boundary. We presented a similar measure for candidates and recipients that are prefrail.

2.8 | Statistical analysis

For participants in the prospective cohort, differences in recipient, donor, and transplant characteristics by frailty status were assessed using the chi-square (categorical variables) and Mann-Whitney rank-sum (continuous variables) tests. We used a two-sided α of 0.05 to indicate a statistically significant difference. All analyses were performed using Stata 15/MP for Linux (College Station, Texas).

2.9 | Sensitivity analyses

We built prediction models that were used to inform a multiple imputation approach. All models were run after multiple imputation for baseline characteristics. Conceptually, we used multiple imputation by chained equation (MICE) to predict the frailty status of individuals in the general transplant population by treating the frailty status of those not in our prospective cohort as missing-at-random. A prediction model for frailty was built in our prospective cohort to maximize AUC. The variables from this prediction model were then used to generate 100 imputed datasets (after 10 run-in datasets) using MICE and Rubins' rules for pooled estimation.

TABLE 2 Characteristics of a prospective cohort of living donor kidney transplant recipients from 2008-2018 by frailty status (n = 817)

	Not frail	Prefrail	Frail	*P* value
N (%)	574 (70.3%)	176 (21.5%)	67 (8.2%)	
Recipient characteristics				
Age, y[a]	50.0 (38.0-60.0)	51.0 (40.0-62.0)	53.0 (41.0-60.0)	.4
Female, %	40.5	46.6	46.3	.4
African American, %	10.8	14.8	19.4	.03
Hispanic, %	35.3	28.4	17.9	<.001
BMI, kg/m^2[a]	28.0 (24.4-31.9)	28.1 (24.3-31.7)	27.5 (22.6-31.1)	.3
Dialysis vintage, y[a]	0.5 (0.0-1.9)	0.7 (0.0-2.4)	0.9 (0.0-3.1)	.1
HCV, %	2.5	1.1	0	.2
College educated, %	67.9	65.7	70.8	.6
Employed, %	45.8	46	47.0	.9
Public insurance, %	42.0	40.9	41.8	1.0
Diabetes, %	27.6	28.4	31.3	.5
Hypertension, %	16.0	13.6	11.9	.4
Previous transplant, %	14.5	19.9	20.9	.2
PRA >80 at listing, %	20.1	20	15.4	.5
Donor characteristics				
Age, y[a]	42.0 (33.0-52.0)	44.5 (35.5-52.0)	45.0 (35.0-54.0)	.1
Female, %	64.8	63.1	64.2	.9
African American, %	7.6	10.2	13.4	.09
Hispanic, %	32.3	25.6	17.9	.01
BMI, kg/m^2[a]	27.3 (24.1-30.5)	26.9 (23.9-29.7)	26.9 (23.9-30.1)	.5
eGFR[a]	104.4 (87.7-118.3)	103.0 (88.7-117.3)	99.9 (88.0-112.3)	.3
Biologically related, %	39.9	44.3	32.8	.3
Transplant characteristics				
ABO Incompatible, %	5.5	6.8	6	.9
Zero HLA mismatch, %	5.9	4.6	4.5	.6
Cold ischemia time, h[a]	1.3 (1.1-1.9)	1.3 (1.0-2.0)	1.6 (1.0-4.0)	.02

HCV, hepatitis C virus; PRA, panel reactive antibody.
[a]Median (interquartile range).

In addition, we estimated the national prevalence of frailty among KT candidates, living donor KT (LDKT) recipients, and deceased donor KT (DDKT) recipients living outside the Stroke Belt using IPSW and MICE. We defined states in the Stroke Belt to include Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee.

We also compared the distribution of impairment characterized by the Karnofsky Performance Score (KPS) and frailty across DSAs among KT candidates and KT recipients using tetrachoric correlation. KPS impairment was defined as at or below 70%.

3 | RESULTS

3.1 | Prospective cohort characteristics

Among 4616 KT candidates in our prospective cohort, 612 (13.3%) were frail. Frail participants were more likely to be older (55.0 years vs 52.0 years, $P < .001$), African American (41.2% vs 25.8%, $P < .001$), have diabetes (41.3% vs 35.9%, $P < .01$), and have a history of previous transplantation (19.8% vs 15.1%, $P < .01$), and less likely to be Hispanic (22.4% vs 37.5%, $P < .001$) and employed at the time of listing (24.8% vs 37.1%, $P < .001$) compared to nonfrail participants (Table 1).

Among the 817 LDKT recipients in our prospective cohort, 67 (8.2%) were frail. Frail participants were less likely to be Hispanic (17.9% vs 35.3%, $P < .01$) but were similar to nonfrail participants in other characteristics (Table 2).

Among the 946 DDKT recipients in our prospective cohort, 168 (17.8%) were frail. Frail participants were more likely to be African American (52.4% vs 39.2%, $P < .01$), older (59 years vs 54 years, $P < .001$), have higher BMI (29.6 vs 28.1, $P = .03$), and have hepatitis C virus (HCV) infection (17.4% vs 7.4%, $P < .001$), and were less likely to be Hispanic (4.8% vs 26.3%, $P < .001$) or have public insurance (59.5% vs 72.0%, $P < .01$) at the time of KT (Table 3) compared to nonfrail participants. In addition, frail DDKT recipients were more

TABLE 3 Characteristics of prospective cohort of deceased donor kidney transplant recipients from 2008-2018 by frailty status (n = 946)

	Not frail	Prefrail	Frail	*P* value
N	533 (56.3%)	245 (25.9%)	168 (17.8%)	
Recipient characteristics				
Age, y[a]	54.0 (42.0-62.0)	58.0 (46.0-64.0)	59.0 (50.0-66.5)	<.001
Female, %	37.4	37.6	40.5	.5
African American, %	39.2	42.9	52.4	<.01
Hispanic, %	26.3	15.5	4.8	<.001
BMI, kg/m^2[a]	28.1 (24.5-32.0)	28.7 (25.1-32.4)	29.6 (25.3-33.2)	.03
Dialysis vintage, y[a]	4.0 (1.8-6.6)	3.0 (1.3-6.2)	2.8 (0.9-4.9)	<.001
HCV, %	7.9	11.5	17.4	<.001
College educated, %	54.8	55.9	55.2	.9
Employed, %	32.2	34.2	25	.07
Public insurance, %	72.0	65.3	59.5	<.01
Diabetes, %	25.4	26.1	24.4	.8
Hypertension, %	34.2	32.7	37.5	.4
Previous transplant, %	16.7	17.1	12.5	.2
PRA >80 at listing, %	13.2	11.8	13.9	.8
Donor characteristics				
Age, y[a]	34.0 (23.0-47.0)	35.0 (25.0-50.0)	36.0 (26.0-49.0)	.10
Female, %	41.1	42.4	41.7	.9
African American, %	18.0	22	20.8	.4
Hispanic, %	19.2	14.7	5.4	<.001
BMI, kg/m^2[a]	26.6 (23.0-31.2)	26.8 (23.3-32.3)	25.7 (23.0-30.0)	.3
KDPI[a]	42.7 (23.7-63.5)	46.1 (27.9-67.7)	52.8 (36.8-71.1)	<.001
Transplant characteristics				
Zero HLA mismatch, %	5.1	4.1	5.4	.9
Cold ischemia time, h[a]	22.1 (15.3-29.1)	24.0 (16.3-30.0)	25.0 (15.8-32.0)	.04

HCV, hepatitis c virus, PRA, panel reactive antibody.

[a]Median (interquartile range).

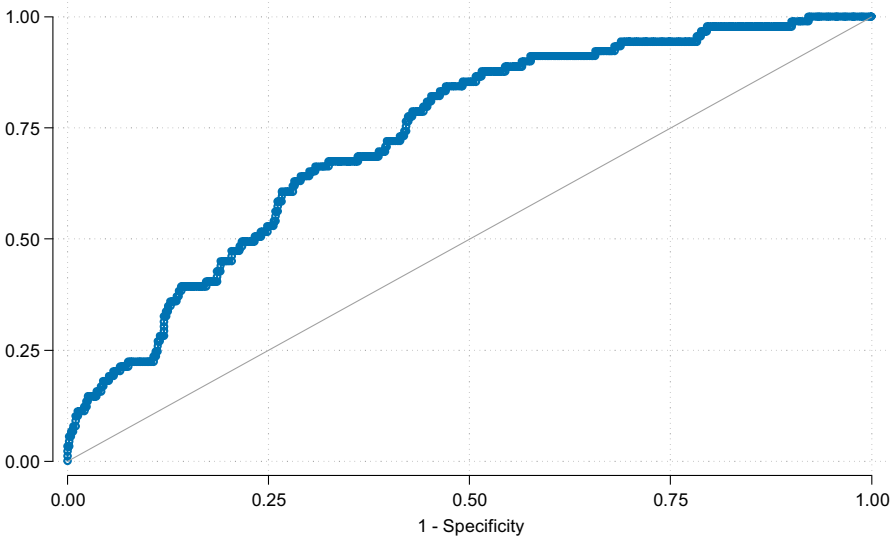

FIGURE 1 Prediction model performance (AUC = 0.731) for frailty among kidney transplant recipients [Color figure can be viewed at wileyonlinelibrary.com]

likely to receive higher median KDPI donors than nonfrail DDKT recipients (52.8 vs 42.7, $P < .001$) and have a longer cold ischemia time (25.0 hours vs 22.1 hours, $P = .04$).

3.2 | National prevalence of frailty

In our prospective cohort, the frailty prediction model had an AUC of 0.731 for KT recipients (Figure 1).

A total of 560 143 KT candidates were listed during our study period (01/2000-06/2018). We estimated that 16.4% (N = 91 738, 95% CI 14.4%-18.4%) of transplant candidates were frail (Table 4). In addition, there were a total of 243 508 transplant recipients during our study period, and we estimated that 14.3% (N = 34 822, 95% CI 12.3%-16.3%) of transplant recipients were frail; 8.2% of LDKT recipients and 17.8% of DDKT recipients were frail.

3.3 | Geographic distribution

Among KT candidates, the median (interquartile range [IQR]) prevalence of frailty across 58 DSAs was 13.9% (12.6%-14.6%) and across 288 transplant centers was 13.4% (11.6%-14.7%). Among KT recipients, the median (IQR) prevalence of frailty across 58 DSAs was 18.8% (18.0%-20.5%) and across 288 transplant centers was 18.2% (16.4%-20.5%).

Based on our prediction model for frailty, we estimated the number of frail and prefrail candidates (Figure 2) and recipients (Figure 3) by DSA. The highest concentration of prefrail and frail candidates were in California and New York. Our estimates also suggest variation in the transplant/candidate ratio for frail and prefrail individuals by DSA (Figure 4). The lowest access to transplant in frail candidates were in California, Texas, Alabama, and Georgia.

3.4 | Sensitivity analyses

Using MICE, we estimated that 20.5% (N = 49 904, 95% CI 14.5%-26.5%) of transplant recipients were frail, and we estimated that 16.4% (N = 92 003, 95% CI 15.4%-17.5%) of transplant candidates were frail.

After exclusion of states in the Stroke Belt, the national prevalence of frailty estimates among KT candidates, LDKT recipients, and DDKT recipients was similar to our primary results using IPSW and MICE (Table S1A,B).

Among our KT candidate cohort, 30 of 612 frail candidates had KPS impairment, and among our KT recipient cohort, 7 of 235 frail recipients had KPS impairment. Among national KT candidates, 24.3% had KPS impairment. KPS impairment correlated poorly with frailty measurements for KT candidates in our cohort (rho 0.07). Furthermore, among national KT recipients, 26.8% had KPS impairment. KPS impairment correlated poorly with frailty measurements for KT recipients in our cohort (rho 0.13).

4 | DISCUSSION

Nationally, we estimated that 16.4% of KT candidates were frail, and 14.3% of KT recipients were frail from 2000-2018; 8.2%

TABLE 4 National estimates of frailty among kidney transplant candidates, living donor kidney transplant (LDKT) recipients, and deceased donor kidney transplant (DDKT) recipients.

	N	IPSW (95% confidence interval)[a]
KT candidates	560 143	16.4% (14.4%-18.4%)
LDKT	81 322	8.2% (6.3%-10.1%)
DDKT	162 186	17.8% (15.3%-20.2%)
All KT recipients	243 508	14.3% (12.3%-16.3%)

[a]IPSW: inverse probability of selection weights.

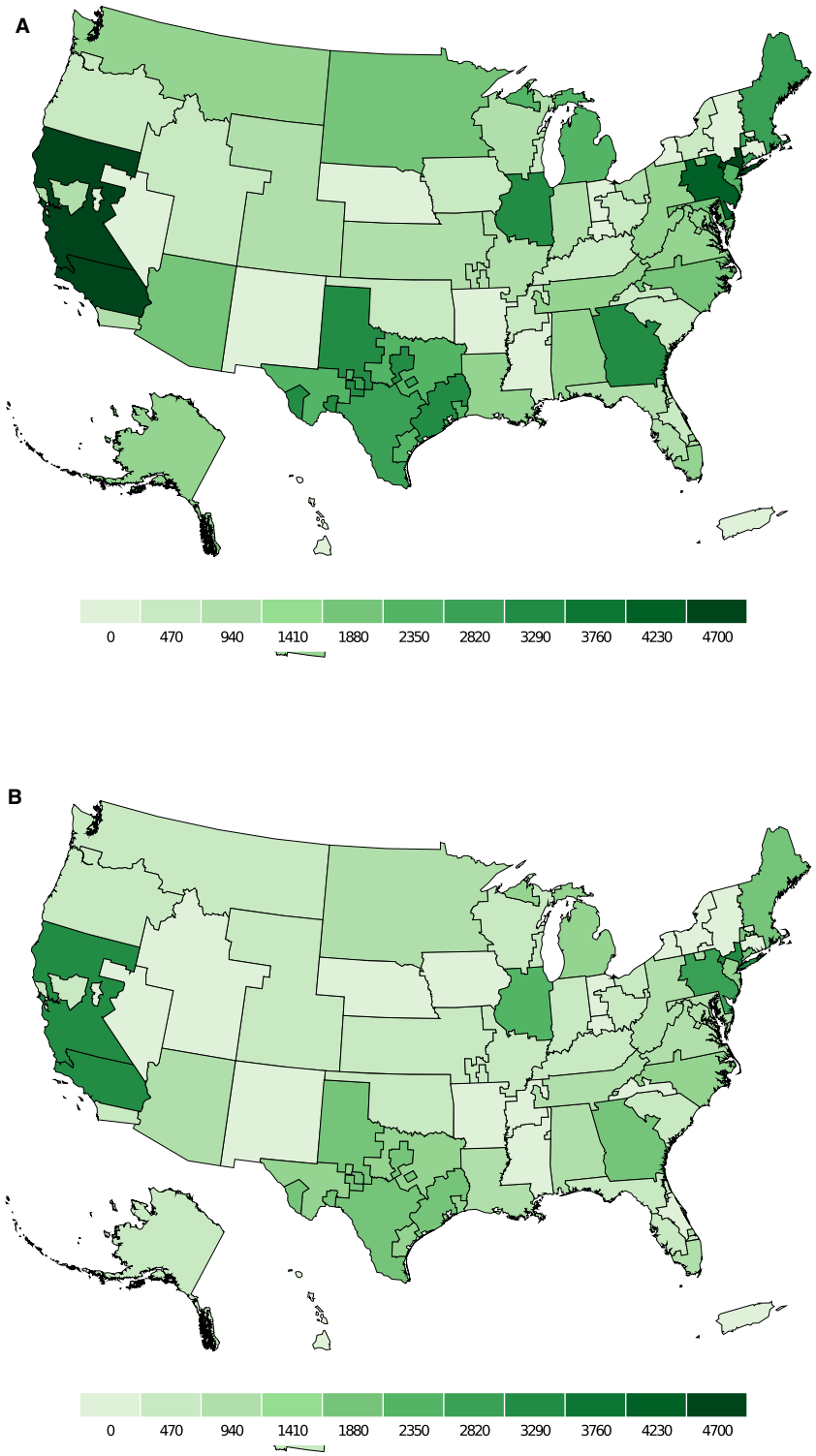

FIGURE 2 Number of (A) prefrail and (B) frail KT candidates by donor service area from 2000-2018 [Color figure can be viewed at wileyonlinelibrary.com]

of LDKT recipients and 17.8% of DDKT recipients were frail. Furthermore, the prevalence of frailty among KT recipients and candidates varies across the United States. In our three-center prospective cohort study of frailty in more than 6000 participants, we found that 8.2% of LDKT recipients and 17.8% of DDKT recipients were frail. Frail KT candidates were more likely to be older ($P < .001$) and African American ($P < .001$) and less likely to be Hispanic ($P < .001$). Similarly, frail DDKT recipients were more likely to be older ($P < .001$) and African American ($P < .01$) and less likely to be Hispanic ($P < .001$).

Our finding that 16.4% of KT candidates were frail from national estimates was lower than that seen in other studies of

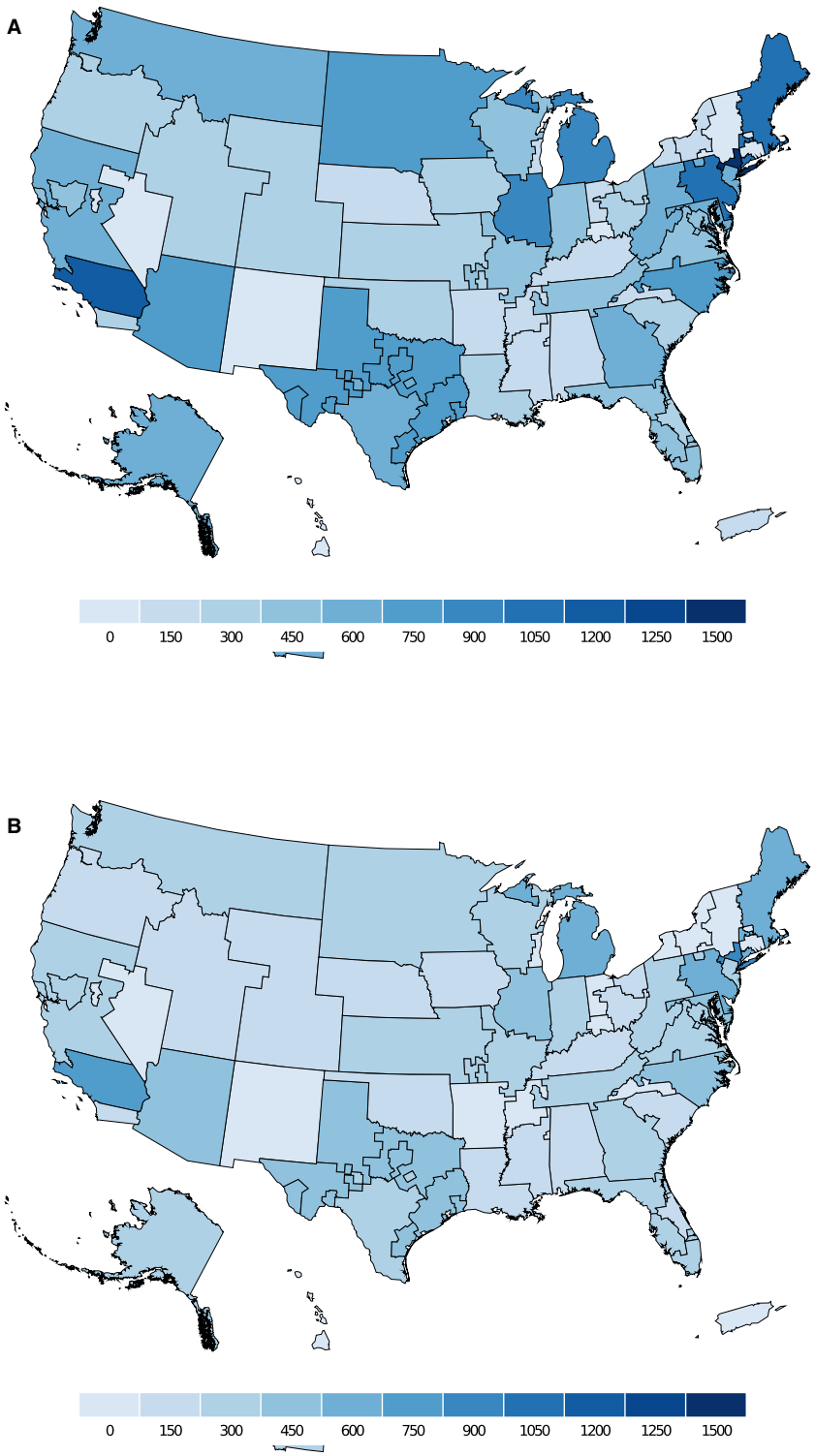

FIGURE 3 Number of (A) prefrail and (B) frail kidney transplant recipients by donor service area from 2000-2018 [Color figure can be viewed at wileyonlinelibrary.com]

hemodialysis patients using the Fried physical frailty phenotype with modification for weight loss (30%-60% frail).[25,26] However, this finding is not surprising considering that frail participants have nearly a 2-fold decreased chance of being listed for KT at evaluation compared to nonfrail participants. In addition, our findings that frail participants were more likely to be older and have diabetes were similar to findings in the aforementioned study of hemodialysis patients.[25] Identification of frail candidates at evaluation can help with patient counseling with regard to poor waitlist outcomes such as increased waitlist mortality and lower rate of KT,[2] and also identify patients who may benefit from closer follow-up and interventions.

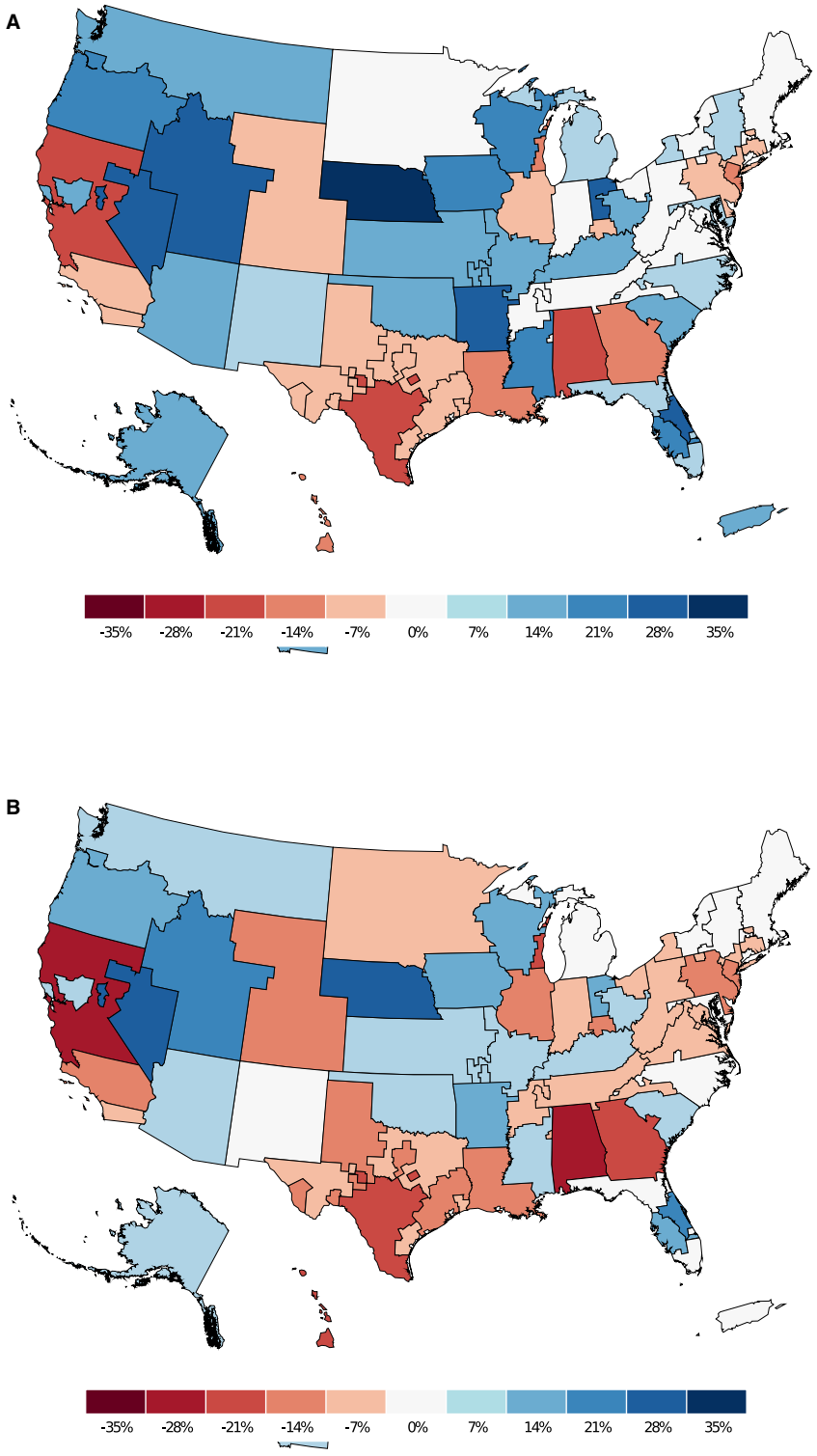

FIGURE 4 Number of (A) prefrail and (B) frail percentage difference from median transplant/candidate ratio to assess access to transplantation for among frail and nonfrail candidates from 2000-2018. The lowest access to transplant in frail candidates were in California, Texas, Alabama, and Georgia [Color figure can be viewed at wileyonlinelibrary.com]

In addition, using national registry data, we estimated that 8.2% of LDKT recipients and 17.8% of DDKT recipients in the United States were frail at the time of transplantation. Our results highlight the importance of identification of recipients at the time of transplantation, given that one in five KT recipients will be at an increased odds of delirium [5] and longer length of stay,[6] increased risk of delayed graft function,[19] early hospital readmission,[7] immunosuppression intolerance,[8] cognitive decline,[10] and mortality.[11] Identification of these vulnerable patients can help clinicians target those patients to mitigate poor outcomes after KT,[2] and quantifying the national prevalence of frailty in KT candidates and recipients is important for resource allocation planning.

The strengths of this study include a large sample of KT candidates and recipients from three transplant centers and a prospective cohort study of frailty. In addition, the use of the novel measurement of frailty and national projections to estimate national prevalence are not currently possible through use of registry data; frailty is not captured in national registries. There are several limitations to this study. One limitation is the selection bias of participants who were referred from the community to the three transplant centers; however, we have no way to measure frailty in participants who were not referred for evaluation. Furthermore, there is a selection bias of who is referred and listed for transplantation, but the goal of our study was to inform decision-making at two distinct times for two distinct populations: at KT evaluation/listing for candidates and at admission for KT for recipients. Another notable limitation is that our national estimates may not be accurate given the prospective study population characteristics, and these should be noted as estimates. However, demographics between the three transplant centers are quite different (age, race, time on dialysis, living donor), which is a strength of this study.[2]

In conclusion, we estimated that 16.4% of KT candidates and 14.3% of KT recipients in the United States were frail from 2000-2018, and that the prevalence of frailty in KT candidates and recipients varied by geographic location. Given the high prevalence of frailty, transplant programs should consider assessing frailty during KT evaluation to improve informed consent and identify candidates for pre-KT interventions. Our findings can encourage centers to include frailty as part of their evaluation and help identify a vulnerable population of patients that may benefit from potential interventions like prehabilitation.[27]

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DISCLOSURE

The authors of this manuscript have no conflicts of interest to disclose as described by the *American Journal of Transplantation*.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

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

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