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Research Article

Development and Validation of an Abridged Physical Frailty Phenotype for Clinical Use: A Cohort Study Among Kidney Transplant Candidates

Xiaomeng Chen, MSPH,[1,†] Nadia M. Chu, PhD, MPH,[1,2,†] Valerie Thompson, BS,[1] Evelien E. Quint, MD,[3] Sami Alasfar, MD,[4] Qian-Li Xue, PhD,[2,4] Daniel C. Brennan, MD,[4] Silas P. Norman, MD,[5] Bonnie E. Lonze, MD, PhD,[6] Jeremy D. Walston, MD,[4] Dorry L. Segev, MD, PhD,[1,6] and Mara A. McAdams-DeMarco, PhD[1,6,*]

[1]Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA.
[2]Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA.
[3]Division of Transplant Surgery, Department of Surgery, University Medical Center Groningen, Groningen, The Netherlands.
[4]Department of Medicine, Johns Hopkins School of Medicine, Baltimore, Maryland, USA.
[5]Department of Medicine, University of Michigan, Ann Arbor, Michigan, USA.
[6]Department of Surgery, NYU Grossman School of Medicine and NYU Langone Health, New York, New York, USA.

*Address correspondence to: Mara McAdams-DeMarco, PhD. E-mail: Mara.McAdamsDeMarco@nyulangone.org
†X.C. and N.M.C. contributed equally to this manuscript.

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Abstract

Background: Frailty is associated with poor outcomes in surgical patients including kidney transplant (KT) recipients. Transplant centers that measure frailty have better pre- and postoperative outcomes. However, clinical utility of existing tools is low due to time constraints. To address this major barrier to implementation in the preoperative evaluation of patients, we developed an abridged frailty phenotype.

Methods: The abridged frailty phenotype was developed by simplifying the 5 physical frailty phenotype (PFP) components in a two-center prospective cohort of 3 220 KT candidates and tested for efficiency (time to completion) in 20 candidates evaluation (January 2009 to March 2020). We examined area under curve (AUC) and Cohen's kappa agreement to compare the abridged assessment with the PFP. We compared waitlist mortality risk (competing risks models) by frailty using the PFP and abridged assessment, respectively. Model discrimination was assessed using Harrell's C-statistic.

Results: Of 3 220 candidates, the PFP and abridged assessment identified 23.8% and 27.4% candidates as frail, respectively. The abridged frailty phenotype had substantial agreement (kappa = 0.69, 95% CI: 0.66–0.71) and excellent discrimination (AUC = 0.861). Among 20 patients at evaluation, abridged assessment took 5–7 minutes to complete. The PFP and abridged assessment had similar associations with waitlist mortality (subdistribution hazard ratio [SHR] = 1.62, 95% CI: 1.26–2.08 vs SHR = 1.70, 95% CI: 1.33–2.16) and comparable mortality discrimination (p = .51).

Conclusions: The abridged assessment is an efficient and valid way to identify frailty. It predicts waitlist mortality without sacrificing discrimination. Surgical departments should consider utilizing the abridged assessment to evaluate frailty in patients when time is limited.

Keywords: Epidemiology, Frailty, Kidney

Frailty has gained traction among surgeons as a tool to identify and improve clinical outcomes for vulnerable patients undergoing elective and emergency surgery (1–5). It is a clinical syndrome characterized by a decrease in physiologic reserve that is manifested as a distinct vulnerability to stressors (6,7). Although surgeons often use a subjective "eyeball test" to measure functional status, studies show that this measure is an inadequate proxy for measuring frailty status and operative risk (8–11).

The association between frailty and pre-/postoperative outcomes after surgery has been described extensively in the kidney transplant (KT) population (12–32). Among KT candidates and recipients specifically, an estimated 16.4% and 14.3% are frail, respectively, according to national projections (12). Among KT candidates undergoing dialysis, frailty is associated with pre-KT falls (13), hospitalizations (14–16), poor cognitive function (17), decreased health-related quality of life (18), lower access to KT (19), and waitlist mortality (14,16,20). Additionally, althought frailty is associated with both pre-KT dialysis and post-KT outcomes (21–32), in clinical practice frailty is almost exclusively used in KT evaluation and rarely measured during the admission for KT (33). Transplantation can occur many years after evaluation resulting in a high waitlist mortality rate, particularly

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for frail candidates (19). Identifying and intervening on candidates who may not survive long enough to receive a KT is a key priority in the field of transplantation. Transplant centers that assess a validated measure of frailty have better pre-KT center outcomes even after accounting for different case mixes (34). Given the promise of frailty as a tool to improve KT risk stratification, a consensus conference on frailty in solid organ transplantation organized by the American Society of Transplantation concluded that "a standard, validated measure of frailty is yet to be established" for the field (35).

Among 67 identified frailty instruments (36), the physical frailty phenotype (PFP), initially studied by Fried et al. in community-dwelling older adults (6), is the most extensively validated (35) and widely used frailty assessment, particularly in research and clinical/surgical settings (36,37). It is composed of 5 components, including unintentional weight loss, decreased grip strength, low physical activity, exhaustion, and slowed walking speed (6). However, despite its promise in improving risk stratification, its clinical utility was called into question by many who have found that it takes too long to complete the full assessment in clinical practice (33); it can take 20 minutes to implement in clinical settings (38), which is impractical particularly during already lengthy, comprehensive preoperative evaluations.

To address this major barrier to implementation of the PFP in the preoperative evaluation of patients, we developed an abridged frailty phenotype assessment specifically designed for use in clinical settings. We sought to: (1) create the tool by simplifying the 5 PFP components and test its efficiency by calculating its duration time, (2) validate the new tool against the original PFP, calculating measures of discrimination, agreement, sensitivity, and specificity, and (3) assess the new tool's predictive validity for mortality risk and compare it to the original PFP.

Method

Study Population

We leveraged a two-center prospective cohort study of 3 220 adult end-stage kidney disease (ESKD) patients being evaluated for KT at the Johns Hopkins Hospital (May 2014 to March 2020, $n = 1$ 298) and University of Michigan University Hospital (March 2015 to May 2017, $n = 80$). Participants were English-speaking and aged 18 years and older who were enrolled at KT evaluation, as described in previous studies (32,39,40). Frailty status was ascertained for each participant using the PFP, as described below, at time of enrollment. Patient characteristics at evaluation were self-reported or abstracted from medical records, including age, sex, race/ethnicity, education, body mass index (BMI), type of dialysis, years on dialysis, and cause of ESKD.

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donor, waitlisted candidates, and transplant recipients in the United States, submitted by the members of the Organ Procurement and Transplantation Network (OPTN). The Health Resources and Services Administration, U.S. Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors.

All research activities being reported are consistent with the Declaration of Helsinki and the Declaration of Istanbul. The study protocol was approved by the Johns Hopkins University Institutional Review Board (IRB), the New York University IRB and the University of Michigan IRB. All participants provided written informed consent.

Operationalization of the PFP

The PFP was operationalized in this study as originally defined and validated by Fried et al. among older adults (6,25,41–51), and by our group in ESKD and KT populations (13,14,17–19,21–27,40,52–55). The PFP was based on 5 components, including: exhaustion (self-reported based on 2 items from the Center for Epidemiological Studies-Depression (CES-D) scale (56): "Everything I did was an effort" and "I could not get going"); shrinking (self-reported unintentional weight loss ≥10 pounds of dry weight in the past year); low activity (kilocalories per week calculated from the short version of the Minnesota Leisure Time Activity questionnaire (57) below an established cutoff by sex and height); slowness (average walking time of 15 feet based on 3 measures below an established cutoff by sex and height); and weakness (average grip strength based on 3 measures below an established cutoff by sex and BMI; Table 1).

Each of the 5 components was scored as 0 (absence) or 1 (presence). The aggregate frailty score was calculated as the sum of all component scores, ranging from 0 to 5. We operationalized frailty both in terms of 3-categories (nonfrail: 0 points; prefrail: 1–2 points; frail: ≥3 points) and as binary (not frail: 0–2 points; frail: ≥3 points).

Development of Abridged Frailty Phenotype

We created the abridged frailty phenotype by simplifying measurements of the 5 PFP components using the prospective cohort of 3 220 ESKD patients (see Supplementary Texts 1 and 2, which give an overview of the abridged frailty phenotype tool and the corresponding instructions). Specifically: (1) exhaustion was measured based on one CES-D item—"Everything I did was an effort," which was determined by comparing the agreement between the component score ascertained by a single item and the corresponding component score ascertained by the original PFP. The observed agreement was 94.6% for item "Everything I did was an effort" whereas 81.3% for item "I could not get going"; (2) shrinking was ascertained by self-report of unintentional weight loss in the past year only; the degree of weight loss was not measured (ie, participants did not need to report—10 lbs or more to meet this criterion); (3) low activity was ascertained by self-report of doing none or only 1 of 3 activities, including walking for exercise (46.5% of the cohort reported 220 kcal/week on average), moderately strenuous chores (39.2% reported 218 kcal/week on average), and other physical activities in the past 2 weeks; (4) slowness was ascertained by one-time measure (the first measure) for walking time of 15 feet below the established cutoff by sex and height; and (5) weakness was ascertained by one-time measure (the first measure) for grip strength below the established cutoff by sex and BMI (Table 1). We then followed the same algorithm to calculate aggregate frailty score and define frailty status as described above for the PFP.

Implementation of Abridged Frailty Phenotype at Evaluation Clinic

After we developed the abridged frailty phenotype, a transplant nephrologist timed how long it took to complete these abridged frailty assessments among 20 sequential ESKD patients at evaluation for KT who met the criteria for the

Table 1. Components of the Original Physical Frailty Phenotype (PFP) and the Abridged Frailty Phenotype

	PFP	Abridged Frailty Phenotype
Exhaustion	Self-report of having either feeling occasionally or most of the time in the past week • "Everything I did was an effort" • "I could not get going"	Self-report of having the feeling occasionally or most of the time in the past week • "Everything I did was an effort"
Shrinking	Unintentional weight loss ≥10 pounds in prior year	Unintentional weight loss in the prior year
Low activity	kcals/wk based on the short version of the Minnesota Leisure Time Activity questionnaire: lowest 20% by sex • Male: <383 kcal/wk • Female: <270 kcal/wk	Self-report of doing none or only 1 of the 3 activities in the past 2 wk: • Walking for exercise • Chores (moderately strenuous) • Any other physical activities
Slowness	Walking time/15 feet based on the average of 3 measures: slowest 20% by sex and height *Male:* • height ≤173 cm: walk time ≥7 s • height >173 cm: walk time ≥6 s *Female:* • height ≤159 cm: walk time ≥7 s • height ≤159 cm: walk time ≥6 s	Walking time/15 feet based on one measure: slowest 20% by sex and height *Male:* • height ≤173 cm: walk time ≥7 s • height >173 cm: walk time ≥6 s *Female:* • height ≤159 cm: walk time ≥7 s • height ≤159 cm: walk time ≥6 s
Weakness	Grip strength based on the average of 3 measures: lowest 20% by sex, BMI *Male:* • BMI ≤24, grip strength ≤29 kg • BMI 24.1–26, grip strength ≤30 kg • BMI 26.1–28, grip strength ≤30 kg • BMI >28, grip strength ≤32 kg *Female:* • BMI ≤23, grip strength ≤ 17 kg • BMI 23.1–26, grip strength ≤17.3 kg • BMI 26.1–29, grip strength ≤18 kg • BMI >29, grip strength ≤21 kg	Grip strength based on 1 measure: lowest 20% by sex, BMI *Male:* • BMI ≤24, grip strength ≤29 kg • BMI 24.1–26, grip strength ≤30 kg • BMI 26.1–28, grip strength ≤30 kg • BMI >28, grip strength ≤32 kg *Female:* • BMI ≤23, grip strength ≤17 kg • BMI 23.1–26, grip strength ≤17.3 kg • BMI 26.1–29, grip strength ≤18 kg • BMI >29, grip strength ≤21 kg

Note: BMI = body mass index; cm = centimeters; kcal = kilocalories; kg = kilograms; s = seconds.

larger prospective cohort, to estimate assessment duration in a clinical setting. For comparison, we conducted the original PFP among 14 sequential ESKD patients at evaluation for KT who were enrolled in our cohort after the analysis for this study.

Comparison of PFP and Abridged Frailty Phenotype

Using the original PFP as the gold standard, we calculated sensitivity (the ability to correctly identify individuals who were frail by original PFP) and specificity (the ability to correctly identify individuals who were not frail by original PFP) for each frailty component and overall frailty status ascertained by the abridged frailty phenotype. We also calculated area under the curve (AUC) for each component and overall frailty status to determine the discriminative ability of the abridged phenotype.

Additionally, we examined the observed proportions of agreement between the phenotype measures. Cohen's kappa coefficient (κ) was used to assess the reliability of the abridged frailty measures. The kappa coefficient presents the proportion of joint judgments in which there is agreement after chance agreement is excluded (58). A kappa coefficient of 0 indicates chance agreement, whereas 1 indicates perfect agreement, specifically ≤0 poor, 0.01–0.20 slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and 0.81–0.99 almost perfect agreement (59). To further account for the various prevalence of frailty components, we calculated prevalence-adjusted bias-adjusted kappa (PABAK) coefficient for each component and overall frailty status, which adjusts kappa coefficient for differences in prevalence of race/ethnicity and for difference in the marginal totals (60).

Risk Prediction of Waitlist Mortality by the PFP and Abridged Frailty Phenotypes

We used Fine and Gray competing risks models to estimate crude and adjusted subdistribution hazard ratios (cSHRs and aSHRs) of waitlist mortality by categorical and binary frailty status, accounting for transplantation as a competing risk. All waitlisted candidates (n = 1 977) were followed until death, transplantation, or administrative censoring (October 2021). The time origin was date of listing, and waitlist mortality was the outcome of interest. Time to event was defined as the period from date of listing to the event date or end of follow-up. Proportional hazard assumptions were confirmed by visually inspecting log–log plots. Adjusted models accounted for age at evaluation, sex, race/ethnicity, cause of ESKD, type of dialysis, and years on dialysis. Separate models were fit for the PFP and the abridged assessment, respectively.

To compare model discrimination, we calculated Harrell's C-statistic for each model, a measure of concordance indicating the model's ability to discriminate between recipients with different times to the event of interest (61). The C-statistic ranges from 0.5 (no discrimination) to 1.0 (perfect

discrimination), where higher values indicate greater prediction accuracy in differentiating which recipients will have longer versus shorter times to event occurrence. We tested whether there was a significant difference between the abridged frailty phenotype model C-statistic and the PFP model C-statistic using the Z-statistic (62).

Statistical Analyses

All analyses were performed using Stata 16 (StataCorp, College Station, TX). Two-sided p values < .05 were considered statistically significant.

Results

Study Population

Among 3 220 ESKD patients at evaluation with a mean age of 54.9 (standard deviation [*SD*]: 13.5 years), 39.8% were female, 44.5% were Black, and 68.8% were undergoing dialysis, with a median time on dialysis of 0.7 years (interquartile range [IQR]: 0.0–2.9; Table 2).

Feasibility of Abridged Frailty Phenotype at Evaluation Clinic

The abridged frailty phenotype was easy to administer in the clinic at KT evaluation. Among the 20 ESKD patients at KT evaluation, abridged frailty assessments took a range of 5–7 minutes to complete in comparison to the 14–17 minutes that it took for the original PFP.

Table 2. Characteristics of Patients With End-stage Kidney Disease (ESKD) at Evaluation for Kidney Transplantation (KT) (n = 3,220)

	ESKD patients (n = 3 220)
Age at enrollment, mean (*SD*)	54.9 (13.5)
Female sex, %	39.8%
Race/ethnicity, %	
Non-Hispanic White	47.1%
Non-Hispanic Black	44.5%
Hispanic	3.1%
Other	5.4%
Education, %	
Below high school	6.0%
High school	38.3%
Above high school	55.6%
BMI (kg/m^2), mean (*SD*)	28.7 (6.2)
Cause of kidney failure, %	
Glomerulonephritis	22.1%
Diabetes mellitus	20.2%
Hypertension	30.7%
Others	27.0%
Type of dialysis, %	
Preemptive KT	31.2%
Hemodialysis	56.2%
Peritoneal dialysis	12.6%
Years on dialysis, median (IQR)	0.7 (0.0, 2.9)

Note: BMI = body mass index; IQR = interquartile range; KT = kidney transplant; *SD* = standard deviation.

Validity of Abridged Frailty Measures

The PFP identified 23.8% of candidates as frail. Low-grip strength (52.0%) was the most prevalent component, followed by low activity (50.9%), exhaustion (33.5%), shrinking (19.0%), and slow walking speed (14.8%). In comparison, the abridged assessment identified 27.4% of candidates as frail, with low activity (58.5%) as the most prevalent component, followed by low-grip strength (55.5%), shrinking (28.4%), exhaustion (28.1%), and slow walking speed (15.4%; Table 3).

Using the original PFP measure as the gold standard, the abridged frailty measure had a sensitivity of 82.5% and a specificity of 89.7%, with excellent discrimination (AUC = 0.861). Additionally, the sensitivity and specificity of specific frailty components were all greater than 80% and showed substantial discriminative ability (all AUC > 0.9), apart from low activity, which had slightly lower specificity (70.4%) and discrimination (AUC = 0.783; Table 3).

Agreement of Frailty Measures

The observed agreement of frailty measures using the PFP and abridged assessment was 88.0%, specifically 94.6% for exhaustion, 90.1% for shrinking, 78.5% for low activity, 95.2% for slowness, and 90.4% for weakness. Most often measures achieved at least substantial agreement (>0.61), with a kappa coefficient of 0.69 (95% confidence interval [CI]: 0.66–0.71) for frailty status, 0.87 (95% CI: 0.86–0.89) for exhaustion, 0.73 (95% CI: 0.70–0.76) for shrinking, 0.81 (95% CI: 0.78–0.84) for slowness, and 0.81 (95% CI: 0.79–0.83) for weakness, whereas low activity measures achieved moderate agreement (kappa = 0.57, 95% CI: 0.54–0.60). Results based on PABAK were similar (Table 3).

Discrimination of Waitlist Mortality

Among waitlisted KT candidates (n = 1 977), 15.4% (n = 305) died on the waitlist and 65.9% (n = 1 302) received a KT during a median follow-up period of 1.94 (IQR = 0.74–3.97) years. Using the PFP, prefrail candidates had a 2.26-fold higher risk of waitlist mortality (cSHR = 2.26, 95% CI: 1.48–3.46) and frail candidates had a 3.74-fold higher risk of waitlist mortality (cSHR = 3.74, 95% CI: 2.39–5.84), compared to nonfrail candidates before adjustment. The estimates were similar using the abridged frailty measure: prefrail candidates had a 2.20-fold higher risk of waitlist mortality (cSHR = 2.20, 95% CI: 1.35–3.57) and frail candidates had a 3.65-fold higher risk of waitlist mortality (cSHR = 3.65, 95% CI: 2.22–6.01), compared to nonfrail candidates (Table 4).

After adjustment of all covariates, prefrail candidates had a 2.00-fold higher risk of waitlist mortality (aSHR = 2.00, 95% CI: 1.30–3.06) and frail candidates had a 2.93-fold higher risk of waitlist mortality (aSHR = 2.93, 95% CI: 1.85–4.64), compared to their nonfrail counterparts when using the PFP. When using the abridged frailty measure, prefrail candidates had a 1.88-fold higher risk of waitlist mortality (aSHR = 1.88, 95% CI: 1.15–3.09) and frail candidates had a 2.98-fold higher risk of waitlist mortality (aSHR = 2.98, 95% CI: 1.78–4.98) compared to those who were nonfrail (Table 4).

Models with the PFP (crude model C-statistic = 0.5636; adjusted model C-statistic = 0.6651) and abridged frailty (crude model C-statistic = 0.5662; adjusted model C-statistic = 0.6644) showed comparable discrimination for waitlist mortality (crude models: p = .81; adjusted models: p = .89; Table 4). The results for binary frailty measures were

Table 3. Validity and Reliability of the Abridged Frailty Phenotype Compared to the Original Physical Frailty Phenotype (PFP) Among Patients with End-stage Kidney Disease Undergoing Evaluation for Kidney Transplantation (n = 3 220)

	Prevalence		Sensitivity	Specificity	AUC	Observed agreement	Kappa (95% CI)	PABAK (95% CI)
	PFP	Abridged						
Frailty component								
Exhaustion	33.5%	28.1%	83.9%	100.0%	0.920	94.6%	0.87 (0.86, 0.89)	0.89 (0.88, 0.91)
Shrinking	19.0%	28.4%	98.7%	88.1%	0.934	90.1%	0.73 (0.70, 0.76)	0.80 (0.78, 0.82)
Low activity	50.9%	58.5%	86.3%	70.4%	0.783	78.5%	0.57 (0.54, 0.60)	0.57 (0.54, 0.60)
Slowness	14.8%	15.4%	85.5%	96.8%	0.912	95.2%	0.81 (0.78, 0.84)	0.90 (0.89, 0.92)
Weakness	52.0%	55.5%	94.2%	86.3%	0.902	90.4%	0.81 (0.79, 0.83)	0.81 (0.79, 0.83)
Frailty status	23.8%	27.4%	82.5%	89.7%	0.861	88.0%	0.69 (0.66, 0.71)	0.76 (0.74, 0.78)

Note: AUC = area under the receiver operating characteristic curve; CI = confidence interval; PABAK = prevalence-adjusted bias-adjusted kappa.

Table 4. Comparing the Abridged Frailty Phenotype With the Original Frailty Phenotype for Prediction of Waitlist Mortality Among Kidney Transplant Candidates (n = 1 977). Adjusted Models Accounted for Age at Evaluation, Sex, Race/Ethnicity, Cause of End-stage Kidney Disease, Type of Dialysis, Years on Dialysis

	Crude models cSHR (95% CI)		p Value	Adjusted models aSHR (95% CI)		p Value
	Original	Abridged		Original	Abridged	
Waitlist mortality						
Categorical frailty						
Nonfrail	Reference	Reference		Reference	Reference	
Prefrail	**2.26 (1.48, 3.46)**	**2.20 (1.35, 3.57)**		**2.00 (1.30, 3.06)**	**1.88 (1.15, 3.09)**	
Frail	**3.74 (2.39, 5.84)**	**3.65 (2.22, 6.01)**		**2.93 (1.85, 4.64)**	**2.98 (1.78, 4.98)**	
Harrell's C-statistic	0.5636	0.5662	.81	0.6651	0.6644	.89
Binary frailty						
Nonfrail/prefrail	Reference	Reference		Reference	Reference	
Frail	**1.89 (1.49, 2.40)**	**1.84 (1.46, 2.33)**		**1.62 (1.26, 2.08)**	**1.70 (1.33, 2.16)**	
Harrell's C-statistic	0.5311	0.5454	.21	0.6562	0.6590	.51

Notes: aSHR = adjusted subdistribution hazard ratio; cSHR = crude subdistribution hazard ratio; CI = confidence interval.
Bold values are statistically significant (p <.05). p Values compare the Harrell's C-statistics between the models with the original and abridged frailty phenotypes.

similar in terms of magnitude of associations and model discrimination (crude models: p = .21; adjusted models: p = .51; Table 4).

Discussion

This study proposes a novel, abridged frailty phenotype for surgical patients that is easier and more efficient to implement in a clinical setting by simplifying the PFP, taking a range of 5–7 minutes to complete, without compromising its validity. We evaluated the accuracy of the abridged assessment, finding that it identified a comparable proportion of ESKD patients with frailty at evaluation for KT (PFP: 23.8% and abridged assessment: 27.4%), had substantial agreement (kappa = 0.69, 95% CI: 0.66–0.71), and had excellent discriminative ability (AUC = 0.861) compared to the original PFP. Additionally, the PFP and abridged assessment had similar predictive validity with waitlist mortality (aSHR = 1.62, 95% CI: 1.26–2.08 vs aSHR = 1.70, 95% CI: 1.33–2.16), demonstrating comparable mortality discrimination (p = .51).

Although research supports the importance of frailty as a prognosticator in surgical patients (1–5,30,63,64), there are several barriers to its widespread implementation in clinical settings. Among the many measures of frailty, the PFP is the most widely used and extensively studied measure (35,36); however, the PFP can take as long as 17 minutes to complete during KT evaluation. Shorter and simpler instruments are most feasible in clinical practice (65). Several quick screening tools have been developed and validated in response to this need for more clinically practical frailty measures (66), such as the Clinical Frailty scale (CFS) (67) and the FRAIL scale (68). The CFS is based on clinical observation by the physician, whereas the FRAIL scale is based on self-report (65). Transplant centers did not report using the CFS in clinical practice (33). In the broader surgical field, the CFS has been found to have good predictive validity for perioperative outcomes compared to the PFP (69); future studies should compare this new measure of the PFP with CFS. Though these quick identification tools are important in the clinical setting, caution is advised given that instruments are not necessarily interchangeable with different items measured (70), as well as the frequent lack of agreement in discriminating patients who are frail from those who are nonfrail using these different assessment instruments (71). For example, among ESKD patients, physician- and patient-reported frailty, though often simpler to apply in clinical settings, were shown to be inadequate proxies of measured frailty, often misclassifying frailty

status (11). This is especially important to consider in parallel with a national survey that found that 99% of KT programs agreed that frailty is a useful concept in evaluating candidacy for KT (33). This study addresses this major limitation; development of the abridged assessment provides a novel, objective approach for measuring frailty in clinical practice, adapted from the most widely used frailty assessment—the PFP. Given that the PFP has been shown to be an excellent method for identifying patients who are robust and can withstand stressors of surgery regardless of their age (30), the abridged frailty assessment can offer a simpler and quicker alternative to the PFP without compromising validity.

This study is not without limitations. Though this study involved a two-center design, with a diverse KT candidate population, results may not be fully generalizable nationally. As such, further research is needed to externally validate the abridged assessment in different populations across the United States and internationally. Furthermore, the assessment of time to completion of the abridged PFP was assessed in a small sample and was not compared to completion time of other frailty instruments. Additionally, the C-statistic suggested moderate predictive validity for both the PFP and the abridged PFP; however, it is comparable to other commonly used scores like the Estimated Post Transplant Survival score which has a C-statistic of 0.67 to 0.69 (72). Finally, the agreement was lowest for low physical activity likely because the Minnesota Leisure Time Activity consists of multiple activities in which participation and duration must be reported. Given the breadth of information collected on this assessment, the agreement is lower when we use an abridged version. Future research should: (1) explore the use of objective measures of physical activity/accelerometry from wearable devices as a replacement for this subjective component, and (2) validate the abridged PFP in multicenter studies across the transplant continuum of care. Nonetheless, this study had several strengths, including its large, diverse population, the use of an objective, validated measure of frailty (the PFP), and its multi-faceted validation process.

Our findings support the use of this novel, validated abridged frailty phenotype in clinical settings. It provides a cost-effective, objective measure of frailty that is easier and more efficient to use compared to the original PFP, without substantially sacrificing its accuracy in identifying frail versus nonfrail patients, as well as its predictive validity for estimating mortality risk. This measure is particularly timely given the new rules for transplant centers requiring reporting of mortality on the waitlist following the Member and Professional Standards Committee of the United Network for Organ Sharing. In light of implementation of this new rule, and with death rates rising to 5.7 deaths per 100 waitlist years (the highest since 2012) and deaths within 6 months of removal from the waitlist increasing dramatically in 2020 (73), transplant centers should identify patients who are frail using light touch frailty and work with a multidisciplinary team to improve physiologic reserve and resolve their frailty.

It is known that frailty has a negative financial impact on hospital income and costs in elective surgery (74). Therefore, surgeons should consider using the abridged assessment when time is limited in order to optimize resource allocation. Furthermore, when frailty is measured, an opportunity arises to intervene and improve frailty status, which in turn may decrease health care costs. Our findings provide a valid frailty tool to reduce clinician workload, improve surgical patient care, and prevent hospital burden during lengthy, comprehensive preoperative evaluations.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

None.

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Author Contributions

Research idea and study design: M.M.D.; data acquisition: D.L.S., M.M.D.; data analysis/interpretation: X.C., N.M.C., V.T., E.E.Q., S.A., Q.X., D.C.B., S.P.N., B.E.L., J.D.W., D.L.S., M.M.D.; statistical analysis: X.C., M.M.D.; supervision or mentorship: D.L.S., M.M.D. Each author contributed important intellectual content during manuscript drafting and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved. X.C. and N.M.C. take responsibility that this study has been reported honestly, accurately, and transparently.

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