A 10-Item Frailty Index Based on a Comprehensive Geriatric Assessment (FI-CGA-10) in Older Adults with Cancer: Development and Construct Validation

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Disclosures of potential conflicts of interest may be found at the end of this article.

Key Words. Frailty • Comprehensive geriatric assessment • Construct validation • Frailty index • Older adults with cancer

ABSTRACT

Background. A frailty index (FI) based on domain-level deficits identified through a comprehensive geriatric assessment (CGA) has been previously developed and validated in general geriatric patients. Our objectives were to construct an FI-CGA and to assess its construct validity in the geriatric oncology setting.

Methods. Five hundred forty consecutive Japanese patients with cancer who underwent a CGA on a geriatric oncology service were included (median age 80 years, range 66–96 years). We developed a 10-item frailty index based on deficits in 10 domains (FI-CGA-10): cognition, mood, communication, mobility, balance, nutrition, basic and instrumental activities of daily living, social support, and comorbidity. Deficits in each domain were scored as 0 (no problem), 0.5 (minor problem), and 1.0 (major problem). Scores were calculated by dividing the sum of the

scores for each domain by 10 and then categorized as fit (<0.2), pre-frail (0.2–0.35), and frail (>0.35). Construct validity was tested by correlating the FI-CGA-10 with other established frailty measures.

Results. FI-CGA-10 was well approximated by the gamma distribution. Overall, 20% of patients were fit, 41% were pre-frail, and 39% were frail. FI-CGA-10 was correlated with Canadian Study of Health and Aging (CSHA) Clinical Frailty Scale ($r = 0.83$), CSHA rules-based frailty definition ($r = 0.67$), and CSHA Function Score ($r = 0.77$). Increasing levels of frailty were significantly associated with functional and cognitive impairments, high comorbidity burden, poor self-rated health, and low estimated survival probabilities.

Conclusion. The FI-CGA-10 is a user-friendly and construct-validated measure for quantifying frailty from a CGA. *The Oncologist* 2021;26:e1751–e1760

Implications for Practice: This article describes the construction of a user-friendly 10-item frailty index based on a comprehensive geriatric assessment (FI-CGA-10) for older adults with cancer: cognition, mood, communication, mobility, balance, nutrition, basic and instrumental activities of daily living, social support, and comorbidity. The FI-CGA-10 simplifies the original FI-CGA used in the general geriatric setting while maintaining its content validity. The index's construct validity was demonstrated in a cohort of older adults with various cancer types. The advantage of the FI-CGA-10 is that a frailty score can be calculated more readily and interpreted in a more clinically sensible manner than the original FI-CGA.

INTRODUCTION

Frailty is a multidimensional syndrome characterized by loss of reserve and resistance to stressors, which increases an

individual's vulnerability to poor health outcomes [1]. Studies of older adults with cancer have shown that frailty is

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associated with chemotherapy intolerance, postoperative complications, and death [2, 3]. Although there is no consensus on how to measure frailty, the two most widely accepted approaches are the phenotype model and the cumulative deficit model [4]. The phenotype model establishes a frailty phenotype using five variables: unintentional weight loss, weak grip strength, self-reported exhaustion, slow gait speed, and low physical activity [5]. The cumulative deficit model forms the basis of a frailty index (FI) based on a wide variety of age-related deficits [6].

Based on these models, many tools have been developed to measure frailty; however, there is currently no gold standard. Sutton et al. performed a systematic review to evaluate the psychometric properties of multicomponent frailty assessment tools specifically designed to measure frailty in older adults [7]. Of 38 tools evaluated in the review, one of only two tools that had acceptable evidence of reliability and validity was the Frailty Index–Comprehensive Geriatric Assessment (FI-CGA).

FI-CGA was constructed by Jones and Rockwood based on domain-level deficits in a standardized comprehensive geriatric assessment (CGA) [8, 9]. Comprehensive Geriatric Assessment is defined as “a multidimensional, interdisciplinary, diagnostic process to identify care needs, plan care, and improve outcomes of frail older people” [10]. The FI-CGA comprised of assessments in 10 impairment domains (cognition, mood, communication, mobility, balance, bowels, bladder, nutrition, daily activities, and social) and a single comorbidity domain. Impairments within each domain are categorized into a three-level rating system: no problem, a minor problem, or a major problem. The FI-CGA score is calculated by counting the number of domain-level impairments and normalizing it to a score between 0 and 1. In a secondary analysis of data from the Canadian Study of Health and Aging-2 (CSHA-2), the FI-CGA correlated highly with the original version of the previously validated frailty index (Pearson’s $r = 0.76$) [9]. Higher FI-CGA score was associated with higher risk of death and institutionalization. For each increment in frailty, the adjusted hazard ratio was 1.23 (95% confidence interval [CI], 1.18–1.29) and 1.20 (95% CI, 1.10–1.32) for death and institutionalization, respectively [9]. This FI-CGA domain-based approach to frailty index has not been tested in older adults with cancer. The objectives of this study were to construct an easy-to-use FI-CGA applicable in the geriatric oncology setting and to investigate its construct validity.

MATERIALS AND METHODS

Patients

The geriatric oncology service at the National Hospital Organization Kyushu Cancer Center (NKCC) in Japan was launched in September 2018. Nurses administered the G8, a geriatric screening tool, for all new patients aged 75 years and older at their initial clinic visit to the NKCC [11]. A referral for CGA conducted at the geriatric oncology service was made at the discretion of the treating physician based on their clinical judgment and the G8 score, where available. A geriatric oncologist (T.F.N.) completed the CGA, which

included four major elements, namely, physical health, functional status, psychological health, and socioenvironmental parameters [12–14]. The assessment was performed not only with the patient but also whenever possible with their caregiver(s). The referring physician was provided with a summary of the CGA findings and recommendations for cancer treatment and targeted interventions to address identified vulnerabilities. In addition, we recorded baseline sociodemographic data, Eastern Cooperative Oncology Group performance status (ECOG PS), tumor and treatment characteristics, and pretreatment laboratory data [15]. The data were prospectively collected into an electronic database. Consecutive patients who had undergone CGA at the geriatric oncology service between September 2018 and October 2020 were included in this cohort. These assessments were conducted as a part of routine clinical practice. Patients provided written informed consent for the collection of clinical data and for the use of the data for research. The study was approved by the Institutional Review Board.

Constructing the FI-CGA-10

We constructed a 10-item FI-CGA (FI-CGA-10) based on a modification of the original FI-CGA. The original FI-CGA consists of an impairment index and a comorbidity index [9]. The impairment index consists of 10 domains: cognition, mood, communication, mobility, balance, bowels, bladder, nutrition, daily activities, and social support. Impairments in each domain are scored as 0 (no problem), 0.5 (a minor problem), and 1.0 (a major problem). The impairment index score ranges from 0 to 10. The comorbidity index is assessed using the Cumulative Illness Rating Scale, and its score is standardized into a range of 0 to 4 [16]. The FI-CGA score is calculated by dividing the sum of the impairment and comorbidity index scores by 14.

In the FI-CGA-10, we reclassified the daily activities, bladder, and bowel domains and simplified the assessment of comorbidity. First, we divided the daily activities domain in the original FI-CGA, which includes both activities of daily living (ADLs) and instrumental activities of daily living (IADLs), into two independent domains: ADL and IADL. We then incorporated the bladder and bowel domains into the ADL domain by defining the ADL impairment level 0.5 as “bladder and/or bowel incontinence.” Second, we treated comorbidity as one of the domains and scored it in the same way as the other domains (i.e., three levels of impairment: 0, 0.5, and 1.0). With these changes, we had a total of 10 domains including comorbidity in the FI-CGA-10.

Table 1 describes the measures and the scoring definitions for the 10 domains. We evaluated each domain with tools commonly used in geriatric oncology and defined the impairment level of each domain based on the original FI-CGA and relevant literature. Cognitive status was initially screened using the Mini-Cog [17]. For patients with a Mini-Cog score ≤ 4 , the Montreal Cognitive Assessment (MOCA) was performed [18]. This threshold was chosen to increase sensitivity to screen for cognitive impairment [19]. For patients with a history of dementia, the Mini-Mental State Exam, instead of the MOCA, was performed [20]. Emotional status was initially assessed using the Patient Health

Table 1. FI-CGA-10 scoring system for each domain based on severity of the problem

10 CGA domains	Scoring system			No. of items	Relevant literature for scoring
	0 (no problem)	0.5 (minor problem)	1.0 (major problem)		
1. Cognition ^a	No cognitive impairment	Mild Cognitive Impairment	Dementia	2 ^b	[8, 9]
2. Emotion	PHQ-2 < 3 or PHQ-9 < 5	5 ≤ PHQ-9 < 10	PHQ-9 ≥ 10	2 ^c	[22]
3. Communication ^a	No interference with activities	Some interference with activities	Major interference with activities	4	[35, 36]
4. Mobility	Gait speed ≥1.0 m/s	0.8 m/s ≤ Gait speed <1.0 m/s	Gait speed <0.8 m/s	1	[37]
5. Balance	No. of falls in past 6 months = 0	No. of falls in past 6 months = 1	No. of falls in past 6 months ≥2	1	[9, 38]
6. Nutrition	Weight loss in past 3–6 months <5%	5% ≤ Weight loss in past 3–6 months ≤10%	Weight loss in past 3–6 months >10%	1	[27, 28]
7. ADL ^a	OARS ADL = 14	OARS ADL = 12 or 13 (only due to incontinence question)	OARS ADL <14 (including at least one impairment other than incontinence)	7	[39]
8. IADL ^a	OARS IADL = 14	OARS IADL = 12 or 13	OARS IADL ≤11	7	[40, 41]
9. Social support ^a	All of the time	Most or Some of the time	A little or None of the time	1	[42]
10. Comorbidity	No. of level 3 or 4 severity CIRS-G categories = 0	No. of level 3 or 4 severity CIRS-G categories = 1 or 2	No. of level 3 or 4 severity CIRS-G categories ≥3	14	[43]

^aSee supplemental online Appendix for more detailed descriptions of scoring definitions.

^bFor patients with a Mini-Cog score ≤ 4, the Montreal Cognitive Assessment (MOCA) was performed. For patients with a history of dementia, the Mini-Mental State Exam (MMSE), instead of the MOCA, was performed. The number of questions for the MOCA and MMSE is 18 and 20, respectively.

^cFor patients with a PHQ-2 score ≥ 3, an additional seven questions were asked to perform the PHQ-9.

Abbreviations: ADL, activity of daily living; CIRS-G, Cumulative Illness Rating Scale for Geriatrics; FI-CGA-10, 10-item frailty index based on a comprehensive geriatric assessment; IADL, instrumental activity of daily living; OARS, Older American Resources and Services; PHQ, Patient Health Questionnaire.

Questionnaire-2 (PHQ-2) [21]. For patients with a PHQ-2 score ≥ 3, the PHQ-9 was performed [22]. Communication was assessed by self-rated hearing and vision status using questions from the Older Americans Resources and Services (OARS) Physical Health Section [23, 24]. Patients were asked to rate their hearing (with a hearing aid if needed) and eyesight (with glasses or contacts) as “excellent,” “good,” “fair,” “poor,” or “totally deaf/blind.” Patients who rated either their hearing or eyesight as “fair,” “poor,” or “totally deaf/blind” were asked, “How much does it interfere with your activities?”, using the following options: “not at all,” “somewhat,” or “a great deal.” Mobility was assessed by gait speed measured using a 4-m course and a stopwatch [25]. Patients were instructed to walk at their usual pace from a standing start. Assistive devices were allowed if needed. Balance was assessed by number of falls in the past 6 months [23, 26]. Nutritional status was assessed by percentage of unplanned weight loss in the last 3 to 6 months [27, 28]. ADLs and IADLs were evaluated using the OARS ADL and IADL subscales, respectively [24, 29]. One of the OARS ADL items assesses bladder and/or bowel incontinence. Tangible social support was assessed with a question from the Medical Outcomes Study Social Support Survey [30], asking patients if they had “someone to help with daily chores if you were sick” with responses options from 1 (none of the time) to 5 (all of the time). Comorbidity was

defined as the sum of conditions that are not related to the index cancer and assessed using the Cumulative Illness Rating Scale for Geriatrics (CIRS-G) [31, 32]. The CIRS-G classifies comorbid conditions by organ systems and grades each condition from level 0 to 4: no problem, mild, moderate, severe, extremely severe. The number of conditions at severity level 3 and 4 was used as a summary score.

The FI-CGA-10 score was calculated by dividing the sum of the scores for each domain by 10, the total number of domains considered. The score was normalized to the range of 0 to 1 in a similar way as the original FI. For example, with 3.5 deficits present, the FI-CGA-10 score would be 3.5/10 = 0.35. The FI-CGA-10 categorized patients into one of the three categories: fit (0 to <0.2), pre-frail (0.2–0.35), and frail (>0.35), according to the cutoff points used in the previously developed FIs for older patients with cancer [33, 34].

Comparator Variables

To assess construct validity, we evaluated the correlation between the FI-CGA-10 and other validated frailty measures. These included the Canadian Study of Health and Aging (CSHA) Clinical Frailty Scale (CFS), the CSHA rules-based frailty definition, and the CSHA Function Score [39, 44]. The CSHA Clinical Frailty Scale classifies patients into one of seven categories: (1) very fit, (2) well,

Table 2. Patient and clinical characteristics (*n* = 540)

Characteristic	Patients (<i>n</i> = 540), <i>n</i> (%)
Age, years	
65–69	9 (2)
70–74	37 (7)
75–79	197 (36)
80–85	185 (34)
85–90	93 (17)
≥90	19 (4)
Sex	
Male	328 (61)
Female	212 (39)
ECOG PS	
0	170 (31)
1	236 (44)
2	84 (16)
3–4	50 (9)
Cancer type	
Gastrointestinal tract	200 (37)
Hepatobiliary and pancreatic	118 (22)
Head and neck	67 (12)
Hematologic malignancy	36 (7)
Genitourinary	32 (6)
Gynecologic	31 (6)
Lung	20 (4)
Other	36 (7)
Cancer stage	
Stage I ^a	105 (19)
Stage II	79 (15)
Stage III	117 (22)
Stage IV	228 (42)
Not applicable	11 (2)
Educational level	
Less than high school	170 (31)
High school graduate	276 (51)
Some college or above	94 (17)
Marital status	
Married	343 (64)
Widowed	153 (28)
Separated, divorced	35 (6)
Single	9 (2)
Household composition	
Lives alone	102 (19)
Lives with family	419 (78)
Lives in a long-term care facility	19 (4)

^aIncludes one patient with stage 0 disease.

Abbreviation: ECOG PS, Eastern Cooperative Oncology Group performance status.

(3) managing well, (4) vulnerable, (5) mildly frail, (6) moderately frail, and (7) severely frail, using clinical judgment based mainly on assessment comorbidity, function, and

Figure 1. Distribution of the FI-CGA-10 (*n* = 540). The histogram represents observational data, and the solid curve is a gamma distribution with the parameters of shape (2.64) and scale (0.13).

Abbreviation: FI-CGA-10, 10-item frailty index based on a comprehensive geriatric assessment.

cognitive status [44]. The CSHA rules-based frailty definition classifies patients into one of four levels based on OARS ADL and cognitive status: level 0 (no cognitive or ADL impairment), level 1 (isolated urinary incontinence), level 2 (dependence in one ADL or having a diagnosis of cognitive impairment with no dementia), or level 3 (dependence in at least two ADLs, having mobility impairment or having a diagnosis of dementia) [39]. The CSHA Function Scale is based on 12 of 14 OARS ADL and IADL items (walking and transferring items were excluded from ADL). Each item is rated as 0 (without help), 1 (with some help), or 2 (completely unable) [44]. The CSHA Function Scale score is calculated by dividing the sum of each item score by 24, with a final score range of 0 to 1 (lower score represents better function).

We also examined the association between the FI-CGA-10 and several features that are commonly seen in frail older adults such as functional and cognitive impairments, high comorbidity burden, and poor self-rated health (SRH) status. Functional status was assessed using the Timed Up and Go test [45], self-reported ability to walk one block and several blocks (1, limited a lot; 2, limited a little; 3, not limited at all) [46], and independent life-space (LS-I; the highest life-space level attained without help from a person and without using any equipment) and life-space using equipment (LS-E; the highest life-space level attained without help from a person, even if equipment was used). LS-I and LS-E levels range from within one's dwelling (level 0) to beyond one's town (level 5) [47]. Cognitive status was represented by the Mini-Cog score. As comparator variables, comorbidity burden was assessed by the Charlson

Table 3. The FI-CGA-10 variables by frailty category

FI-CGA-10 variables	All patients (n = 540), n (%)	Fit (0 to <0.2) (n = 109), n (%)	Pre-Frail (0.2–0.35) (n = 219), n (%)	Frail (>0.35) (n = 212), n (%)
1. Cognition				
0 (no problem)	269 (50)	94 (86)	122 (56)	53 (25)
0.5 (minor problem)	150 (28)	15 (14)	70 (32)	65 (31)
1.0 (major problem)	121 (22)	0	27 (12)	94 (44)
2. Emotion				
0 (no problem)	424 (79)	101 (93)	178 (81)	145 (68)
0.5 (minor problem)	55 (10)	7 (6)	28 (13)	20 (9)
1.0 (major problem)	61 (11)	1 (1)	13 (6)	47 (22)
3. Communication				
0 (no problem)	338 (63)	99 (91)	146 (67)	93 (44)
0.5 (minor problem)	136 (25)	10 (9)	58 (26)	68 (32)
1.0 (major problem)	66 (12)	0	15 (7)	51 (24)
4. Mobility				
0 (no problem)	109 (20)	57 (52)	47 (21)	5 (2)
0.5 (minor problem)	217 (40)	47 (43)	127 (58)	43 (20)
1.0 (major problem)	214 (40)	5 (5)	45 (21)	164 (77)
5. Balance				
0 (no problem)	437 (81)	107 (98)	196 (90)	134 (63)
0.5 (minor problem)	65 (12)	2 (2)	21 (10)	42 (20)
1.0 (major problem)	38 (7)	0	2 (1)	36 (17)
6. Nutrition				
0 (no problem)	352 (65)	97 (89)	141 (64)	114 (54)
0.5 (minor problem)	126 (23)	11 (10)	62 (28)	53 (25)
1.0 (major problem)	62 (11)	1 (1)	16 (7)	45 (21)
7. ADL				
0 (no problem)	368 (68)	102 (94)	188 (86)	78 (37)
0.5 (minor problem)	60 (11)	7 (6)	28 (13)	25 (12)
1.0 (major problem)	112 (21)	0	3 (1)	109 (51)
8. IADL				
0 (no problem)	235 (44)	105 (96)	121 (55)	9 (4)
0.5 (minor problem)	114 (21)	4 (4)	72 (33)	38 (18)
1.0 (major problem)	191 (35)	0	26 (12)	165 (78)
9. Social support				
0 (no problem)	216 (40)	59 (54)	82 (37)	75 (35)
0.5 (minor problem)	270 (50)	50 (46)	113 (52)	107 (50)
1.0 (major problem)	54 (10)	0	24 (11)	30 (14)
10. Comorbidity				
0 (no problem)	88 (16)	42 (39)	36 (16)	10 (5)
0.5 (minor problem)	295 (55)	62 (57)	134 (61)	99 (47)
1.0 (major problem)	157 (29)	5 (5)	49 (22)	103 (49)

Abbreviation: ADL, activities of daily living; FI-CGA-10, 10-item frailty index based on a comprehensive geriatric assessment; IADL, instrumental activities of daily living.

comorbidity index and a number of medications [48]. SRH status was evaluated using a validated single question, “In general, would you say your health is excellent (1), very good (2), good (3), fair (4), or poor (5)?” [49].

As an alternative to assessing the ability of the FI-CGA-10 to predict mortality, we tested the correlation

between the FI-CGA-10 and validated prognostic indices for mortality, such as the Lee index and the Schonberg index [50–53]. The Lee index ranges from 0 to 23 based on 12 weighted items, and the Schonberg index ranges from 0 to 29 based on 11 weighted items. Higher scores reflect a higher risk of mortality within 4 and 10 years

(Lee index) or within 5, 10, and 14 years (Schonberg index).

Lastly, we explored the association between the FI-CGA-10 and the ECOG PS, which is a functional status measure widely used by oncologists [54]. The ECOG PS classifies patients based on their physical ability, daily activity, and self-care ability, ranging from 0 (fully active) to 4 (completely disabled).

Statistical Analysis

Descriptive analyses were performed to summarize sample characteristics. We assessed the fit of the distribution of the observed FI-CGA-10 using a gamma density function. This is a positively skewed distribution with a long right tail that has been observed with the FIs and the original FI-CGA [6, 9, 55]. Correlation analyses were performed using Pearson's correlation. A chi-square test or one-way analysis of variance was used to assess bivariable associations between the frailty categories and frailty characteristics for categorical and continuous variables, respectively. For a more detailed categorization of patient fitness and frailty level, we mapped the FI-CGA-10 to the CFS by calculating descriptive statistics of the FI-CGA-10 scores according to the seven CFS categories. A value of $p < .05$ was considered statistically significant for all analyses. Analyses were performed using Stata 16 software (StataCorp LLC, College Station, TX), an R package ("fitdistrplus"), and BoxPlotR [56].

RESULTS

Patient Characteristics

Five hundred and fifty-nine patients underwent CGA at the geriatric oncology service between September 2018 and October 2020. Later, five patients were found to have a noncancer diagnosis and excluded from the final cohort. For 14 patients who had the CGA done twice at different time points during their cancer treatment, only their initial CGA results were included. The final study population consisted of 540 patients. We did not set any referral criteria for a CGA based on age or G8 score, and 46 patients aged 65–74 years who had not been screened by the G8 were referred. The median age was 80 years (range, 66–96 years), and 61% were male. Most of the patients had ECOG performance scores of 0 or 1 (75%) with a range of 0–4. The most common type of cancer was gastrointestinal tract (37%). Detailed patient characteristics are shown in Table 2.

Characteristics of the FI-CGA-10

The mean $\pm$ SD of the FI-CGA-10 was 0.34 ± 0.18 , and the distribution of scores is shown in Figure 1. By visual inspection of Figure 1, the skewed distribution was well approximated by the gamma distribution parameters of shape (2.64) and scale (0.13). The number of patients with each scoring variable in the FI-CGA-10 is presented in Table 3.

Construct Validity of the FI-CGA-10

Using the FI-CGA-10, 20% of patients ($n = 109$) were categorized as fit, 41% ($n = 219$) as pre-frail, and 39% ($n = 212$)

as frail. Patients with higher scores on the FI-CGA-10 had higher scores on previously validated frailty measures (Table 4). The FI-CGA-10 correlated with the CFS (Pearson's $r = 0.83$; 95% CI, 0.80–0.85; supplemental online Fig. 1), CSHA rules-based frailty definition ($r = 0.67$; 95% CI, 0.62–0.72), and CSHA Function Score ($r = 0.77$; 95% CI, 0.74–0.81). Table 4 summarizes the clinical characteristics by grade of frailty. As expected, the distribution of the frailty indicators differed significantly between each level of frailty. Table 4 also shows prognostic indices by FI-CGA-10–based frailty category. People who were frailer had higher scores on the Lee index and the Schonberg index, suggesting an increased probability of death. The high degree of correlation between the FI-CGA-10 and established frailty measures supports construct validity.

Six Levels of Fitness and Frailty

FI-CGA-10 scores mapped to the seven CFS categories are shown in supplemental online Table 1 and in Figure 2. The number of patients categorized as CFS 1 (very fit, $n = 7$) and CFS 2 (well, $n = 11$) were small and were collapsed into one category. Based on the distribution of the FI-CGA-10 by the CFS, we divided the FI-CGA-10 scores into six levels of fitness and frailty. FI-CGA-10 level 1 has a score of ≤ 0.1 , corresponding to the CFS very fit and well categories; level 2 has a score of 0.15–0.20 (managing well); level 3 has a score of 0.25–0.30 (vulnerable); level 4 has a score of 0.35–0.45 (mildly frail); level 5 has a score of 0.50–0.60 (moderately frail); and level 6 has a score of ≥ 0.65 (severely frail). According to this six-level classification, greater frailty was associated with higher scores for both comparator frailty measures: the CSHA rules-based frailty definition ($r = 0.67$) and the CSHA Function Score ($r = 0.73$). Similar associations were found for the prognostic indices: Lee index ($r = 0.64$) and Schonberg index ($r = 0.54$). Increasing levels of frailty were associated with worse functional and cognitive status, higher comorbidity burden, and worse SRH in a dose-response manner (supplemental online Table 2).

DISCUSSION

In this cohort of older adults with cancer, we constructed an FI-CGA-10 by modifying the FI-CGA developed initially in the general geriatric setting. The FI-CGA was designed to measure the well-described concept of frailty in older people [57]. This new FI-CGA-10 evaluated the same CGA domains as the original FI-CGA, including cognition, mood, communication (hearing and vision), mobility, balance, nutrition, daily activities (including bladder or bowel incontinence), social support, and comorbidity [8, 9]. These domains cover the four cardinal components of CGA—physical health, functional status, psychological health, and socioenvironmental factors [12–14]. Furthermore, almost all of the individual domains of the FI-CGA-10 were associated with adverse outcomes in older adults with cancer [58, 59]. The comprehensiveness of this coverage of CGA domains supports the content validity of our new scale.

The calculation of an FI-CGA-10 score is much more straightforward than for an FI-CGA score. The original FI-CGA comprises of an impairment index (range 0–10) and a

Table 4. Comparator frailty measures, frailty characteristics, and prognostic indices by the three frailty categories

Measures	Fit (0 to <0.2) (n = 109)	Pre-Frail (0.2–0.35) (n = 219)	Frail (>0.35) (n = 212)
Comparator frailty measure, mean (SD) ^a			
CSHA Clinical Frailty Scale (range 1–7)	3.17 (0.87)	4.22 (0.64)	5.60 (0.88)
CSHA rules-based frailty definition (range 0–3)	0.36 (0.71)	1.14 (1.12)	2.40 (0.87)
CSHA Function Score (range 0–1)	0.01 (0.02)	0.05 (0.07)	0.31 (0.21)
Frailty Characteristic			
Timed Up and Go test (seconds), mean (SD) ^a	11.26 (1.82)	13.02 (3.11)	26.34 (20.37)
Self-reported ability to walk one block, n (%) ^a			
Not limited at all	105 (96)	189 (86)	78 (37)
Limited a little	4 (4)	23 (11)	51 (24)
Limited a lot	0 (0)	7 (3)	83 (39)
Self-reported ability to walk several blocks, n (%) ^a			
Not limited at all	90 (83)	124 (57)	30 (14)
Limited a little	15 (14)	67 (31)	55 (26)
Limited a lot	4 (4)	28 (13)	127 (60)
Independent life-space (range 0–5), mean (SD) ^a	4.86 (0.69)	4.34 (1.22)	2.07 (1.73)
Life-space using equipment (range 0–5), mean (SD) ^a	4.93 (0.5)	4.62 (0.76)	2.60 (1.56)
Mini-Cog (range 0–5), mean (SD) ^a	4.71 (0.66)	4.04 (1.27)	3.10 (1.66)
Charlson comorbidity index (range 0–37), mean (SD) ^a	0.79 (1.27)	1.38 (1.54)	1.92 (1.87)
No. of medications, mean (SD) ^a	4.34 (3.38)	5.27 (3.28)	6.39 (3.48)
Self-rated health status, n (%) ^a			
Excellent/very good	28 (26)	31 (14)	6 (3)
Good	39 (36)	63 (29)	41 (19)
Fair	26 (24)	74 (34)	52 (25)
Poor	16 (15)	51 (23)	113 (53)
Prognostic indices for mortality, mean (SD) ^a			
Lee index (range 0–23)	7.33 (1.92)	8.77 (2.36)	12.00 (3.11)
Schonberg index (range 0–29)	10.14 (2.93)	13.08 (3.81)	15.70 (3.47)
Oncology performance status measure			
ECOG PS, mean (SD) ^a	0.37 (0.50)	0.64 (0.59)	1.81 (0.95)
ECOG PS, n (%) ^a			
Score 0	70 (64)	91 (42)	9 (4)
Score 1	38 (35)	117 (53)	81 (38)
Score 2	1 (1)	10 (5)	73 (34)
Score 3–4	0	1 (0.5)	49 (23)

^ap < .0001.^bPatients unable to perform the Timed Up and Go test were included using a surrogate time that was the slowest time of this cohort of patients.

Abbreviations: CSHA, Canadian Study of Health and Aging; ECOG PS, Eastern Cooperative Oncology Group performance status.

comorbidity index (range 0–4) [9]. To calculate the FI-CGA score, the sum of the impairment and comorbidity index scores is divided by 14. By contrast, the FI-CGA-10 consists of 10 domains, with the score calculated by dividing the sum of the scores for each domain by 10. Along with the simple rating system for each domain (no [0 points], minor [0.5 points], or a major problem [1 point]), it is feasible to calculate an FI-CGA-10 score with just pencil and paper.

Even after these modifications, the FI-CGA-10 maintained the mathematical properties of the FIs and the original FI-CGA [6, 9, 55]. For example, the FI-CGA-10 had an asymmetrical

distribution that was well represented by the gamma density function. According to Rockwood and Mitnitski, an optimal frailty index should contain at least 30 items, but the lowest practical limit was suggested to be about 10 to 15 items [60, 61]. They pointed out that carefully selecting the items to be included in the index becomes increasingly important when an index includes fewer items. Notably, the FI-CGA-10 developed following these instructions demonstrated good construct validity and included data for all the domains evaluated in the CGA. Our scale correlated with established frailty measurement tools and health characteristics that are commonly

Figure 2. A box plot to illustrate the distribution of the FI-CGA-10 scores by the Clinical Frailty Scale. Center lines show the medians; box limits indicate the 25th and 75th percentiles; whiskers extend to 5th and 95th percentiles, outliers are represented by dots; crosses represent sample means. $n = 7$ (1, very fit), 11 (2, well), 70 (3, managing well), 189 (4, vulnerable), 153 (5, mildly frail), 71 (6, moderately frail), 39 (7, severely frail) sample points. Abbreviation: FI-CGA-10, 10-item frailty index based on a comprehensive geriatric assessment

observed in frail older people, such as functional impairments. Furthermore, we classified patients into different fitness and frailty degrees, which made the FI-CGA-10 score more clinically interpretable. We proposed six levels of fitness and frailty in addition to the previously reported three categories (fit, pre-frail, and frail) [33, 34]. This more granular categorization may permit a more precise selection of oncologic treatment for individual patients as it correlates with patient function. According to the intensity of treatment, different levels of physiologic reserve and resilience to stressors are desired. The information from our objective measure has the potential to aid the physician, patient, and family in shared decision-making.

There are limitations to our study. First, the present study was conducted at a single Japanese academic cancer center (NKCC) and all included patients were referred for CGA at the discretion of their treating physicians. These factors may limit the generalizability of our findings to the overall population of older adults with cancer. Second, we could not evaluate the criterion validity of the FI-CGA-10. Criterion validation is usually divided into two types: concurrent validation and predictive validation [62]. Because there is no “gold standard” measure of frailty to test concurrent validity, another form of criterion validation, predictive validation, has been assessed for frailty measures. For the original FI-CGA, the predictive ability for adverse outcomes was evaluated [8, 9]. Jones et al. showed that a higher FI-CGA score was associated with a higher risk of institutionalization and death in the CSHA-2 cohort [9]. The FI-CGA correlated well with

the FI ($r = 0.76$), and the predictive performance of the FI-CGA was comparable to that of the FI. The area under the receiver operating characteristic curve (AUC) for predicting 5-year mortality was 0.67 and 0.70, respectively, for the FI-CGA and the FI. Additionally, Pilotto et al. reported that the FI-CGA and the FI had similar AUCs for 1-year mortality (0.727 vs. 0.729) in a prospective cohort study of hospitalized older patients [63].

Recently, several FIs with more than 30 variables were developed, and their predictive validity was studied in the field of geriatric oncology [33, 34, 64]. Guerard et al. constructed the 36-item Carolina Frailty Index (CFI) from the Carolina Senior Registry (NCT01137825), an institutional database of patients with cancer 65 years or older who completed a cancer-specific geriatric assessment [33]. CFI scores were categorized as robust (0 to <0.2), pre-frail (0.2–0.35), and frail (>0.35). In a sample of 546 patients, the 5-year survival probability was 72% in robust patients, 58% in pre-frail patients, and 34% in frail patients (log-rank test, $p < .0001$). Because of the limited follow-up duration in the present study, we could not determine the predictive validity of the FI-CGA-10. As indirect evidence, the FI-CGA-10 highly correlated to the prognostic indices for mortality, which have been extensively validated in general geriatric populations and also studied in older adults with breast cancer [50–53, 65]. With more mature survival data, we plan to test how well our index correlates with mortality and the validity of the cutoff values defining each level of frailty.

The strength of the FI-CGA-10 compared with other FIs is that it gives a better summary of what constitutes a certain level of fitness and frailty. This comes from the fact that the FI-CGA-10 counts domain-level deficits and other FIs count item-level deficits. By calculating a FI-CGA-10 score, it becomes clear where vulnerabilities exist in a patient and how severe they are. This information is fundamental to holistic understanding of the patient’s overall health status and to performing multidimensional and interdisciplinary interventions based on the identified vulnerabilities, which is the purpose of CGA. If the predictive validity of the FI-CGA-10 is established, it could be a more clinically meaningful and actionable scale.

CONCLUSION

We developed the FI-CGA-10 by simplifying the original FI-CGA while maintaining its content validity. We demonstrated the construct validity of our index in a cohort of older adults with various cancer types. The advantage of the FI-CGA-10 is that a score can be calculated more readily and interpreted in a more clinically sensible manner than the original FI-CGA and other FIs. In addition to grading the level of frailty, this tool can improve a patient’s health status by pointing to the need for tailored interventions to address the identified vulnerabilities. If the predictive validity and external validity are demonstrated, the FI-CGA-10 will be a useful CGA-based frailty measure in the geriatric oncology setting.

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DISCLOSURES

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