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ORIGINAL RESEARCH

Comparing the predictive accuracy of frailty, comorbidity, and disability for mortality: a 1-year follow-up in patients hospitalized in geriatric wards

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Background: Studies evaluating and comparing the power of frailty, comorbidity, and disability instruments, together and in parallel, for predicting mortality are limited.

Objective: This study aimed to evaluate and compare the measures of frailty, comorbidity, and disability in predicting 1-year mortality in geriatric inpatients.

Design: Prospective cohort study.

Patients and setting: A total of 307 inpatients aged ≥65 years in geriatric wards of a general hospital participated in the study.

Measurements: The patients were evaluated in relation to different frailty, comorbidity, and disability instruments during their hospital stays. These included three frailty (the seven-category Clinical Frailty Scale [CFS-7], a 41-item frailty index [FI], and the FRAIL scale), two comorbidity (the Cumulative Illness Rating Scale for Geriatrics [CIRS-G] and the comorbidity domain of the FI [Comorbidity-D-FI]), and two disability instruments (disability in basic activities of daily living [ADL-Katz] and the instrumental and basic activities of daily living domains of the FI [IADL/ADL-D-FI]). The patients were followed-up over 1 year.

Results: Using FI, CIRS-G, Comorbidity-D-FI, and ADL-Katz, this study identified a patient group with a high (≥50%) 1-year mortality rate in all of the patients and the two patient subgroups (ie, patients aged 65–82 years and ≥83 years). The CFS-7, FI, FRAIL scale, CIRS-G, Comorbidity-D-FI, and IADL/ADL-D-FI (analyzed as full scales) revealed useful discriminative accuracy for 1-year mortality (ie, an area under the curve >0.7) in all the patients and the two patient subgroups (all $P<0.001$). Thereby, CFS-7 (in all patients and the two patient subgroups) and FI (in the subgroup of patients aged ≥83 years) showed greater discriminative accuracy for 1-year mortality compared to other instruments (all $P<0.05$).

Conclusion: All the different instruments emerged as suitable tools for risk stratification in geriatric inpatients. Among them, CFS-7, and in those patients aged ≥83 years, also the FI, might most accurately predict 1-year mortality in the aforementioned group of individuals.

Keywords: frailty, comorbidity, disability, hospitalized geriatric patients, older people, health status, survival

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Introduction

Older people are the fastest growing population in many Western societies.[1,2] They represent a heterogeneous group with respect to their health status. Some old people reveal good physical and cognitive status and are active, whereas others are frail and/

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or suffer from multiple chronic diseases and/or disabilities.[3] Frailty is a clinically recognizable state of increased vulnerability to stressors associated with an increased risk for adverse clinical outcomes.[3–5] Comorbidity can be characterized as the concurrent presence of two or more medically diagnosed diseases.[3] Disability is defined as difficulty or dependency in performing activities of daily living (ADLs).[3] Measures of frailty, comorbidity, and/or disability can be used to estimate the biological age of older people.[6,7] Such estimates of biological age were found to better predict mortality than chronological age in older people.[8] Risk stratification, particularly estimating mortality risk, is important in terms of medical decision-making and optimal management of older patients.

Several different frailty, comorbidity, or disability instruments have been developed and evaluated. The Canadian Study on Health and Ageing Clinical Frailty Scale (CFS-7),[5] and a Rockwood and Mitnitski frailty index (FI),[5,9–12] for example, allow for the evaluation of older people in terms of the broader/larger construct of frailty.[4] The FRAIL scale,[13–15] among other instruments,[16,17] can be used to evaluate people in terms of the construct of physical frailty.[4] The Cumulative Illness Rating Scale for Geriatrics (CIRS-G)[18,19] or an index or list based on several major diseases[20] represents established comorbidity instruments. The Katz index[21] or an index or list that comprises several major instrumental activities related to daily living (IADLs) and basic ADLs[22,23] can be used to assess the ADL and IADL/ADL disability burden of older people.

Frailty, comorbidity, or disability instruments have been found to be successful in predicting mortality in different settings, including patients hospitalized in geriatric wards.[24–30] However, data evaluation and comparison of the power of frailty, comorbidity, and disability instruments, together and in parallel, for predicting adverse clinical outcomes such as mortality are limited.[31–33] It should be noted that the individual prognostic power of these measures of adverse clinical outcomes may vary between different age groups of older people.[31,34] We had previously evaluated and compared the accuracy of different frailty instruments, together and in parallel, in predicting mortality in older patients hospitalized in geriatric wards.[12,26,35] Until now, no study has adequately investigated and collated major different frailty, comorbidity, and disability instruments in terms of their ability to predict mortality in a cohort of older geriatric inpatients.

With this background, the present study aimed to analyze and contrast the ability of major frailty, comorbidity, and disability instruments in predicting 1-year mortality in older patients hospitalized in geriatric wards by considering different age ranges of the patients.

Methods

Study design and study population

This study was a prospective longitudinal analysis with a 1-year follow-up of hospitalized patients who were admitted to the geriatric wards of the Geriatrics Centre of the Hospital of the Congregation of St Francis Sisters of Vierzehnheiligen, Erlangen, Germany. The inclusion criterion was that age should be ≥65 years; the exclusion criteria were inability to give written informed consent and nonavailability of a legal guardian to give written informed consent on behalf of the study participant. The objective of this study was to evaluate and compare the ability of major different frailty (Rockwood et al's[5] seven-category Canadian Study on Health and Aging CFS-7, a Rockwood et al and Mitnitski et al's[5,9–12] 41-item FI, and the Abellan van Kan et al's[13,14] FRAIL scale), comorbidity (the Miller et al's[19] CIRS-G and the comorbidity domain of FI [Comorbidity-D-FI]), and disability instruments (ADL disability based on the ADLs of the Katz et al's[21] Katz Index [ADL-Katz] and the IADL/ADL domain of the aforementioned FI [IADL/ADL-D-FI]) in predicting 1-year mortality in older patients hospitalized in geriatric wards. To this end, we performed the analyses on all the study participants and the two subgroups, that is, patients aged less than the median age and patients aged greater than or equal to the median age of the total study cohort, as well. The patients were evaluated in terms of different degrees of frailty, comorbidity, or disability according to the aforementioned instruments (baseline examination) at the same time before discharge of patients who were hospitalized in geriatric wards after treatment for an acute disease or the exacerbation of a chronic disease leading to hospital admission. Follow-up data were obtained 12 months after the baseline examination. These data included, among others, information about the death of the study participants during the follow-up period. Follow-up data were collected through telephonic interviews with patients, their physicians, specialists, relatives, or legal guardians. The study followed the principles of the Declaration of Helsinki and Good Clinical Practice. The study protocol was approved by the local ethics committee, that is, the Ethics Committee of the University of Erlangen-Nürnberg. Written informed consent was obtained from each study participant or from his or her legal guardian.

Instruments used for the evaluation of patients in terms of frailty, comorbidity, and disability

The seven-category Canadian Study on Health and Aging CFS-7

The CFS-7 allows grading of the frailty status of a patient by seven categories, as has previously been described in detail by Rockwood et al.[5] In this way, the CFS-7 takes a persons' fitness level, motivation, disease symptoms, fatique, performance in IADLs and ADLs as well as his/her clinical state of being terminally ill into account.[5] The seven categories of the CFS-7 are: category 1 (very fit), category 2 (well), category 3 (well, with treated comorbid disease), category 4 (apparently vulnerable), category 5 (mildly frail), category 6 (moderately frail), and category 7 (severely frail/terminally ill).[5]

The 41-item FI

The FI consisted of 41 items (Table 1). The criteria reported by Searle et al[11] and Rockwood et al[36] were considered in order to operationalize FI. Thus, it can be regarded as a classical Rockwood and Mitnitski et al[5,9–12] FI. The FI was based on data from a standardized comprehensive geriatric assessment (CGA).[37] Table 1 summarizes the 41 items of the FI. The FI was calculated according to the sum of the scores for each item divided by the total number of items considered, resulting in a score ranging in magnitude from 0 to 1.

The FRAIL scale

The FRAIL scale is based on five components: fatigue, resistance, ambulation, illness, and loss of weight.[13–15] For this study, fatigue was operationalized as self-report of "feeling tired all the time," resistance was operationalized as "inability to climb a flight of stairs," ambulation was operationalized as "needing assistance with walking or he/she being unable to walk," illness was operationalized as

> five or more of the following 11 illnesses: heart attack, congestive heart failure, peripheral vascular disease, stroke, cancer, diabetes mellitus, arthritis, chronic lung disease, kidney disease, dementia, and depression,

and weight loss was operationalized as "weight loss of 5% or more within the last 12 months." Patients with none of these components were considered to be robust; those with one or two to be pre-frail, and those with three or more to be frail.

The CIRS-G

The Cumulative Illness Rating Scale (CIRS) was initially developed and introduced by Linn et al[18] in 1968. Miller et al[19] later revised the CIRS, aiming to reflect the common problems of older people and renamed the index (CIRS-G). The CIRS-G is based on 14 items representing individual body systems: 1) heart, 2) vascular, 3) hematopoietic, 4) respiratory, 5) eyes, ears, nose, throat, and larynx, 6) upper gastrointestinal, 7) lower gastrointestinal, 8) liver, 9) renal, 10) genitourinary, 11) musculoskeletal/integument, 12) neurological, 13) endocrine/metabolic and breast, and 14) psychiatric illness.[19] In this way, the severity of chronic diseases in each aforementioned 14 individual body systems is rated along a five grade system with a minimum score of 0 (no problem affecting that system) up to a maximum score of 4 (extremely severe problem) according to the criteria described previously in detail by Miller et al.[19] Theoretically, the total score of the CIRS-G varies from 0 to 56.[19]

The Comorbidity-D-FI and the IADL/ADL domain of the FI (IADL/ADL-D-FI)

Individual items from the aforementioned FI can be referred to different domains of a CGA[37] (Table 1). The score for the Comorbidity-D-FI was calculated as the sum of the scores for items 27–41 of the FI divided by 15. The score for the IADL/ADL-D-FI was calculated as the sum of the scores for items 10–24 of the FI divided by 15. Theoretically, the scores of the Comorbidity-D-FI and the IADL/ADL-D-FI can consequently range from 0 to 1.

The disability burden based on the six ADLs of the Katz index (ADL-Katz)

The ADL-Katz considers the six ADLs of the Katz Index,[21] namely 1) bathing, 2) dressing, 3) toileting, 4) transferring, 5) continence (bowel and bladder), and 6) feeding.[21] For this study, performance in functioning each of the ADLs was scored as follows: needing help with =1 and independence =0. Thus, the score for the ADL-Katz can vary from 0 (independence in all the six ADLs of the Katz index) to 6 (needing help in all the six ADLs of the Katz index).

Statistical analysis

All the statistical analyses were performed using SPSS software (SPSS Statistics 23; IBM Corporation, Armonk, NY, USA). The results are expressed as mean ± standard deviation, median (interquartile range), or percentage. Cox

Table 1 Operationalization of the 41-item frailty index (FI)

Item	Cutoff point	CGA domain to which the item corresponds
1. Cognition problem	Dementia =1, mild cognitive impairment, no dementia =0.5, no cognitive impairment =0	Cognition
2. Emotion problem	GDS >10=1, 5–10=0.5, 0–4=0	Emotion
3. Impaired vision	Yes =1, no =0	Communication
4. Impaired hearing	Yes =1, no =0	Communication
5. Speaking difficulty	Yes =1, no =0	Communication
6. Mobility difficulty	TUG>19=1, 10–19=0.5, <10=0	Mobility
7. History of falls	More than yearly falls =1, less than yearly falls =0.5, no falls =0	Balance
8. Urinary incontinence	Yes =1, catheter =1, no =0	Bladder function
9. Bowel incontinence	Yes =1, no =0	Bowel function
10. Help with meal preparation	Yes =1, no =0	IADL
11. Help with ordinary housework	Yes =1, no =0	IADL
12. Help with managing finances	Yes =1, no =0	IADL
13. Help with managing medications	Yes =1, no =0	IADL
14. Help with phone use	Yes =1, no =0	IADL
15. Help with shopping	Yes =1, no =0	IADL
16. Help with transportation	Yes =1, no =0	IADL
17. Help with mobility in bed	Yes =1, no =0	ADL
18. Help with transfer	Yes =1, no =0	ADL
19. Help with locomotion inside and outside the home	Yes =1, no =0	ADL
20. Help with dressing	Yes =1, no =0	ADL
21. Help with eating	Yes =1, no =0	ADL
22. Help with toilet use	Yes =1, no =0	ADL
23. Help with personal hygiene	Yes =1, no =0	ADL
24. Help with bathing	Yes =1, no =0	ADL
25. Weight loss	>5% weight change =1, 0.5%–5% weight change =0.5, stable weight =0	Nutrition
26. Self-rating of health	Poor =1, fair =0.75, good =0.25, very good to excellent =0	Self-rating of health
27. Heart attack	Yes =1, suspect =0.5, no =0	Comorbidity
28. Congestive heart failure	Yes =1, suspect =0.5, no =0	Comorbidity
29. Peripheral vascular disease	Yes =1, suspect =0.5, no =0	Comorbidity
30. Stroke	Yes =1, suspect =0.5, no =0	Comorbidity
31. Cancer	Yes =1, suspect =0.5, no =0	Comorbidity
32. Diabetes mellitus	Yes =1, suspect =0.5, no =0	Comorbidity
33. Arthritis	Yes =1, suspect =0.5, no =0	Comorbidity
34. Chronic lung disease	Yes =1, suspect =0.5, no =0	Comorbidity
35. Kidney disease	Yes =1, suspect =0.5, no =0	Comorbidity
36. Constipation	Yes =1, no =0	Comorbidity
37 and 38. Other medical problems	None =0, maximum =2	Comorbidity
39. Anxiety	Yes =1, suspect =0.5, no =0	Comorbidity
40. Alcohol use	Yes =1, suspect =0.5, no =0	Comorbidity
41. Other psychiatric illness	Yes =1, suspect =0.5, no =0	Comorbidity

Abbreviations: CGA, comprehensive geriatric assessment; GDS, Geriatric Depression Scale; TUG, Timed Up and Go Test; IADL, instrumental activities of daily living; ADL, activities of daily living.

proportional hazard models were performed to analyze the hazard ratios for 1-year mortality risk of each increment in category or score of 0.1 of the different frailty, comorbidity, or disability instruments unadjusted and adjusted for age and gender. Receiver operating characteristic (ROC) curves were calculated to estimate the areas under the curve (AUCs) for the different instruments, analyzed as continuous variables, in relation to 1-year

mortality. AUC values >0.7 indicate at least "useful" predictive accuracy of the model.[38] Comparisons among the AUCs were performed using the method of Hanley and McNeil.[39] The level of statistical significance was set a priori at $P<0.050$.

Results

A total of 307 (208 female and 99 male) patients were included in the study. One-year follow-up data were obtained from 305 patients (99.3%). The two patients who withdrew from the study during the 1-year follow-up period were 89.0±4.2 years old, one female and one male, and had a CFS-7 category of 5.00±0.0, FI score of 0.24±0.1, number of FRAIL scale components of 2.50±0.7, CIRS-G score of 10±2.8 points, Comorbidity-D-FI score of 0.18±0.0, ADL-Katz score of 1.00±0.0, and IADL/ADL-D-FI score of 0.30±0.4.

The clinical characteristics of the 305 patients from whom follow-up data were obtained and stratified into all patients, a subgroup of 139 patients aged between 65 and 82 years (ie, patients with an age less than the median age of the total study cohort), and a subgroup of 166 patients aged ≥83 years (ie, patients with an age greater than or equal to the median age of the total study cohort), are summarized in Table 2. Patients aged between 65 and 82 years were younger and taller, had a greater body weight, had a greater body mass index, and except for lung disease had lower percentage of history of individual diseases or adverse medical conditions (congestive heart failure, kidney disease, and bowel incontinence), lower percentage of patients who were institutionalized, lower CFS-7 category, FI, CIRS-G, ADL-Katz, IADL/ADL-D-FI score, and lower 1-year mortality rate compared to the patients aged ≥83 years (Table 2). Patients aged between 65 and 82 years

Table 2 Clinical characteristics of the total study cohort and the two patient subgroups

Clinical characteristics	All patients (n=305)	Subgroup of patients aged 65–82 years (n=139)	Subgroup of patients aged ≥83 years or older (n=166)	*P*-value*
Age (years)	82.9±6.4 (n=305)	77.1±3.9 (n=139)	87.7±3.4 (n=166)	<0.001
Female	67.9 (207) (n=305)	66.2 (92) (n=139)	69.3 (115) (n=166)	0.565
Height (cm)	163±9.7 (n=305)	165±9.5 (n=139)	162±9.6 (n=166)	0.005
Weight (kg)	73.2±16 (n=305)	79.3±17 (n=139)	68.0±13 (n=166)	<0.001
BMI (kg/m²)	27.5±5.6 (n=305)	29.3±6.1 (n=139)	26.0±4.5 (n=166)	<0.001
MMSE (points)	25.5±4.6 (n=299)	25.3±4.2 (n=135)	25.6±4.8 (n=164)	0.359
GDS (points)	2.98±3.0 (n=297)	4.03±3.4 (n=134)	3.93±2.7 (n=163)	0.866
Congestive heart failure	47.5 (145) (n=305)	40.3 (56) (n=139)	53.6 (89) (n=166)	0.020
Heart attack	13.8 (42) (n=305)	10.8 (15) (n=139)	16.3 (27) (n=166)	0.167
Stroke	20.3 (62) (n=305)	20.9 (29) (n=139)	19.9 (33) (n=166)	0.832
Cancer	14.4 (44) (n=305)	10.8 (15) (n=139)	17.5 (29) (n=166)	0.098
Diabetes mellitus	38.4 (117) (n=305)	41.7 (58) (n=139)	35.5 (59) (n=166)	0.269
Lung disease	16.7 (51) (n=305)	22.3 (31) (n=139)	12.0 (20) (n=166)	0.017
Kidney disease	64.9 (198) (n=305)	59.0 (82) (n=139)	69.9 (116) (n=166)	0.047
Urinary incontinence or catheterized	23.6 (72) (n=305)	19.4 (27) (n=139)	27.1 (45) (n=166)	0.116
Bowel incontinence	8.2 (25) (n=305)	4.3 (6) (n=139)	11.4 (19) (n=166)	0.024
More than five medications	96.1 (293) (n=305)	95.7 (133) (n=139)	96.4 (160) (n=166)	0.753
Institutionalized	16.1 (49) (n=305)	10.8 (15) (n=139)	20.5 (34) (n=166)	0.022
CFS-7 (category)	5.34±1.2 (n=305)	5.13±1.2 (n=139)	5.52±1.2 (n=166)	0.007
FI (–)	0.34±0.2 (n=305)	0.32±0.16 (n=139)	0.36±0.15 (n=166)	0.008
FRAIL scale components (number)	1.89±1.2 (n=305)	1.75±1.3 (n=139)	2.02±1.3 (n=166)	0.070
CIRS-G (points)	17.5±5.6 (n=305)	16.7±5.6 (n=139)	18.2±5.5 (n=166)	0.037
Comorbidity-D-FI (–)	0.30±0.1 (n=305)	0.29±0.1 (n=139)	0.31±0.1 (n=166)	0.087
ADL-Katz (points)	2.1±1.9 (n=305)	1.78±1.8 (n=139)	2.34±1.9 (n=166)	0.005
IADL/ADL-D-FI (–)	0.41±0.28 (n=305)	0.38±0.3 (n=139)	0.44±0.3 (n=166)	0.040
Mortality during 1-year follow-up	20.3 (62) (n=305)	13.7 (19) (n=139)	25.9 (43) (n=166)	0.008

Notes: Data shown as mean ± SD (total patient number) or percentage (n) (total patient number). **P*-value reported for comparison of patients aged between 65 and 82 years versus patients aged ≥83 years. (–) indicates no unit of measurement.

Abbreviations: ADL, basic activities of daily living; ADL-Katz, disability burden based on the six ADLs of the Katz index; BMI, body mass index; CFS-7, Canadian Study on Health and Aging Clinical Frailty Scale; GDS, Geriatric Depression Scale; CIRS-G, Cumulative Illness Rating Scale for Geriatrics; Comorbidity-D-FI, Comorbidity domain of the frailty index; IADL, instrumental activities of daily living; IADL/ADL-D-FI, IADL/ADL domain of the frailty index; MMSE, Mini Mental State Examination; FI, frailty index.

did not differ from the patients aged ≥83 years with respect to the percentage of female patients, Mini Mental State Examination, Geriatric Depression Scale score, percentage of patients with history of heart attack, stroke, diabetes mellitus, percentage of patients with urinary incontinence or those being catheterized, percentage of patients with >5 medications, FRAIL scale components, and Comorbidity-D-FI score.

The mortality rates of the patients stratified into different categories or groups in terms of different frailty, comorbidity, or disability instruments, in all the patients and the two patient subgroups are summarized in Table 3. Table 3 implied that the FI, CIRS-G, Comorbidity-D-FI, and ADL-Katz were able to identify a group of patients with a 1-year mortality rate of 50% or higher, in all the patients and the two patient subgroups. Each increment in category or score of 0.1 of the different instruments with respect to frailty, comorbidity, or disability was associated with higher 1-year mortality risk independent of age and gender, in all the patients and the two patient subgroups (Table 4).

Except for the ADL-Katz in patients aged between 65 and 82 years, all the frailty, comorbidity, or disability instruments revealed a useful discriminative accuracy for 1-year mortality, as indicated by an AUC >0.7 for 1-year mortality, in all the patients and the two patient subgroups (Table 5). The CFS-7 and, in the subgroup of patients aged ≥83 years, also the FI showed superior discriminative accuracy for 1-year mortality compared to the FRAIL scale, CIRS-G, Comorbidity-D-FI, ADL-Katz, and IADL/ADL-D-FI (Table 5). In all the patients, but not in the subgroup

Table 3 One-year mortality rates of the patients stratified into different degrees of frailty, comorbidity, or disability according to the different frailty, comorbidity, or disability instruments

Instrument	Category/score	All patients (n=305)	Subgroup of patients aged 65–82 years (n=139)	Subgroup of patients aged ≥83 years (n=166)
CFS-7				
	Category 1	NA (n=0)	NA (n=0)	NA (n=0)
	Category 2	0.0% (0) (n=1)	0.0% (0) (n=1)	NA (n=0)
	Category 3	0.0% (0) (n=18)	0.0% (0) (n=12)	0.0% (0) (n=6)
	Category 4	1.5% (1) (n=67)	0.0% (0) (n=34)	3.0% (1) (n=33)
	Category 5	9.5% (7) (n=74)	5.7% (2) (n=35)	12.8% (5) (n=39)
	Category 6	17.7% (14) (n=79)	20.0% (7) (n=35)	15.9% (7) (n=44)
	Category 7	60.6% (40) (n=66)	45.5% (10) (n=22)	68.2% (30) (n=44)
FI				
	Score of 0	NA (n=0)	NA (n=0)	NA (n=0)
	Score of 0.001–0.100	0.0% (0) (n=14)	0% (0) (n=10)	0.0% (0) (n=4)
	Score of 0.101–0.200	2.4% (1) (n=42)	4.5% (1) (n=22)	0.0% (0) (n=20)
	Score of 0.201–0.300	7.7% (6) (n=78)	10.0% (4) (n=40)	5.3% (2) (n=38)
	Score of 0.301–0.400	15.2% (10) (n=66)	7.7% (2) (n=26)	20.0% (8) (n=40)
	Score of 0.401–0.500	29.4% (15) (n=51)	22.7% (5) (n=22)	44.5% (10) (n=29)
	Score of 0.501–0.600	55.9% (19) (n=34)	27.3% (3) (n=11)	69.6% (16) (n=23)
	Score of 0.601–0.700	55.0% (11) (n=20)	50.0% (4) (n=8)	58.3% (7) (n=12)
FRAIL scale				
	Robust	1.7% (1) (n=58)	0.0% (0) (n=29)	3.4% (1) (n=29)
	Prefrail	14.4% (20) (n=139)	10.6% (7) (n=66)	17.8% (13) (n=73)
	Frail	38.0% (41) (n=108)	27.3% (12) (n=44)	45.3% (29) (n=64)
CIRS-G				
	0 points	NA (n=0)	NA (n=0)	NA (n=0)
	1–4 points	NA (n=0)	NA (n=0)	NA (n=0)
	5–8 points	0.0% (0) (n=18)	0.0% (0) (n=11)	0.0% (0) (n=7)
	9–12 points	2.3% (1) (n=44)	4.2% (1) (n=24)	0.0% (0) (n=20)
	13–16 points	13.7% (10) (n=73)	8.6% (3) (n=35)	18.4% (7) (n=38)
	17–20 points	18.9% (14) (n=74)	12.9% (4) (n=31)	23.3% (10) (n=43)
	21–24 points	27.4% (17) (n=62)	25.9% (7) (n=27)	28.6% (10) (n=35)
	25–28 points	57.7% (15) (n=26)	25.0% (2) (n=8)	72.2% (13) (n=18)
	29–32 points	80.0% (4) (n=5)	50.0% (1) (n=2)	100% (3) (n=3)
	33–36 points	33.3% (1) (n=3)	100% (1) (n=1)	0.0% (0) (n=2)

(*Continued*)

Table 3 (*Continued*)

Instrument	Category/score	All patients (n=305)	Subgroup of patients aged 65–82 years (n=139)	Subgroup of patients aged ≥83 years (n=166)
Comorbidity-D-FI				
	Score of 0	0.0% (0) (n=1)	0.0% (0) (n=1)	NA (n=0)
	Score of 0.001–0.100	0.0% (0) (n=18)	0.0% (0) (n=9)	0.0% (0) (n=9)
	Score of 0.101–0.200	4.3% (3) (n=69)	2.5% (1) (n=40)	6.9% (2) (n=29)
	Score of 0.201–0.300	20.0% (15) (n=75)	18.5% (5) (n=27)	20.8% (10) (n=48)
	Score of 0.301–0.400	29.5% (26) (n=88)	20.9% (9) (n=43)	37.8% (17) (n=45)
	Score of 0.401–0.500	25.6% (10) (n=39)	0.0% (0) (n=11)	35.7% (10) (n=28)
	Score of 0.501–0.600	53.3% (8) (n=15)	50.0% (4) (n=8)	57.1% (4) (n=7)
ADL-Katz				
	No disability	6.3% (5) (n=79)	8.5% (4) (n=47)	3.1% (1) (n =32)
	1 disability	11.6% (8) (n=69)	9.4% (3) (n=32)	13.5% (5) (n=37)
	2 disabilities	19.0% (8) (n=42)	6.2% (1) (n=16)	26.9% (7) (n=26)
	3 disabilities	14.7% (5) (n=34)	7.7% (1) (n=13)	19.0% (4) (n=21)
	4 disabilities	41.5% (17) (n=42)	37.5% (6) (n=16)	42.3% (11) (n=26)
	5 disabilities	38.1% (8) (n=21)	11.1% (1) (n=9)	58.3% (7) (n=12)
	6 disabilities	61.1% (11) (n=18)	50.0% (3) (n=6)	66.7% (8) (n=12)
IADL/ADL-D-FI				
	Score of 0	0.0% (0) (n=31)	0.0% (0) (n=17)	0.0% (0) (n=14)
	Score of 0.001–0.100	10.0% (2) (n=20)	9.1% (1) (n=11)	11.1% (1) (n=9)
	Score of 0.101–0.200	5.8% (3) (n=52)	7.1% (2) (n=28)	4.2% (1) (n=24)
	Score of 0.201–0.300	8.0% (2) (n=25)	7.1% (1) (n=14)	9.1% (1) (n=11)
	Score of 0.301–0.400	12.5% (5) (n=40)	14.3% (2) (n=14)	11.5% (3) (n=26)
	Score of 0.401–0.500	36.4% (8) (n=22)	11.1% (1) (n=9)	53.8% (7) (n=13)
	Score of 0.501–0.600	28.2% (11) (n=39)	28.6% (4) (n=14)	28.0% (7) (n=25)
	Score of 0.601–0.700	30.4% (7) (n=23)	22.2% (2) (n=9)	35.7% (5) (n=14)
	Score of 0.701–0.800	48.0% (12) (n=25)	27.3% (3) (n=11)	64.3% (9) (n=14)
	Score of 0.801–0.900	53.8% (7) (n=13)	20.0% (1) (n=5)	75.0% (6) (n=8)
	Score of 0.901–1.000	33.3% (5) (n=15)	28.6% (2) (n=7)	62.5% (3) (n=8)

Note: Data in columns 3–5 are shown as percentage of patients who died (number of patients who died) (number of patients in the group).
Abbreviations: ADL, basic activities of daily living; ADL-Katz, disability burden based on the six ADLs of the Katz index; CFS-7, Canadian Study on Health and Aging Clinical Frailty Scale; FI, frailty index; CIRS-G, Cumulative Illness Rating Scale for Geriatrics; Comorbidity-D-FI, Comorbidity domain of the frailty index; IADL, instrumental activities of daily living; IADL/ADL-D-FI, IADL/ADL domain of the frailty index; NA, not applicable.

of patients aged ≥83 years, the CFS-7 revealed better discriminative accuracy for 1-year mortality compared to the FI (Table 5).

Discussion

We evaluated and compared the ability of major frailty (CFS-7, FI, and FRAIL scale), comorbidity (CIRS-G and Comorbidity-D-FI), or disability instruments (ADL-Katz and IADL/ADL-D-FI) in predicting 1-year mortality in 305 patients hospitalized in geriatric wards. Thereby, we considered different patient age ranges (ie, all the patients, a subgroup of patients aged between 65 and 82 years, and a subgroup of patients aged ≥83 years). Except for the ADL-Katz in the subgroup of patients aged between 65 and 82 years, all the different frailty, comorbidity, or disability instruments revealed at least useful discriminative accuracy for 1-year mortality, as indicated by an AUC >0.7 for 1-year mortality, in all patients and the two patient subgroups. Nevertheless, the ADL-Katz among other aforementioned instruments was able to identify a group of patients with a high 1-year mortality rate, that is, a 1-year mortality rate of 50% or higher, in all patients and the two patient subgroups, as well. Thus, all the aforementioned different frailty, comorbidity, or disability instruments were found to be powerful tools for estimating the 1-year mortality risk.

In addition, we found a dose–response relationship of all the aforementioned frailty, comorbidity, or disability instruments with 1-year mortality that was independent of age and gender. Such a dose-dependent relationship of frailty, comorbidity, or disability instruments with mortality was also found in other studies in older hospitalized patients[40,41] and/or older patients who were hospitalized in geriatric wards.[25–27,35]

Table 4 Unadjusted and adjusted hazard ratios for the risk of 1-year mortality of the patients according to each increment in category or score of 0.1 of the different frailty, comorbidity, or disability instruments

Instrument	All patients (n=305)				Subgroup of patients aged 65–82 years (n=139)				Subgroup of patients aged ≥83 years (n=166)			
	HR (95% CI)	*P*-value	Adj* HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	Adj* HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	Adj* HR (95% CI)	*P*-value
CFS-7 (per each category increment)	3.789 (2.681–5.354)	<0.001	3.667 (2.590–5.194)	<0.001	3.871 (2.137–7.011)	<0.001	3.950 (2.124–7.343)	<0.001	3.550 (2.323–5.427)	<0.001	3.485 (2.276–5.337)	<0.001
FI (per each 0.1 score increment)	1.954 (1.644–2.323)	<0.001	1.918 (1.607–2.289)	<0.001	1.763 (1.310–2.371)	<0.001	1.812 (1.323–2.482)	<0.001	2.006 (1.618–2.486)	<0.001	1.981 (1.592–2.464)	<0.001
FRAIL Scale (per each category increment)	3.708 (2.347–5.857)	<0.001	3.570 (2.263–5.631)	<0.001	3.885 (1.714–8.805)	0.001	3.818 (1.658–8.788)	0.002	3.488 (2.012–6.046)	<0.001	3.515 (2.027–6.098)	<0.001
CIRS-G (per each 4 point increment)	1.799 (1.523–2.126)	<0.001	1.763 (1.486–2.091)	<0.001	1.891 (1.362–2.626)	<0.001	1.899 (1.352–2.667)	<0.001	1.710 (1.407–2.078)	<0.001	1.701 (1.390–2.083)	<0.001
Comorbidity-D-FI (per each 0.1 score increment)	1.719 (1.399–2.111)	<0.001	1.727 (1.392–2.144)	<0.001	1.759 (1.231–2.513)	0.002	1.724 (1.184–2.511)	0.005	1.660 (1.285–2.144)	<0.001	1.727 (1.311–2.274)	<0.001
ADL-Katz (per each disability increment)	1.543 (1.352–1.761)	<0.001	1.507 (1.316–1.726)	<0.001	1.405 (1.120–1.764)	0.003	1.427 (1.122–1.813)	0.004	1.585 (1.344–1.870)	<0.001	1.559 (1.317–1.845)	<0.001
IADL/ADL-D-FI (per each 0.1 score increment)	1.335 (1.219–1.462)	<0.001	1.321 (1.202–1.452)	<0.001	1.258 (1.081–1.465)	0.003	1.264 (1.079–1.482)	0.004	1.376 (1.226–1.545)	<0.001	1.364 (1.211–1.536)	<0.001

Note: *Cox proportional hazard model considering age, female gender, and the instrument, with respect to frailty, comorbidity, or disability.

Abbreviations: Adj, adjusted; ADL, basic activities of daily living; ADL-Katz, disability burden based on the six ADLs of the Katz index; CFS-7, Canadian Study on Health and Aging Clinical Frailty Scale; FI, frailty index; CIRS-G, Cumulative Illness Rating Scale for Geriatrics; Comorbidity-D-FI, Comorbidity domain of the frailty index; IADL, instrumental activities of daily living; IADL/ADL-D-FI, IADL/ADL domain of the frailty index; CI, confidence interval; HR, hazard ratio.

Table 5 Discriminative accuracy and comparison of the discriminative accuracy of the different frailty, comorbidity, or disability instruments (full scales) for 1-year mortality

	AUC (95% CI)	*P*-value	*P*-value, AUC 1 vs AUCs 2, 3, 4, 5, 6, and 7	*P*-value, AUC 2 vs AUCs 1, 3, 4, 5, 6, and 7	*P*-value, AUC 3 vs AUCs 1, 2, 4, 5, 6, and 7	*P*-value, AUC 4 vs AUCs 1, 2, 3, 5, 6, and 7	*P*-value, AUC 5 vs AUCs 1, 2, 3, 4, 6, and 7	*P*-value, AUC 6 vs AUCs 1, 2, 3, 4, 5, and 7	*P*-value, AUC 7 vs AUCs 1, 2, 3, 4, 5, and 6
All patients (n=305)									
1. CFS-7	0.841 (0.788–0.893)	<0.001	–	0.047	<0.001	0.004	<0.001	<0.001	<0.001
2. FI	0.812 (0.754–0.869)	<0.001	0.047	–	<0.001	0.045	<0.001	<0.001	<0.001
3. FRAIL scale	0.727 (0.661–0.792)	<0.001	<0.001	<0.001	–	0.096	0.489	0.296	0.154
4. CIRS-G	0.770 (0.708–0.913)	<0.001	0.004	0.045	0.096	–	0.041	0.225	0.339
5. Comorbidity-D-FI	0.726 (0.663–0.789)	<0.001	<0.001	<0.001	0.489	0.041	–	0.329	0.208
6. ADL-Katz	0.744 (0.674–0.814)	<0.001	<0.001	<0.001	0.296	0.225	0.329	–	0.232
7. IADL/ADL-D-FI	0.757 (0.695–0.819)	<0.001	<0.001	<0.001	0.154	0.339	0.208	0.232	–
Subgroup of patients aged 65–82 years (n=139)									
1. CFS-7	0.844 (0.767–0.922)	<0.001	–	0.003	0.003	0.018	0.006	<0.001	<0.001
2. FI	0.752 (0.639–0.865)	<0.001	0.003	–	0.281	0.456	0.299	0.011	0.044
3. FRAIL scale	0.727 (0.619–0.835)	0.002	0.003	0.281	–	0.285	0.479	0.243	0.313
4. CIRS-G	0.757 (0.650–0.864)	<0.001	0.018	0.456	0.285	–	0.217	0.088	0.162
5. Comorbidity-D-FI	0.724 (0.618–0.830)	0.002	0.006	0.299	0.479	0.217	–	0.231	0.378
6. ADL-Katz	0.668 (0.525–0.812)	0.019	<0.001	0.011	0.243	0.088	0.231	–	0.104
7. IADL/ADL-D-FI	0.703 (0.588–0.818)	0.004	<0.001	0.044	0.313	0.162	0.378	0.104	–
Subgroup of patients aged ≥83 years (n=166)									
1. CFS-7	0.834 (0.763–0.904)	<0.001	–	0.394	<0.001	0.036	0.006	0.014	0.039
2. FI	0.840 (0.774–0.907)	<0.001	0.394	–	<0.001	0.016	0.001	0.001	0.002
3. FRAIL scale	0.724 (0.640–0.807)	<0.001	<0.001	<0.001	–	0.165	0.492	0.127	0.063
4. CIRS-G	0.768 (0.689–0.846)	<0.001	0.036	0.016	0.165	–	0.099	0.494	0.339
5. Comorbidity-D-FI	0.725 (0.645–0.806)	<0.001	0.006	0.001	0.492	0.099	–	0.465	0.109
6. ADL-Katz	0.770 (0.691–0.850)	<0.001	0.014	0.001	0.127	0.494	0.465	–	0.246
7. IADL/ADL-D-FI	0.785 (0.711–0.859)	<0.001	0.039	0.002	0.063	0.339	0.109	0.246	–

Abbreviations: ADL, basic activities of daily living; ADL-Katz, disability burden based on the six ADLs of the Katz index; AUC, area under the curve; CFS-7, Canadian Study on Health and Aging Clinical Frailty Scale; FI, frailty index; CIRS-G, Cumulative Illness Rating Scale for Geriatrics; Comorbidity-D-FI, Comorbidity domain of the frailty index; IADL, instrumental activities of daily living; IADL/ADL-D-FI, IADL/ADL domain of the frailty index.

Among the different frailty, comorbidity, or disability instruments, the CFS-7 and, in the subgroup of patients aged ≥83 years, also the FI showed superior discriminatory accuracy for 1-year mortality. Both CFS-7 and FI are the tools that allow for the evaluation of patients in relation to the larger construct of frailty.[4,5] They consider disability and comorbidity directly or indirectly. Data from previous studies in hospitalized patients and people living in the community indicate that comorbidity and disability impact mortality additively or synergistically in older people.[7,42,43] A synergistic interaction between comorbidity and disability on mortality during a median follow-up period of 10.9 years was previously found in a cohort of 12,804 acutely disabled patients with a mean age of 73±12 years who were admitted for inpatient rehabilitation in Singapore rehabilitation community hospitals.[7] An additive prognostic effect of comorbidity and ADL disability according to the Katz index on mortality over a follow-up period of 2.8 years was detected in 1,099 older people aged 77–100 years who were living in the community and institutions.[42] A combined effect of multi-morbidity and disability on 4-year mortality was found in 364 patients aged ≥80 years who were living in the community in the Aging and Longevity Study in the Sirente geographic area.[43] The findings of the present study indicate that such an additive or synergistic effect of comorbidity and disability also holds true in patients hospitalized in geriatric wards. In addition, both CFS-7 and FI, in contrast to the FRAIL scale and other instruments that allow for the evaluation of patients in relation to physical frailty, such as the Fried and Walston frailty phenotype[16,44] or the Study of Osteoporotic Fractures Frailty index,[17] allow for a fine grading of frailty. This more differentiated grading of frailty severity might explain the superiority of the CFS-7 and, in the subgroup of patients aged ≥83 years, also the FI compared to the FRAIL scale in predicting 1-year mortality in the cohort of this study.

When applying a tool for risk stratification in a hospital setting, aspects such as time and/or skills needed for the application of the instrument and health care costs may be of relevance. In light of the findings of this study, we think that it is important to mention that with respect to the CFS-7, in particular, adequate judgment with respect to the state of a patient being terminally ill, that is, the probability that a patient might die within the next 6 months, needs experience and skills. In addition, with respect to the FI, the evaluation of patients in relation to a large list of potential health deficits may be time consuming. Similarly, the evaluation of patients in relation to the CIRS-G is complex, which needs some training and is also time consuming.

This study has some major strengths. This is the first study that has evaluated and compared different frailty, comorbidity, and disability instruments, together and in parallel, as predictors of mortality in a cohort of hospitalized patients from geriatric wards. Moreover, we considered different age ranges of patients being hospitalized in the geriatric wards. In addition, this study considered different major measures of frailty capturing two (ie, the CFS-7 and the FI) in terms of the larger construct of frailty,[4,5] and one (ie, the FRAIL scale) in terms of the construct of physical frailty,[4] and major measures of comorbidity and disability. The CFS-7,[5,45,46] FI,[5,9,10] and FRAIL scale[15,47,48] have been repeatedly and very well validated as powerful predictors of mortality in older people. However, so far, no study has considered a comparative analysis of the accuracy of these three aforementioned frailty instruments, together and in parallel, in predicting mortality in older hospitalized patients. Among comorbidity instruments, the CIRS-G and, with respect to disability instruments, disability in ADLs that construct the Katz index have been found to be powerful predictors of mortality in previous comparative studies in older people.[49–51] The CIRS-G and the Geriatric Index of Comorbidity revealed the largest coefficient of determination for 1-year mortality among six comorbidity indexes including the CIRS-G, the Charlson Comorbidity Index, Index of Coexistent Diseases, Kaplan, Geriatric Index of Comorbidity, and Chronic Disease Score in 444 older patients (mean age of 85 years) discharged from an acute geriatric hospital in Switzerland.[49] The CIRS-G and the Charlson Comorbidity Index revealed a good and comparable ability to predict 3-month mortality in a cohort of older individuals.[50] ADL disability in the items of the Katz index was at least as powerful in predicting 360-day mortality as ADL disability based on the Barthel index in 86 centenarians (102±1 years old).[51] ADL disability according to the Katz index had the highest impact on mortality during a mean follow-up period of 2.8 years, among other parameters, in 1,099 older Swedish persons with an age of 77–100 years from the Kungsholmen Project.[42]

This study has some limitations. The study cohort included only hospitalized patients from geriatric wards. As was the case in other studies of hospitalized patients in geriatric wards,[12,25,26,52] in the present study, a large proportion of patients were frail and suffered from multiple diseases and disabilities. Consequently, extrapolation of the findings of the current study to other patient groups or settings may be misleading. This analysis was a single-center study. The clinical profile of the patients treated and cared

for at geriatric wards might be unequal among individual hospitals due to different characteristics and focuses on single hospitals. In this study, we did not use any special inclusion or exclusion criteria (except for patients aged ≥65 years [as an inclusion criterion] and the inability to give written, informed consent or non-availability of a legal guardian to give written informed consent on behalf of the study participant [as exclusion criteria]). Thus, the cohort of this study includes all inpatients admitted to geriatric wards of a general hospital. Several different instruments for evaluating frailty, comorbidity, or disability have been developed.[4,5,20,22,23,49–51,53] It might be misleading to compare our findings with those obtained using other instruments than were applied in the study presented here for assessing frailty, comorbidity, or disability.

Conclusion

All frailty, comorbidity, or disability instruments evaluated in this study emerged as powerful tools for risk stratification of hospitalized patients on geriatric wards in relation to 1-year mortality risk across different patient age ranges. Thereby, among the different instruments, the CFS-7 and, in the subgroup of patients aged ≥83 years, also the FI were found to reveal superior discriminative accuracy for 1-year mortality.

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Disclosure

The authors report no conflicts of interest in this work.

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