SUPPLEMENTARY MATERIALS

SUPPLEMENTARY METHODS

Sample Size Justification

The sample size of 150 was fixed by the companion cross-sectional study design (detailed in the main manuscript). Post-hoc power calculations confirmed adequate power for the primary Andersen–Gill analysis; power for the four-level frailty–comorbidity composite was limited by the small Frail/Low CCI cell (n=7), as acknowledged in the Limitations.

Andersen–Gill Counting-Process Expansion

The Andersen-Gill extension of the Cox proportional hazards model requires conversion of person-level data into a counting-process format with (start, stop] intervals. A patient with k hospitalizations at times $t_1 < t_2 < ... < t_k$ and follow-up ending at T contributes $k + 1$ rows: k event rows (each with event indicator = 1) and one final censoring row (event indicator = 0). A patient with zero hospitalizations contributes a single censoring row spanning (0, T]. For the 141 patients who survived to 12 months, $T = 365.25$ days. All nine deaths in the cohort occurred during hospitalization; for these patients, follow-up ends at the time of the fatal admission. In cases where the censoring interval yielded *interval start = interval end* (i.e., death coinciding with the time of the last recorded event), a 0.5-day offset was added to the interval end to satisfy the counting-process requirement that interval start < interval end. This convention is consistent with established practice for recurrent event analysis and has negligible influence on parameter estimates.

Proportional Hazards Assessment

Schoenfeld residual tests confirmed proportional hazards for the primary Andersen–Gill model (global p=0.134; Supplementary Table S7).

Relationship to the Companion Cross-Sectional Study

Table S1. Comparison of the present prospective cohort and the companion cross-sectional study

Dimension	Cross-sectional study	Present prospective study
Primary outcome	Patient-reported health status (KCCQ-12)	Recurrent all-cause hospitalization
Study design	Single-visit cross-sectional assessment	Prospective cohort with 12-month follow-up
Analytical methods	Multivariable linear regression	Andersen–Gill recurrent event model; negative binomial regression; Fine–Gray competing risks
Novel constructs	None (standard predictor–outcome modeling)	Frailty–comorbidity composite variable; head-to-head frailty vs. LVEF prognostic comparison
Role of KCCQ-12	Primary outcome	Baseline descriptive variable only
Role of LVEF	Covariate in regression (non-significant)	Comparator in prognostic model discrimination

KCCQ-12, Kansas City Cardiomyopathy Questionnaire-12; LVEF, left ventricular ejection fraction.

Table S2. Sensitivity analyses of the association between frailty and recurrent all-cause hospitalization

Model/Analysis	Estimate (95% CI)	p-value
Sensitivity 1: Adjustment for NT-proBNP		
Frailty (adjusted for age, sex, and NT-proBNP)	1.80 (1.10–2.98)	0.019
Sensitivity 2: BMI stratification (obesity paradox)		
BMI in frail group (IRR per unit)	0.95 (0.83–1.09)	0.491
BMI in non-frail group (IRR per unit)	1.04 (0.89–1.21)	0.634
Interaction: frailty × BMI	0.93 (0.76–1.14)	0.485
Sensitivity 3: Competing risks (Fine–Gray)		
Frailty (subdistribution HR)	1.72 (1.06–2.81)	0.029
Frailty–comorbidity composite		
Non-frail, High CCI	0.66 (0.34–1.26)	0.208
Frail, Low CCI	1.18 (0.58–2.41)	0.642
Frail, High CCI	1.54 (0.85–2.82)	0.156

BMI, body mass index; CCI, Charlson Comorbidity Index; CI, confidence interval; HR, hazard ratio; IRR, incidence rate ratio; NT-proBNP, N-terminal pro-B-type natriuretic peptide.

Table S3. Baseline characteristics of the study patients, according to the frailty–comorbidity composite group

Characteristic	Non-frail, Low CCI	Non-frail, High CCI	Frail, Low CCI	Frail, High CCI	p trend	p-value
Age (y)	68 (64–75)	75 (68–84)	75 (75–80)	84 (75–87)	<0.001	<0.001
Male sex	48 (71.6)	14 (48.3)	3 (42.9)	24 (51.1)	N/A	0.050
BMI (kg/m²)	21.6 (2.0)	21.8 (2.3)	20.9 (1.6)	21.5 (2.6)	0.378	0.461
LVEF (%)	49 (37–66)	46 (38–68)	36 (20–68)	50 (40–64)	0.869	0.781
NT-proBNP (pg/mL)	642 (210–2121)	562 (135–2154)	1354 (236–3675)	562 (154–1678)	0.956	0.721
NYHA class III–IV	4 (6.0)	6 (20.7)	3 (42.9)	30 (63.8)	<0.001	<0.001
ADL limitation	1 (1.5)	0 (0.0)	4 (57.1)	33 (70.2)	<0.001	<0.001
IADL limitation	0 (0.0)	0 (0.0)	7 (100.0)	47 (100.0)	<0.001	<0.001
KCCQ-12 overall summary score	81.8 (76.6–88.0)	63.4 (59.9–72.4)	60.4 (55.7–65.1)	52.9 (41.2–59.9)	<0.001	<0.001
Mortality	2 (3.0)	1 (3.5)	0 (0.0)	6 (12.8)	0.036	0.128
Patients with ≥1 hospitalization	29 (43.3)	13 (44.8)	5 (71.4)	32 (68.1)	0.006	0.036
Total hospitalizations	0 (0–1)	0 (0–1)	1 (0–2)	1 (0–2)	0.003	0.025

Values are presented as median (IQR) or n (%). High CCI defined as CCI ≥ cohort median.

ADL, activities of daily living; CCI, Charlson Comorbidity Index; IADL, instrumental activities of daily living; KCCQ-12 OSS, Kansas City Cardiomyopathy Questionnaire-12 overall summary score; LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide; NYHA, New York Heart Association.

Table S4. Discrimination and fit of prognostic models for recurrent all-cause hospitalization, according to frailty- and LVEF-based stratification

Model	C-statistic	AIC	BIC	LR test p-value
Andersen–Gill (Recurrent Events)				
Frailty alone	0.581 (0.529–0.633)	1508.26	1511.29	0.024
LVEF classification alone	0.568 (0.518–0.619)	1516.56	1522.62	<0.001
Frailty + LVEF	0.610 (0.560–0.661)	1504.82	1513.91	Reference
Frailty–comorbidity composite	0.594 (0.540–0.648)	1510.04	1519.13	N/A
Frailty–comorbidity + LVEF	0.617 (0.566–0.668)	1507.42	1522.57	N/A
Negative binomial (hospitalization count)				
Frailty alone	N/A	459.40	468.43	N/A
LVEF classification alone	N/A	469.20	481.24	N/A
Frailty + LVEF	N/A	459.68	474.73	N/A
Frailty–comorbidity composite	N/A	462.06	477.11	N/A
Frailty–comorbidity + LVEF	N/A	462.99	484.06	N/A

C-statistic: Harrell's concordance index for discriminative ability, computed from each Andersen–Gill counting-process model with patient-clustered robust standard errors. Confidence intervals for the frailty and LVEF models overlapped; these model comparisons were exploratory and were not internally validated (no bootstrap optimism correction or split-sample validation was performed). Lower AIC and BIC indicate better fit.

AIC, Akaike information criterion; BIC, Bayesian information criterion; LR, likelihood ratio; LVEF, left ventricular ejection fraction.

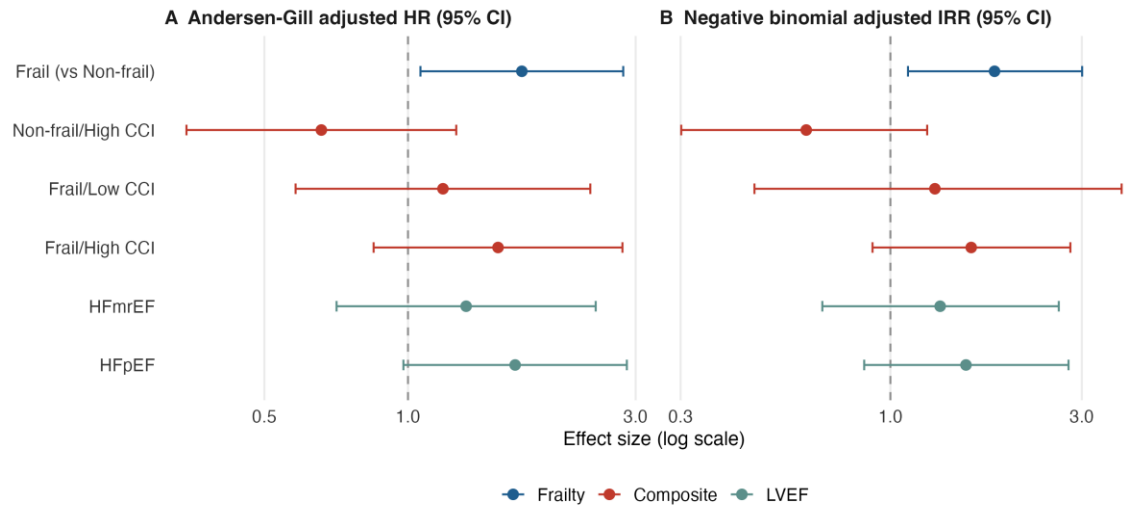

Fig. S1. Adjusted Hazard Ratios and Incidence-Rate Ratios for Recurrent All-Cause Hospitalization. (A) shows adjusted hazard ratios from the Andersen-Gill model; (B) shows adjusted incidence rate ratios from the negative binomial model. All estimates are adjusted for age and sex. The primary predictor, frailty status (blue), is presented alongside secondary predictors including frailty-comorbidity composite groups (red) and LVEF categories (green). Error bars represent 95% confidence intervals. CI, confidence interval; CCI, Charlson Comorbidity Index; HFmrEF, heart failure with mildly reduced ejection fraction; HFpEF, heart failure with preserved ejection fraction; HFrEF, heart failure with reduced ejection fraction; LVEF, left ventricular ejection fraction.

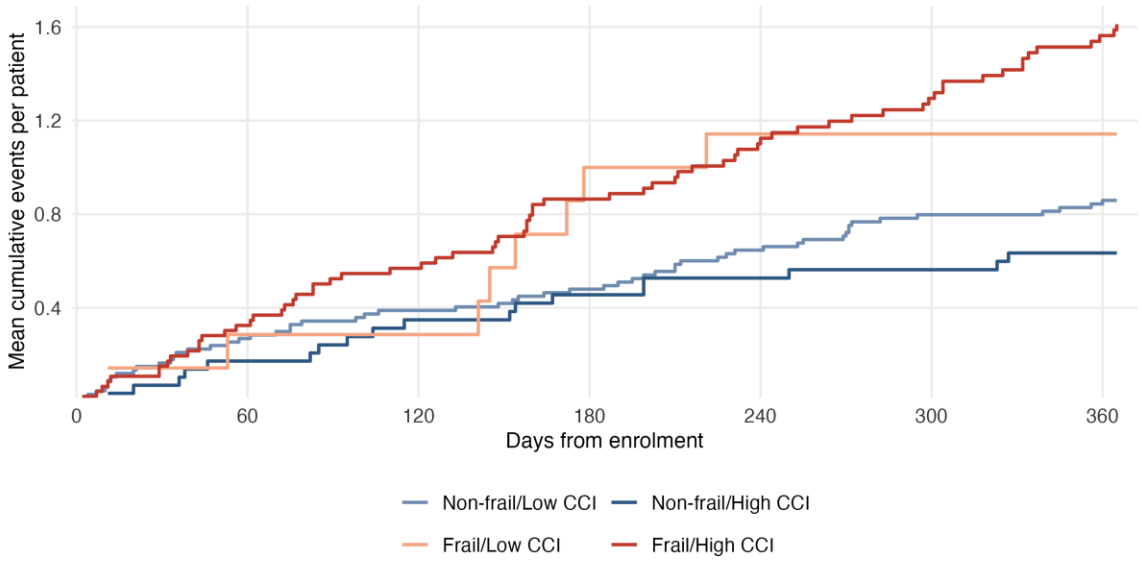

Fig. S2. Mean cumulative number of all-cause hospitalizations, according to the frailty–comorbidity composite group. Mean cumulative function (Nelson–Aalen estimator) for recurrent hospitalizations per patient over 12 months, stratified by frailty–comorbidity composite group. CCI, Charlson Comorbidity Index.

Table S5. Prespecified subgroup analyses, according to CCI tertile

Subgroup	Andersen–Gill		Negative binomial	
	HR (95% CI)	**p-value**	**IRR (95% CI)**	**p-value**
CCI T1 (low)	Reference	—	Reference	—
CCI T2 (mid)	0.88 (0.50–1.54)	0.656	0.89 (0.49–1.62)	0.699
CCI T3 (high)	1.02 (0.54–1.93)	0.959	1.01 (0.54–1.86)	0.983

Adjusted hazard ratios (Andersen–Gill) and incidence rate ratios (negative binomial) for recurrent all-cause hospitalization, by Charlson Comorbidity Index (CCI) tertile. Tertile 1 (lowest CCI) is the reference; both models are adjusted for age and sex. The CCI severity gradient was pre-specified; raw 1–9 Clinical Frailty Scale scores were not retained at the level of granularity required for a 5/6/≥7 severity stratification, so the comorbidity axis is reported here.

AG, Andersen–Gill recurrent-event Cox model with robust standard errors clustered by patient; CI, confidence interval; HR, hazard ratio; IRR, incidence rate ratio; NB, negative binomial regression with log person-time offset.

Table S6. All-cause hospitalization event rates, according to CCI tertile

	n	Total events	Person-years	Rate per 100 person-years
CCI T1 (low)	50	50	49.1	101.8
CCI T2 (mid)	50	49	47.5	103.1
CCI T3 (high)	50	67	47.8	140.2

Crude (unadjusted) event rates rise monotonically across Charlson Comorbidity Index (CCI) tertiles. After adjustment for age and sex, neither the middle nor the highest tertile differed significantly from the lowest tertile (Supplementary Table S5), reflecting the extent to which CCI tracks age in this older cohort.

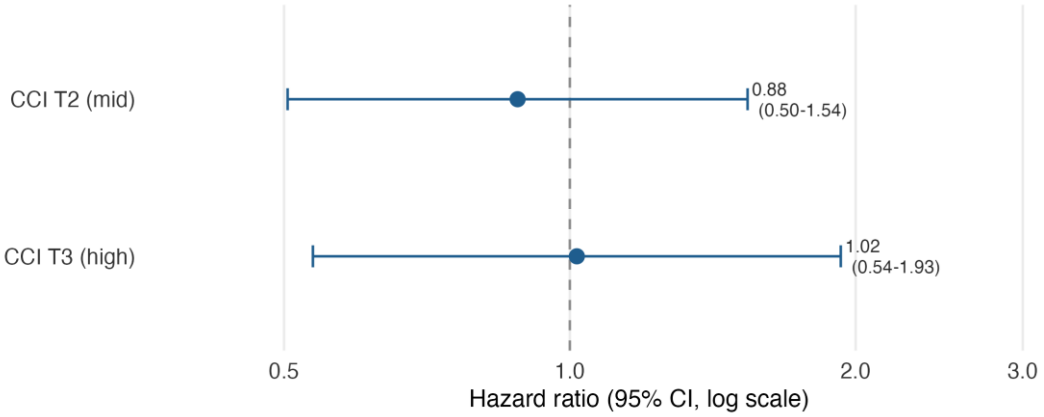

Fig. S3. Adjusted hazard ratios for recurrent all-cause hospitalization, according to Charlson Comorbidity Index (CCI) tertile. Adjusted hazard ratios (Andersen–Gill model, adjusted for age and sex) for recurrent all-cause hospitalization across CCI tertiles; Tertile 1 is the reference. Estimates are from Supplementary Table S5; crude event rates are in Supplementary Table S6.

Table S7. Schoenfeld residual proportional-hazards diagnostic for the primary adjusted Andersen–Gill model

Term	χ^2	df	p-value
Frailty (CFS ≥ 5)	2.115	1	0.146
Age	2.909	1	0.088
Sex (male)	1.299	1	0.254
GLOBAL test	5.572	3	0.134

Schoenfeld residuals from the primary Andersen–Gill model.

CFS, Clinical Frailty Scale.

All p>0.05.