



# Frailty is a prognostic marker of mortality and sepsis in patients $\geq 70$ years with acute left-sided colonic diverticulitis

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## Abstract

**Background** Acute left-sided colonic diverticulitis (ALCD) has a more complicated course in older patients. Rather than age, frailty may be crucial in ALCD prognosis in this heterogeneous population. This study aims to define the influence of the Clinical Frailty Scale (CFS) on mortality and clinical outcomes in patients aged 70 or older with ALCD.

**Methods** All patients aged  $\geq 70$  years admitted to the emergency department for ALCD between January 2018 and December 2022 were included. Frailty was assessed through the CFS, and three groups of patients were identified accordingly: non-frail patients (CFS 1–3); moderately frail patients (CFS 4–6); and severely frail patients (CFS 7–9). The endpoints were: 30-day mortality, sepsis onset, 30-day readmission, and length of hospital stay (LOS).

**Results** A total of 1127 patients were enrolled. Severely frail patients had a significantly higher rate of sepsis onset, mortality, and longer LOS at univariate analysis. Higher CFS scores were significantly associated with mortality, both as a continuous (OR 1.42) and discrete variable (OR 12.47), and sepsis, both as a continuous (OR 1.5) and discrete variable (OR 6.52) at multivariate analysis.

**Conclusion** A higher CFS score, rather than age, is associated with higher rates of mortality, sepsis, and longer LOS. After adjusting for covariates, higher CFS scores were significantly associated with increased risk of 30-day mortality and sepsis. A comprehensive frailty assessment using the CFS should be considered to predict the need for closer monitoring and guiding appropriate care goals for older patients.

**Keywords** Diverticulitis · Frailty · Elderly · Clinical frailty scale · Complicated diverticulitis

## Introduction

Acute left-sided colonic diverticulitis (ALCD) is the inflammation of colonic diverticula [1] that mainly involves the sigmoid colon, with a clinical presentation varying from abdominal pain associated with fever, to pericolic abscess, bleeding, digestive perforations, and sepsis [2, 3]. The prevalence of diverticular disease progressively increases with age, reaching the peak among people aged 60 to 80 years old [4], with an estimated 4% lifetime risk of progression to ALCD [5]. While presenting with similar clinical features, older patients with ALCD exhibit a

higher mortality rate compared to younger individuals [3]. This disparity can be attributed to several factors, including a greater prevalence of comorbidities, reduced levels of resilience to acute illnesses, and a diminished immune response, which can complicate the course of diverticulitis and increase the risk of severe complications [6, 7]. Nevertheless, the elderly population is highly diverse, and age alone is not always a reliable predictor of mortality and morbidity [6, 7]. For these reasons, the concept of frailty was introduced to bridge the gap between chronological age, coexisting medical conditions, and the overall health status and prognosis of older adults [8, 9]. In addition, the World Health Organization's forecast of a threefold rise in the global octogenarian population by 2050 [10], underscores the increasing burden of frailty, which will place significant challenges for healthcare systems and societies worldwide. Therefore, identifying frailty in patients

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aged 70 or older can contribute to tailored ALCD treatment plans, potentially predicting mortality and morbidity. Various methods and screening tools based on objective performance, comorbidities, disabilities, or social factors have been proposed to assess frailty, with no defined gold standard [9, 11, 12]. Among them, the Clinical Frailty Scale (CFS) [13] has already been validated as an independent predictor of mortality for elective and emergency surgical and nonsurgical populations [14–20]. However, its reliability for ALCD in elderly patients remains unproven in the emergency setting.

This study aims to define the influence of frailty assessed by the CFS at the Emergency Department (ED) admission on mortality and clinical outcomes in patients aged 70 or older with a proven diagnosis of ALCD.

## Methods

### Study design

This is a single-center observational cohort study conducted at the ED of the Fondazione Policlinico Universitario “Agostino Gemelli” IRCCS in Rome, a tertiary care university hospital with an average annual patient volume of 75,000, of which 87% are adults. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline (eTable 1 in Supplemental material).

### Inclusion and exclusion criteria

After obtaining approval from the Institutional Review Board (Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Rome, Italy, ID: #0025817/22), all patients aged 70 or older who were consecutively admitted to the ED for ALCD between January 2018 and December 2022 were included, regardless of their treatment modality. Patients who declined participation or had incomplete frailty assessments were excluded. Informed consent was obtained from all patients before data collection, and all procedures complied with the Declaration of Helsinki. Patients with incomplete data were excluded from the analysis (no data imputation was performed). Clinical data for the included patients were collected from a prospectively maintained database and identified using the International Classification of Disease, 9th Revision, Clinical Modification (ICD-9-CM) codes [21], as follows: ICD-9-CM codes 562.11 (diverticulitis without mention of hemorrhage) and 562.13 (diverticulitis with mention of hemorrhage), either as the primary or secondary diagnosis. All patients in the study cohort had a complete follow-up at 30 days.

### Study variables

The following demographic, clinical, and laboratory data were collected at admission: age, gender, frailty assessed using the CFS [13], clinical presentation (fever, dyspnea, abdominal pain, gastrointestinal bleeding [including both minor – hematochezia—and major—rectal bleeding – presentations], vomiting, diarrhea, fatigue, symptom duration), vital signs (heart rate, systolic and diastolic blood pressure, peripheral oxygen saturation, body temperature), hemoglobin, red cell distribution width, white blood cell count, platelet count, serum glucose, serum creatinine, C-reactive protein, procalcitonin, NTproBNP. Symptom duration was recorded at admission and dichotomized as  $\leq 24$  or  $> 24$  h, as defined a priori in the study protocol. Clinical history and comorbidities, including dementia, cerebrovascular diseases, coronary artery disease, chronic heart failure, peripheral vascular disease, chronic obstructive pulmonary disease, diabetes, liver cirrhosis, chronic kidney disease, solid and hematologic malignancies, were recorded, and the Charlson Comorbidity Index (CCI) [22] was calculated for each patient. The presence of complicated diverticulitis at admission (which included complications such as abscess and perforation) was also noted, and ALCD management was categorized into four groups: non-operative management, percutaneous drainage, sigmoidectomy with colorectal anastomosis, or Hartmann’s procedure. In particular, perforation was defined as free air distant from the colon, excluding cases with minor pericolic free air, which does not necessarily indicate a full-thickness bowel perforation.

### ALCD assessment and management

ALCD was diagnosed at ED admission through clinical examination, laboratory tests, and radiological imaging, such as computed tomography (CT). Patients with ALCD were treated based on disease severity and medical judgment. Non-operative treatment included antibiotics, pain control, and fluid therapy as needed. Operative management consisted of percutaneous drainage or surgery (sigmoidectomy with or without colorectal anastomosis) when indicated [23]. Patients were classified into two groups according to the World Society of Emergency Surgery (WSES) classification [23]: uncomplicated ALCD (infection limited to the colonic wall) and complicated ALCD (infection extending beyond the colonic wall and visceral peritoneum). Hinchey’s classification [24] was not consistently available because many patients arrived at the ED with external CT scans and only paper-based radiology reports. Therefore, the WSES classification was

exclusively used to categorize ALCD as uncomplicated or complicated. This dichotomous classification allowed for robust categorization even with limited imaging details.

The need for surgery was based on a standardized protocol that included clinical, imaging, and conservative treatment failure criteria. These included:

- Imaging: Evidence of perforation (e.g., free air distant from the colon).
- Clinical: hemodynamic or clinical instability, persistent intense or worsening abdominal pain, signs of infection despite antibiotic therapy.
- Conservative failure: lack of clinical improvement within 48–72 h of medical management.

### Clinical frailty scale assessment

Frailty was assessed prospectively by a specialized and dedicated Geriatrics/Frailty Unit integrated into the ED workflow. Frailty was assessed at admission using the CFS [13]. Patients were categorized into three groups based on the CFS: non-frail (CFS 1–3), moderately frail (CFS 4–6), and severely frail (CFS 7–9). Additionally, CFS was analyzed as both a continuous and dichotomous variable. The study subgroups were defined a priori in the study protocol, based on the CFS. The CFS is a mixed scale that was applied prospectively and systematically in this study by a dedicated geriatric team, minimizing interobserver variability.

### Study endpoints

The study endpoints were 30-day mortality, sepsis onset, length of hospital stay (LOS) from admission to discharge or death, and 30-day readmission.

### Statistical analysis

Continuous variables were presented as median and interquartile range and compared using the Mann–Whitney U test. Categorical variables were presented as absolute numbers and percentages and compared using the Chi-square test (or Fisher exact test when appropriate). Multiple comparisons were adjusted for false discovery rate (FDR) using the Benjamini–Hochberg method. The CFS score was also included as a continuous variable in the multivariate analysis to assess the risk associated with each point increase. The multivariate logistic regression model included statistically significant variables in the univariate analysis. No a priori sample size was calculated since all the patients evaluated during the study period were included in the study cohort. No sensitivity analysis was performed. To prevent model overfitting and parameter overestimation, multivariate models did not include individual items that were part of any

derived variable. The risk of 30-day mortality, sepsis onset, and 30-day readmission was expressed as odds ratios (OR) with 95% confidence intervals (CI). The 30-day mortality and readmission were also assessed using the Kaplan–Meier analysis. A two-sided  $p$ -value  $\leq 0.05$  was considered statistically significant for all analyses. Data analysis was performed using SPSS v25® (IBM, Armonk, NY, USA).

## Results

### Patients' characteristics

During the study period, 1127 patients aged 70 or older with ALCD (690 females and 437 males, median age 78 years) were admitted to the ED. The patients' flow diagram is reported in Fig. 1. Table 1 summarizes the demographic and clinical characteristics. Overall, 380 patients (33.7%) had a

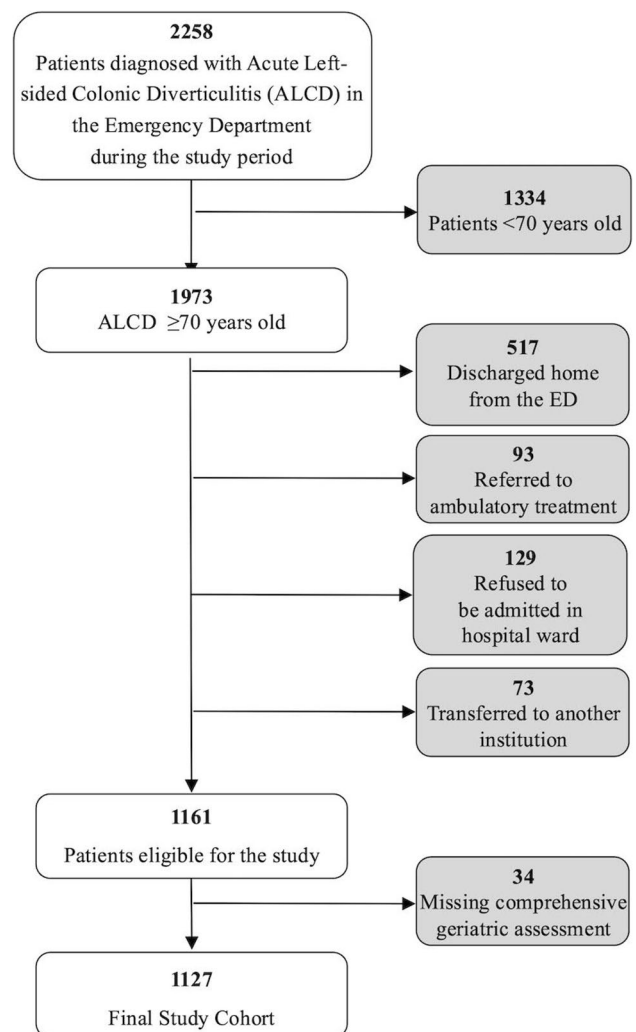


Fig. 1 Patients' flow diagram

**Table 1** Demographics and clinical characteristics of included patients according to the frailty as assessed by the Clinical Frailty Scale at Emergency Department admission

Variable	All patients (n = 1127)	CFS 1–3 (n = 380)	CFS 4–6 (n = 651)	CFS 7–9 (n = 96)	P value
Age, median (IQR)	78 (71–83)	75 (71–81)	79 (73–85)	82 (77–88)	< 0.001
Male sex, No. (%)	437 (38.8)	143 (37.6)	256 (39.3)	41 (42.7)	0.52
CFS, median (IQR)	5 (3–5)	3 (3–3)	5 (5–6)	7 (7–7)	< 0.001
CCI, median (IQR)	4 (3–5)	3 (2–4)	4 (3–5)	6 (5–9)	< 0.001
Comorbidities, No. (%)					
Coronary artery disease	145 (12.9)	38 (10)	76 (11.7)	31 (32.3)	< 0.001
Heart failure	119 (10.6)	28 (7.4)	76 (11.7)	15 (15.6)	0.02
Peripheral vascular disease	42 (3.7)	3 (0.8)	31 (4.8)	8 (8.3)	< 0.001
Cerebrovascular disease	62 (5.5)	20 (5.3)	28 (4.3)	14 (14.6)	< 0.001
COPD	57 (5.1)	2 (0.5)	25 (3.8)	30 (31.3)	< 0.001
Liver Cirrhosis	19 (1.7)	2 (0.5)	16 (2.5)	1 (1)	0.06
Diabetes	122 (10.8)	38 (10)	68 (10.4)	16 (16.7)	0.15
CKD	7 (0.6)	0	3 (0.5)	4 (4.2)	< 0.001
Solid tumor	91 (8.1)	16 (4.2)	48 (7.4)	27 (28.1)	< 0.001
Hematological neoplasm	19 (1.7)	2 (0.5)	6 (0.9)	11 (11.59)	< 0.001
Dementia	30 (2.7)	2 (0.5)	17 (2.6)	11 (11.5)	< 0.001
Vital signs, median (IQR)					
Heart Rate, bpm	85 (74–98)	87 (78–100)	84 (73–97)	85 (70–97)	0.15
Systolic blood pressure, mmHg	130 (112–150)	133 (117–149)	130 (110–150)	121 (104–150)	0.25
Diastolic blood pressure, mmHg	73 (64–85)	78 (68–88)	71 (63–83)	70 (60–81)	0.05
SpO <sub>2</sub> , %	96 (95–98)	97 (95–98)	97 (95–98)	95(93–97)	< 0.001
Body temperature, °C	36.5 (36–37.4)	36.3 (36.1–36.4)	36.4 (36–37)	36.9 (36.3–37.7)	0.02
Symptoms, No. (%)					
> 24 h onset	426 (37.8)	156 (41.1)	231 (35.5)	39 (40.6)	0.17
Fever	792 (70.3)	287 (75.5)	451 (69.3)	54 (56.3)	0.001
Dyspnea	448 (39.8)	167 (43.9)	242 (37.2)	39 (40)	0.1
Abdominal pain	162 (14.4)	31 (8.2)	107 (16.4)	24 (25)	< 0.001
GI bleeding	713 (63.3)	266 (70)	401 (61.6)	46 (47.9)	< 0.001
Laboratory test, median (IQR)					
Hemoglobin, gr/dL	12 (10.2–13.5)	12.5 (11–13.7)	11.9 (9.8–13.5)	11.1 (10–13)	0.19
White blood cells, × 10 <sup>9</sup> /L	10.3 (7.3–14.7)	12 (8.5–15.9)	10 (7.1–14.2)	8.5 (6.6–13.6)	0.09
Creatinine, mg/dL	1 (0.7–1.4)	0.9 (0.7–1.1)	1 (0.8–1.5)	1.2(0.7–1.8)	< 0.001
NTproBNP, ng/mL	2541 (447–3846)	383 (327–2967)	2606 (447–4145)	2510 (1239–6159)	0.19
Platelets, × 10 <sup>9</sup> /L	236 (189–322)	250 (201–330)	235 (182–318)	211 (173–321)	0.06
Procalcitonin, ng/mL	0.24 (0.06–0.93)	0.16 (0.06–0.93)	0.23 (0.06–0.79)	0.53 (0.05–1.04)	0.61
C-reactive protein, mg/L	70 (15–166)	86 (34–175)	60 (12–154)	78 (11–167)	0.1
Complicated diverticulitis, No. (%)					
Abscess	88 (7.8)	28 (7.4)	52 (8)	8 (8.3)	0.9
Perforation	71 (6.3)	20 (5.3)	49 (7.5)	2 (2.1)	0.7
Type of management, No. (%)					
Non-operative	995 (88.3)	343 (90.3)	575 (88.3)	77 (80.2)	
Percutaneous drainage	27 (2.4)	6 (1.6)	18 (2.8)	3 (3.1)	0.145
Sigmoidectomy with colorectal anastomosis	39 (3.5)	13 (3.4)	20 (3.1)	6 (6.3)	
Hartmann's procedure	66 (5.8)	18 (4.7)	38 (5.8)	10 (10.4)	
Length of stay, median (IQR), days	6 (3–10)	5 (3–8)	6 (3–11)	8 (5–16)	< 0.001
Sepsis	52 (4.6)	9 (2.4)	29 (4.5)	14 (14.6)	< 0.001
30-day mortality, No. (%)	25 (2.2)	1 (0.3)	13 (2)	11 (11.5)	< 0.001
30-day readmission	24 (2.1)	8 (2.1)	11 (1.7)	5 (5.2)	0.08

Statistically significant results are highlighted in bold

CCI Charlson Comorbidity Index, CFS Clinical Frailty Scale, CKD Chronic Kidney Disease, COPD chronic obstructive pulmonary disease, GI Gastrointestinal, IQR Interquartile range

**Table 2** Variables associated with mortality

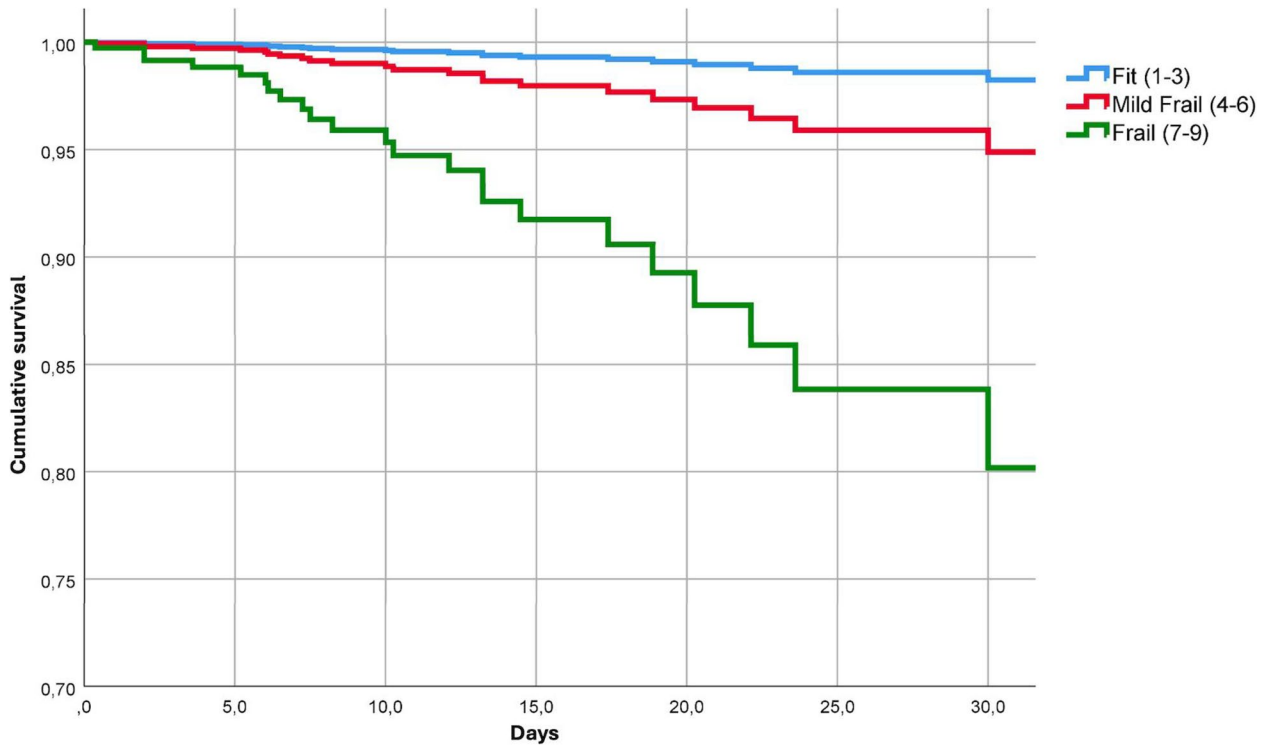
Variable	Alive (n = 1102)	Dead (n = 25)	Univariate <i>P</i> value	Odds ratio (95% CI)	Multivariate <i>P</i> value
Age, median (IQR)	78 (71–83)	80 (76–85)	0.1		
Male sex, No. (%)	432 (38.4)	14 (56)	0.07		
CFS, median (IQR)	5 (3–5)	5 (4–7)	<b>&lt; 0.001</b>	<b>1.42 (1.02–2)</b>	<b>0.038</b>
CFS 1–3, No. (%)	379 (34.4)	1 (4)	<b>&lt; 0.001</b>	<b>12.47 (1.4–110)*</b>	<b>0.003*</b>
CFS 4–6, No. (%)	638 (57.9)	13 (52)			
CFS 7–9, No. (%)	85 (7.7)	11 (44)			
CCI, median (IQR)	4 (3–5)	5 (3–6)	<b>0.014</b>		0.36
<b>Comorbidities, No. (%)</b>					
Coronary artery disease	126 (11.4)	19 (76)	<b>&lt; 0.001</b>		
Heart failure	114 (10.3)	5 (20)	0.12		
Peripheral vascular disease	39 (3.5)	3 (12)	<b>0.027</b>		
Cerebrovascular disease	58 (5.3)	4 (16)	<b>0.02</b>		
COPD	57 (5.2)	0 (0)	0.24		
Liver Cirrhosis	19 (1.7)	0 (0)	0.5		
Diabetes	120 (10.9)	2 (8)	0.64		
CKD	7 (0.6)	0 (0)	0.69		
Solid tumor	70 (6.4)	3 (12)	0.25		
Hematological neoplasm	18 (1.6)	1 (4)	0.36		
Dementia	30 (2.7)	0 (0)	0.4		
<b>Vital signs, median (IQR)</b>					
Heart Rate, bpm	85 (74–98)	94 (81–98)	0.09		
Systolic blood pressure, mmHg	130 (113–150)	145 (110–158)	0.5		
Diastolic blood pressure, mmHg	73 (63–85)	80 (72–91)	0.09		
SpO <sub>2</sub> , %	97 (95–98)	93 (92–96)	<b>0.001</b>		
Body temperature, °C	36.5 (36–37.4)	36.4 (36.1–36.8)	0.69		
<b>Symptoms, No. (%)</b>					
> 24 h onset	419 (38)	7 (28)	0.3		
Fever	779 (70.7)	13 (52)	<b>0.04</b>		
Dyspnea	442 (40.1)	6 (24)	0.1		
Abdominal pain	154 (14)	8 (32)	<b>0.01</b>		
GI bleeding	701 (63.6)	12 (48)	0.1		
<b>Laboratory test, median (IQR)</b>					
Hemoglobin, gr/dL	12 (10–13.6)	11.8 (10.5–12.8)	0.66		
White blood cells, × 10 <sup>9</sup> /L	10.4 (7.3–14.9)	8 (5–11.4)	0.07		
Creatinine, mg/dL	1 (0.7–1.4)	1.5 (1.1–2.4)	<b>0.004</b>		
NTproBNP, ng/mL	2632 (446–3920)	1028 (870–3870)	0.64		
Platelets, × 10 <sup>9</sup> /L	236 (191–322)	228 (95–302)	0.2		
Procalcitonin, ng/mL	0.24 (0.06–0.93)	0.12 (0.05–8.33)	0.97		
C-reactive protein, mg/L	70 (15–161)	126 (20–394)	0.23		
<b>Complicated diverticulitis, No. (%)</b>					
Abscess	87 (7.9)	1 (4)	0.47		
Perforation	70 (6.4)	1 (4)	0.63		
<b>Type of management, No. (%)</b>					
Non-operative	983 (89.2)	12 (48)	<b>&lt; 0.001</b>	Reference	
Percutaneous drainage	26 (2.4)	1 (4)		3.1 (0.4–25.1) <sup>°</sup>	0.268
Sigmoidectomy with colorectal anastomosis	33 (3)	6 (24)		<b>14.9 (5.3–42.1)<sup>°</sup></b>	<b>&lt; 0.001</b>
Hartmann's procedure	60 (5.4)	6 (24)		<b>8.2 (2.9–22.6)<sup>°</sup></b>	<b>&lt; 0.001</b>
<b>Outcomes, No. (%)</b>					
Sepsis	49 (4.4)	3 (12)	0.07		
Length of stay, median (IQR), days	6 (3–10)	10 (6–19)	<b>0.002</b>		

Statistically significant results are highlighted in bold

\*It refers to the odds of the CFS group 7–9 versus the CFS group 4–6

<sup>°</sup>It refers to the odds of the invasive procedure versus non-operative management

CCI Charlson Comorbidity Index, CFS Clinical Frailty Scale, CKD Chronic Kidney Disease, COPD chronic obstructive pulmonary disease, GI Gastrointestinal, IQR Interquartile range



**Fig. 2** Kaplan–Meier curve of 30-day cumulative survival among the three CFS classes

CFS of 1–3, 651 patients (57.8%) had a CFS of 4–6, and 96 patients (8.5%) had a CFS of 7–9. Median age increased significantly with frailty severity, reaching 82 years in CFS 7–9 compared to the other two groups ( $p < 0.001$ ). Comorbidities were more frequent in severely frail patients, with a median CCI of 6 for severely frail compared to 4 and 3 for moderately and non-frail groups, respectively ( $p < 0.001$ ). The most common clinical signs at admission were fever (70.3%) and gastrointestinal bleeding (63.3%), both significantly less frequent in frailer patients ( $p = 0.001$  and  $p < 0.001$ , respectively). The three groups had no significant differences in abscess formation or perforation. Severely frail patients showed significantly higher rates of sepsis ( $p < 0.001$ ), mortality ( $p < 0.001$ ), and a longer LOS ( $p < 0.001$ ), compared to moderately and non-frail patients.

### Factors associated with 30-day mortality

Table 2 summarizes the variables associated with 30-day mortality. Univariate analysis revealed no differences in age or sex between patients who died within 30 days and survivors. Deceased patients were more frequently severely frail (44% vs 7.7%,  $p < 0.001$ ) and had higher CCI (5 vs 4,  $p = 0.014$ ). After adjusting for covariates, CFS was independently associated with mortality, both as continuous (median CFS, OR 1.42, 95% CI: 1.02–2,  $p = 0.038$ ) and

discrete variable (OR 12.47, 95% CI: 1.4–110,  $p = 0.003$  for CFS 7–9 compared to CFS 4–6). Additionally, sigmoidectomy with or without colorectal anastomosis was associated with mortality, compared to nonoperative management (OR 14.9, 95% CI: 5.3–42.1,  $p < 0.001$  and OR 8.2, 95% CI: 2.9–22.6,  $p < 0.001$ , respectively). Kaplan–Meier analysis (Fig. 2) showed significant differences in 30-day cumulative survival between the three CFS groups ( $p < 0.001$ ).

### Factors associated with sepsis

Table 3 presents the variables associated with sepsis. Severe frailty (CFS 7–9) (26.9% vs. 7.6%,  $p < 0.001$ ), higher CCI (5 vs 4,  $p < 0.001$ ), and higher rates of abscesses (48.1% vs. 5.9%,  $p < 0.001$ ) and perforations (34.6% vs. 4.9%,  $p < 0.001$ ) were significantly more common in septic patients. Septic patients also had prolonged LOS (14 vs. 6 days,  $p < 0.001$ ) and higher 30-day readmission rates (7.7% vs. 1.9%,  $p = 0.004$ ). Multivariate analysis identified CFS, both as continuous (OR 1.5, 95% CI: 1.2–1.87,  $p < 0.001$ ) and discrete variable (OR 6.52, 95% CI: 4.42–11.26,  $p < 0.001$  for CFS 7–9 compared to CFS 4–6), abscesses (OR 10.4, 95% CI: 5.0–21.0,  $p < 0.001$ ), perforations (OR 16.9, 95% CI: 8.4–34.2,  $p < 0.001$ ), percutaneous drainage (OR 4.6, 95% CI: 1.5–14.1,  $p = 0.006$ ), Hartmann’s procedure (OR 5.3, 95% CI: 2.6–11.1,

**Table 3** Variables associated with sepsis

Variable	No sepsis ( <i>n</i> = 1075)	Sepsis ( <i>n</i> = 52)	Univariate <i>P</i> value	Odds ratio (95% CI)	Multivariate <i>P</i> value
Age, median (IQR)	78 (71–83)	79 (73–82)	0.59		
Male sex, No. (%)	411 (38.2)	26 (50)	0.09		
CFS, median (IQR)	5 (3–5)	5 (4–7)	<b>&lt; 0.001</b>	<b>1.5 (1.2–1.87)</b>	<b>&lt; 0.001</b>
CFS 1–3, No. (%)	371 (34.5)	9 (17.3)	<b>&lt; 0.001</b>	<b>6.52 (4.42–11.26)*</b>	<b>&lt; 0.001*</b>
CFS 4–6, No. (%)	622 (57.9)	29 (55.8)			
CFS 7–9, No. (%)	82 (7.6)	14 (26.9)			
CCI, median (IQR)	4 (3–5)	5 (3–7)	<b>&lt; 0.001</b>		
<b>Comorbidities, No. (%)</b>					
Coronary artery disease	129 (12)	16 (30.8)	<b>&lt; 0.001</b>		
Heart failure	117 (10.9)	2 (3.8)	0.1		
Peripheral vascular disease	40 (3.7)	2 (3.8)	0.96		
Cerebrovascular disease	61 (5.7)	1 (1.9)	0.24		
COPD	48 (4.5)	9 (17.3)	<b>&lt; 0.001</b>		
Liver Cirrhosis	18 (1.7)	1 (1.9)	0.89		
Diabetes	115 (10.7)	7 (13.5)	0.53		
CKD	7 (0.7)	0 (0)	0.56		
Solid tumor	66 (6.1)	7 (13.5)	<b>0.03</b>		
Hematological neoplasm	14 (1.3)	5 (9.6)	<b>0.01</b>		
Dementia	27 (2.5)	3 (5.8)	0.15		
<b>Vital signs, median (IQR)</b>					
Heart Rate, bpm	85 (74–97)	99 (80–108)	<b>0.002</b>		
Systolic blood pressure, mmHg	130 (116–150)	110 (95–149)	<b>&lt; 0.001</b>		
Diastolic blood pressure, mmHg	75 (64–85)	68 (60–75)	<b>0.001</b>		
SpO <sub>2</sub> , %	97 (95–98)	95 (92–97)	<b>&lt; 0.001</b>		
Body temperature, °C	36.5 (36–37)	37.8 (37.1–38.9)	<b>&lt; 0.001</b>		
<b>Symptoms, No. (%)</b>					
> 24 h onset	405 (37.7)	21 (40.4)	0.69		
Fever	762 (70.9)	30 (57.7)	<b>0.04</b>		
Dyspnea	411 (38.2)	37 (71.2)	<b>&lt; 0.001</b>		
Abdominal pain	151 (14)	11 (21.2)	0.15		
GI bleeding	693 (64.5)	20 (38.5)	<b>&lt; 0.001</b>		
<b>Laboratory test, median (IQR)</b>					
Hemoglobin, gr/dL	11.9 (10–13.5)	13 (11–14)	<b>0.04</b>		
White blood cells, × 10 <sup>9</sup> /L	10.2 (7.3–14.9)	11.2 (5.7–13.7)	0.86		
Creatinine, mg/dL	1 (0.7–1.4)	1.4 (0.9–1.9)	<b>&lt; 0.001</b>		
NTproBNP, ng/mL	2570 (447–3846)	1628 (427–6406)	0.8		
Platelets, × 10 <sup>9</sup> /L	240 (192–325)	180 (154–246)	<b>0.001</b>		
Procalcitonin, ng/mL	0.16 (0.05–0.49)	6.1 (1.04–12.7)	<b>&lt; 0.001</b>		
C-reactive protein, mg/L	68 (14.6–161)	83 (48–224)	<b>0.045</b>		
<b>Complicated diverticulitis, No. (%)</b>					
Abscess	73 (6.8)	15 (28.8)	<b>&lt; 0.001</b>	<b>10.4 (5.0–21.0)</b>	<b>&lt; 0.001</b>
Perforation	53 (4.9)	18 (34.6)	<b>&lt; 0.001</b>	<b>16.9 (8.4–34.2)</b>	<b>&lt; 0.001</b>
<b>Type of management, No. (%)</b>					
Non-operative	959 (89.3)	36 (69.2)	<b>&lt; 0.001</b>	Reference	
Percutaneous drainage	23 (2.1)	4 (7.7)		<b>4.6 (1.5–14.1)°</b>	<b>0.006</b>
Sigmoidectomy with colorectal anastomosis	38 (3.5)	1 (1.9)		0.7 (0.1–5.2)°	0.72
Hartmann's procedure	55 (5.1)	11 (21.2)		<b>5.3 (2.6–11.1)°</b>	<b>&lt; 0.001</b>
Need for invasive treatment	119 (11.1)	13 (25)	<b>0.002</b>	<b>2.7 (1.5–6.32)</b>	<b>0.049</b>
30-day mortality	22 (2)	3 (5.8)	0.07		

**Table 3** (continued)

Variable	No sepsis ( <i>n</i> = 1075)	Sepsis ( <i>n</i> = 52)	Univariate <i>P</i> value	Odds ratio (95% CI)	Multivariate <i>P</i> value
Length of stay, median (IQR), days	6 (3–10)	14 (8–25)	<b>&lt; 0.001</b>	<b>5.42 (3.58–9.33)</b>	<b>0.005</b>
30-day readmission	20 (1.9)	4 (7.7)	<b>0.004</b>		

Statistically significant results are highlighted in bold

\*It refers to the odds of the CFS group 7–9 versus the CFS group 4–6

+ It refers to the odds of complicated versus uncomplicated diverticulitis

°It refers to the odds of the invasive procedure versus non-operative management

CCI Charlson Comorbidity Index, CFS Clinical Frailty Scale, CKD Chronic Kidney Disease, COPD chronic obstructive pulmonary disease, GI Gastrointestinal, IQR Interquartile range

$p < 0.001$ ), and LOS (OR 5.42, 95% CI: 3.58–9.33,  $p = 0.005$ ) as risk factors for sepsis.

### Factors associated with 30-day readmission

Table 4 highlights the factors associated with 30-day readmission. Severe frailty (20.8% vs. 7.4%,  $p = 0.047$ ), perforations (20.8% vs. 6.0%,  $p = 0.003$ ), longer LOS (16.7 vs. 4.2 days,  $p = 0.002$ ), and sepsis (16.7% vs. 4.2%,  $p = 0.003$ ) were more frequent in readmitted patients at univariate analysis. The Kaplan–Meier analysis (Fig. 3) showed significant differences in 30-day cumulative readmission rates between the CFS 4–6 group and the other two CFS classes ( $p < 0.001$ ).

## Discussion

This study evaluated the role of frailty, measured by the CFS, in predicting outcomes among 1127 consecutive patients aged 70 or older admitted to the ED for ALCD. The study's multidisciplinary approach involved emergency medicine physicians, emergency surgeons, colorectal surgeons, and geriatricians, ensuring comprehensive care for all patients. This investigation is one of the few in the literature exploring the association between frailty and ALCD outcomes, and this is the only study using the CFS to assess frailty in this geriatric population. The findings demonstrated that severely frail patients (CFS 7–9) had higher rates of mortality, sepsis, and longer LOS. Moreover, higher CFS scores remained significantly associated with increased risk of 30-day mortality and sepsis at multivariate analysis after adjusting for covariates.

The prevalence of diverticular disease increases with age, ranging from 10% in patients under 40 to 66% in those aged 80 and older [25], with 10–25% of these developing ALCD [26]. Due to the growing aging population, the incidence of ALCD is expected to rise [27]. Moreover, elderly patients typically present with more comorbidities and a diminished capacity to cope with acute stress, making the management

of ALCD more challenging [28]. However, the latest WSES guidelines for ALCD management did not provide specific recommendations for the elderly population [23]. While several studies have reported a higher risk of morbidity and mortality in the geriatric population compared to younger patients [27, 29–31], the present study found no significant correlation between age alone and mortality, sepsis onset, or 30-day hospital readmission. This disparity may arise from the heterogeneity of the geriatric population in terms of functional reserve. Thus, chronological age alone may not accurately predict higher morbidity and mortality, as it fails to account for overall health status and comorbidities [11, 12]. Consequently, frailty has emerged as a more comprehensive measure of physiological decline and resilience, offering a valuable predictor of adverse outcomes in the elderly [14, 15, 32]. The CFS is a simple, reliable, and validated tool for assessing frailty [13, 16] that avoids the complexity of formal evaluations and time-consuming specialized tests, making it suitable for integration into routine clinical practice [32–40].

By identifying frail patients early, the CFS can facilitate the timely involvement of allied healthcare professionals, such as physiotherapists, social workers, and occupational therapists, to address physical, emotional, and social deterioration [41, 42]. Additionally, prolonged LOS, as observed in patients with higher CFS scores, can exacerbate physical decline and impair quality of life, placing additional burdens on caregivers [41–43]. Therefore, using the CFS to recognize frail patients may facilitate timely interventions to alleviate these challenges.

The findings of this study align with recent investigations into the impact of frailty on ALCD outcomes. A recent nationwide propensity-matched analysis by Rasheed et al. [44] compared two cohorts of 21,720 frail and non-frail patients with ALCD using the Hospital Frailty Risk Score [45], showing significantly higher in-hospital mortality (1.1% vs. 0.2%;  $P < 0.001$ ), prolonged median LOS (4 days vs. 3 days;  $P < 0.001$ ), and increased rates of open colectomy (5.8% vs 5.3%;  $p = 0.035$ ) in the frail group. Similarly, McKechnie et al. [41] analyzed a cohort of 26,826

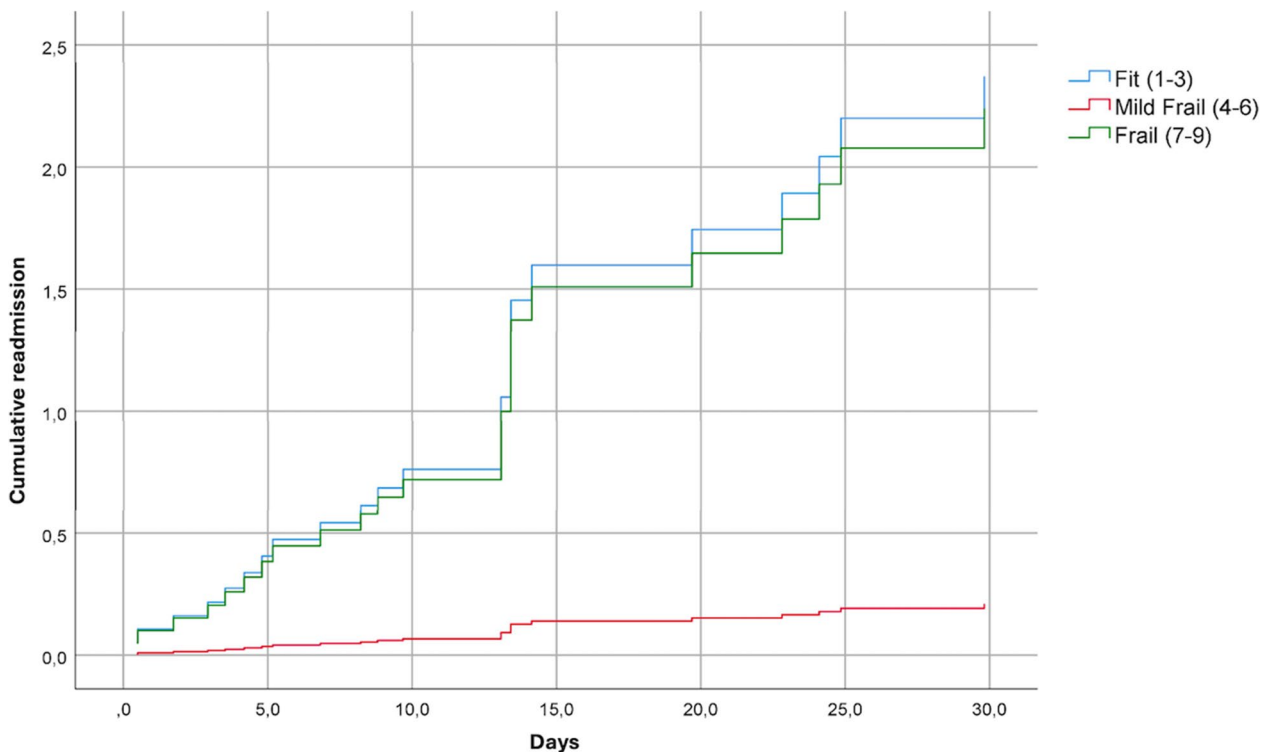
**Table 4** Variables associated with 30-day readmission

Variable	No readmission at 30 days ( <i>n</i> = 1078)	Readmission at 30 days ( <i>n</i> = 24)	Univariate <i>P</i> value	Odds ratio (95% CI)	Multivariate <i>P</i> value
Age, median (IQR)	78 (71–83)	78 (72–79)	0.6		
Male sex, No. (%)	415 (38.5)	8 (33.3)	0.6		
CFS, median (IQR)	5 (3–5)	4 (3–6)	0.55		
CFS 1–3, No. (%)	371 (34.4)	8 (33.3)	<b>0.047</b>	0.81 (0.32–2.04)	0.66
CFS 4–6, No. (%)	627 (58.2)	11 (45.8)			
CFS 7–9, No. (%)	80 (7.4)	5 (20.8)			
CCI, median (IQR)	4 (3–5)	4 (3–5)	0.33		0.34
<b>Comorbidities, No. (%)</b>					
Coronary artery disease	124 (11.5)	2 (8.3)	0.62		
Heart failure	111 (10.3)	3 (12.5)	0.72		
Peripheral vascular disease	37 (3.4)	3 (8.3)	0.19		
Cerebrovascular disease	57 (5.3)	1 (4.2)	0.8		
COPD	54 (5)	3 (12.5)	0.2		
Liver Cirrhosis	19 (1.8)	0 (0)	0.5		
Diabetes	120 (11.1)	0 (0)	0.08		
CKD	5 (0.5)	2 (8.3)	<b>&lt; 0.001</b>		
Solid tumor	67 (6.2)	3 (12.5)	0.21		
Hematological neoplasm	15 (1.4)	3 (12.5)	<b>&lt; 0.001</b>		
Dementia	29 (2.7)	1 (4.2)	0.6		
<b>Vital signs, median (IQR)</b>					
Heart Rate, bpm	85 (74–98)	84 (72–107)	0.77		
Systolic blood pressure, mmHg	130 (113–149)	130 (102–153)	0.95		
Diastolic blood pressure, mmHg	73 (64–85)	80 (60–84)	0.73		
SpO <sub>2</sub> , %	97 (95–98)	97 (95–97)	0.65		
Body temperature, °C	36.5 (36–37.2)	38 (36.7–38.9)	<b>0.003</b>		
<b>Symptoms, No. (%)</b>					
> 24 h onset	419 (38.9)	0 (0)	<b>&lt; 0.001</b>		
Fever	766 (71.7)	13 (54.2)	0.07		
Dyspnea	437 (40.5)	5 (20.8)	0.051		
Abdominal pain	135 (12.5)	19 (79.2)	<b>&lt; 0.001</b>		
GI bleeding	695 (64.5)	6 (25)	<b>&lt; 0.001</b>		
<b>Laboratory test, median (IQR)</b>					
Hemoglobin, gr/dL	12 (10–13.5)	13.1 (10–13.8)	0.2		
White blood cells, × 10 <sup>9</sup> /L	10.4 (7.3–14.9)	9.9 (1.6–13.4)	0.2		
Creatinine, mg/dL	1 (0.7–1.4)	1.6 (0.8–2)	<b>0.02</b>		
Platelets, × 10 <sup>9</sup> /L	236 (191–325)	260 (38–264)	0.29		
Procalcitonin, ng/mL	0.21 (0.06–0.78)	0.93 (0.49–1.04)	0.12		
C-reactive protein, mg/L	70 (14–161)	78 (44–276)	0.37		
<b>Complicated diverticulitis, No. (%)</b>					
Abscess	86 (8)	1 (4.2)	0.49		
Perforation	65 (6)	5 (20.8)	<b>0.003</b>	0.3 (0.1–1.1)	0.07
<b>Type of management, No. (%)</b>					
Non-operative	965 (89.6)	18 (75)	0.14	Reference	
Percutaneous drainage	25 (2.3)	1 (4.2)		2.1 (0.2–16.7) <sup>°</sup>	0.46
Sigmoidectomy with colorectal anastomosis	31 (2.9)	2 (8.3)		3.4 (0.7–15.5) <sup>°</sup>	0.10
Hartmann's procedure	57 (5.2)	3 (12.5)		2.8 (0.8–9.8) <sup>°</sup>	0.10
<b>Outcomes, No. (%)</b>					
Sepsis	45 (4.2)	4 (16.7)	<b>0.003</b>		
Length of stay, median (IQR), days	6 (3–10)	8 (5–20)	<b>0.002</b>		

Statistically significant results are highlighted in bold

<sup>°</sup>It refers to the odds of the invasive procedure versus non-operative management

Abbreviations: *CCI* Charlson Comorbidity Index, *CFS* Clinical Frailty Scale, *CKD* Chronic Kidney Disease, *COPD* chronic obstructive pulmonary disease, *GI* Gastrointestinal, *IQR* Interquartile range



**Fig. 3** Kaplan–Meier curve of 30-day cumulative readmission rate among the three CFS classes

patients undergoing elective surgery for colonic diverticular disease, of which 2632 (9.8%) were identified as frail using the Modified Frailty Index-11 [46]. They reported a significant increase in mortality (OR 2.16, 95% CI 1.38–3.38;  $p = 0.001$ ) and LOS (MD 1.78 days, 95% CI: 1.46–2.11,  $p < 0.001$ ) in frail patients compared to non-frail ones. Although these studies used different frailty assessment tools, such as the Hospital Frailty Risk Score and the Modified Frailty Index-11, the results consistently highlight the importance of frailty as a predictive measure for vulnerable patients in the emergency setting, also encouraging preoperative optimization strategies before elective surgery. Nevertheless, the use of frailty risk scores different from CFS makes direct comparisons with our results less straightforward.

The present study has several limitations. First, the lack of randomization may be associated with potential selection bias, limiting the possibility of establishing a causal relationship between the variables of interest. Nevertheless, the inclusion of all consecutive patients aged 70 or older with ALCD, regardless of the type of treatment performed, minimized the risk of excluding frailer patients who were not candidates for invasive procedures. Secondly, the lack of complete patient data precluded the analysis of discharge destinations, such as home or long-term care facilities, which are particularly relevant for geriatric populations. This limitation may have restricted our ability to fully assess the social and healthcare implications of frailty

in this context. Another limitation lies in the exclusion of outpatient treatments due to a lack of structured follow-up data. This exclusion may have underestimated the overall burden of disease in the studied population. Additionally, due to paper-only reports in many external referrals, the Hinchey classification could not be applied consistently. WSES classification was chosen to allow a dichotomous but clinically robust classification into uncomplicated and complicated diverticulitis. The reliance on WSES classification instead of Hinchey's classification addressed the variability in imaging availability and quality in the case of external CT scans and paper-based reports, reflecting the reality and challenges of a tertiary referral center, but may have limited comparability with studies using alternative classifications. Notably, however, rates of complicated diverticulitis were not significantly different across the frailty groups, supporting the robustness of our classification. Symptom duration was categorized using a binary threshold of 24 h, based on our study protocol. While clinically relevant, this may limit the detection of more subtle time-related outcome effects. Moreover, this study did not analyze the subspecialization of the surgeons performing the interventions. This is acknowledged as a potential limitation, as previous studies have shown improved outcomes with specialized colorectal surgeons. Lastly, the focus on short-term outcomes without evaluating the long-term consequences of ALCD in the geriatric population limits the broader applicability of our

findings. Although frailty assessments were standardized and performed by a trained unit, no formal interobserver reliability analysis was conducted. Future studies should aim to address these gaps by incorporating longitudinal analyses. Every effort was made to minimize potential sources of bias by employing a consistent protocol for data collection throughout the study period. A specialized Geriatrics/Frailty Unit conducted all frailty assessments using a standardized approach, reducing interobserver variability. Patients with incomplete or inconsistent clinical data were excluded from the analysis to ensure data quality. Furthermore, a post-hoc sample size analysis confirmed that the study had adequate power for evaluating sepsis outcomes, although it was slightly underpowered for assessing all-cause in-hospital mortality. Some multivariable estimates showed wide confidence intervals, reflecting the limited number of events and indicating statistical instability; the results should therefore be interpreted with caution.

In conclusion, frailty, as assessed by the CFS, was associated with higher mortality, prolonged hospital stays, and adverse outcomes in elderly patients with ALCD. While the study design and its potential bias preclude definitive causal inferences, these findings underscore the importance of incorporating frailty assessments into clinical workflows to stratify risk for this vulnerable population. Future research should aim to establish specific recommendations for managing geriatric patients with ALCD, focusing on both short- and long-term outcomes.

**Authors contributions** Study conception and design: V.L., M.C., C.A.S., F.R. Acquisition of data: M.C., D.D.P., A.R., S.S., C.R., A.R., C.C., F.F. Analysis and interpretation of data: M.C., D.D.P., V.L., C.A.S., F.R. Drafting of the manuscript: V.L., C.A.S., F.R., M.C. Critical revision: V.L., M.C., C.A.S., D.D.P., A.R., S.S., N.dA., G.Q., C.R., C.F., A.R., C.C., F.F., S.A., F.R.

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**Data Availability** The data that support the findings of this study are available on request from the corresponding authors.

## Declarations

**Ethics** All procedures followed the ethical standards of the responsible committee on human experimentation (institutional and national), and with the Helsinki Declaration of 1964 and later versions.

**Competing interests** The authors declare no competing interests.

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