


Comparison of three frailty measures for 90-day outcomes of elderly patients undergoing elective abdominal surgery

Yanyan Yin,*† Li Jiang ‡ and Lixin Xue§

*Department of Intensive Care Medicine, Fuxing Hospital, Capital Medical University, Beijing, China

†Department of Urology and Metabolism, Beijing Rehabilitation Hospital, Capital Medical University, Beijing, China

‡Department of Critical Care Medicine, Xuanwu Hospital, Capital Medical University, Beijing, China and

§Department of General Surgery, Fuxing Hospital, Capital Medical University, Beijing, China

Key words

90-day mortality, clinical frailty scale, FRAIL, frailty index, long-term hospitalization.

Correspondence

Dr Li Jiang, Department of Critical Care Medicine, Xuanwu Hospital, Capital Medical University, No. 45 Changchun Street, Xicheng District, Beijing 100053, China. Email: jianglipaper@sina.com

Y. Yin MD; L. Jiang MD, DA; L. Xue MM.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

Accepted for publication 13 September 2020.

doi: 10.1111/ans.16357

Introduction

Worldwide, there were 962 million people aged 60 years or older in 2017. By 2030, this number is projected to grow to 1.4 billion. Nearly one in four people aged 60 years or older in the world in 2017 lived in China.¹ As the population ages, increasing numbers of older adults are undergoing surgery. Older surgical patients have higher rates of adverse health outcomes. In recent years, frailty measures have fast become important tools for predicting outcomes in the aging population.² A number of approaches to screen for and grade frailty have been proposed with no consensus on which one to use.³

In Suggestions from Chinese Experts on Preoperative Evaluation of Elderly Patients in 2015, the “FRAIL” scale was recommended, which is very concise and consists of only five items (fatigue, resistance, ambulation, illness, weight loss). The FRAIL questionnaire was first validated in a group of African Americans, aged 49 to 65 years old. Morley and colleagues found that the definition of

Abstract

Background: To compare the predictive power of three different evaluation methods of frailty for 90-day outcomes of elderly patients undergoing elective abdominal surgery.

Methods: A prospective cohort study was conducted with 194 patients and a postoperative follow-up period of 90 days. Preoperative frailty was evaluated using the five-item FRAIL questionnaire, 54-item frailty index (FI), and nine-item Clinical Frailty Scale (CFS). Receiver operating curves were used to compare the predictive ability for 90-day mortality and long-term hospitalization (LTH), and logistic regression was used to calculate odds ratios and 95% confidence intervals.

Results: The incidence rates of frailty assessed using FRAIL, FI, and CFS criteria were 43.8%, 32.5% and 36.6%, respectively. The 90-day mortality and LTH of frail patients were significantly higher than those of non-frail patients regardless of which criteria were used. The CFS and FI predicted 90-day mortality better than FRAIL (CFS versus FRAIL: $P = 0.005$; FI versus FRAIL: $P = 0.041$), and the CFS predicted LTH better than FRAIL ($P = 0.032$).

Conclusions: Patients diagnosed with frailty had significantly higher 90-day mortality and LTH regardless of which criteria were used. The CFS and FI were better predictors of 90-day mortality, and the CFS was a better predictor of LTH.

“frail” according to FRAIL at baseline was significantly associated with future activities of daily living difficulties and an increased risk of mortality.⁴ No previous studies have evaluated the FRAIL questionnaire in patients undergoing abdominal surgery. Another widely used approach is deficit accumulation, which was first proposed by Mitnitski *et al.*,⁵ according to which frailty is defined as the proportion of a large number of deficits (symptoms, signs, diseases or limitations in activity living) present at the time of evaluation, which is recognized as the frailty index (FI). The FI has been studied in various surgical procedures, such as urological,⁶ orthopaedic⁷ and vascular surgeries,⁸ to determine the risk of postoperative mortality, morbidity and readmission. Nevertheless, many experts in the ICU prefer the Clinical Frailty Scale (CFS),⁹ which mainly includes measures of activity ability and mental state and has nine levels.

Currently, no studies have compared the three measures and assessed their ability to predict the main adverse outcomes after elective abdominal surgery. Therefore, the primary aim of this

study was to compare the ability of these three measures to predict 90-day mortality and long-term hospitalization (LTH) after abdominal surgery, with the goal of identifying a more concise and effective method for the surgeon.

Methods

Study cohort

The present investigation was conducted as a prospective observational study. The study was approved by the Ethics Committee of Fuxing Hospital (affiliated with Capital Medical University) and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants included in the study. All patients were older than 65 years and admitted to the general surgery department, urological surgery department or gynaecology department of Fuxing Hospital between March 2017 and August 2019 for elective surgery. Patients suffering from hypothyroidism, Parkinson's disease or previous stroke and those with similar debilitating symptoms due to treatment with carbidopa/levodopa, donepezil or antidepressants were excluded. Patients with severe cognitive impairment or mental illness, those who refused to participate, those who were bedridden for long times, those who were completely incapable of participation or those who were unable to undergo frailty assessment were also excluded. A total of 194 patients were enrolled in the study, and all patients were followed for 90 days after the operation or until death.

Frailty measures

We selected three different methods to evaluate frailty. The first is the FRAIL scale,⁴ which is a simple questionnaire containing five factors (fatigue, resistance, ambulation, illness, weight loss); the presence of three or more factors is considered frail, the presence of one or two factors is considered pre-frail and no factors present is considered robust. The second is the FI, which is derived from comprehensive geriatric assessment parameters. This scale was first used by Krishnan *et al.*¹⁰ and contains several domains including motivation, health status, cognitive capacity, comorbidities, medicines, emotional state, mobility and functional independence of the patient. According to the scale, the deficits were given points. The total number of the denominator was 54, and all of the variables satisfied the five criteria in the study by Searle *et al.*¹¹ in our patient group. FI scores of the patients were generated after calculating the results by dividing total deficit points by total points for the evaluated deficits. A score of ≤ 0.25 is considered robust, a score of 0.25–0.4 is considered pre-frail and a score of > 0.4 is considered frail. The third method is the CFS, which had been used in a large number of studies on the CFS and prognosis of patients in emergency departments and ICUs in the past 2 years.^{9,12} The CFS has nine levels separated into three categories: levels 1–3 are considered robust, level 4 is considered pre-frail and levels 5–9 are considered frail. Forty-eight hours prior to surgery, the FRAIL, FI and CFS were assessed.

Data collection

Baseline demographic data were collected when the patients were admitted to the hospital. The patient's name, sex, age, height, weight, comorbidities and surgical site were recorded. The Charlson Comorbidity Index (CCI) was calculated. Assessments of the patients' FRAIL, FI and CFS scores were completed 48 h before the operation by two doctors. All patients completed a 90-day follow-up after the operation, and 90-day mortality was recorded as the primary outcome. Some patients remained in the hospital until follow-up and were defined as LTH patients, and LTH was considered the secondary outcome.

Statistical analysis

Statistical analysis was carried out using SPSS version 26.0. Quantitative data were compared using a nonpaired *t*-test or Mann-Whitney *U*-test as appropriate, and a chi-squared test or Fisher's exact test was used to assess differences in categorical data. A weighted kappa statistic was used to assess the agreement among the FRAIL, FI and CFS using a three-level risk categorization.¹³ Logistic regression analysis was performed to assess the association of each FRAIL, FI and CFS category with 90-day mortality and LTH after the operation. In the logistic regression, the covariates were age, sex, operative site and the CCI. The discriminative ability of the criteria to correctly predict mortality was assessed by calculating the area under the curve of the receiver operating characteristic (ROC) curve. A comparison of the ROC curves was performed using the method described by DeLong *et al.*¹⁴ A *P*-value of less than 0.05 was considered significant.

Results

Of the 223 patients older than 65 years old who underwent a planned surgery at our hospital, six patients suffered from hypothyroidism, Parkinson's disease or previous stroke; five patients had similar debilitating symptoms due to treatment with carbidopa/levodopa, donepezil or antidepressants; eight patients refused to participate in the study; four patients were unable to communicate and six patients were lost to follow-up. Thus, a total of 194 patients were ultimately enrolled in the study. The characteristics of the whole study cohort are shown in Table 1.

Comparison of the incidence of frailty

Frailty was diagnosed in 85 (43.8%), 63 (32.5%) and 71 (36.6%) patients using the FRAIL, FI and CFS classifications, respectively. The FRAIL criteria were more sensitive than the FI (43.8% versus 32.5%, *P* = 0.021), and no difference was found between the CFS and FI (36.6% versus 32.5%, *P* = 0.393) or between the FRAIL criteria and the CFS (43.8% versus 36.6%, *P* = 0.147) (Table 2). Among the three frailty measures, the highest level of agreement was found between the CFS and the FI (agreement = 80.9%; weighted kappa = 0.79, 95% CI 0.73–0.85) (Table 3).

Table 1 Characteristics of the patients at baseline

Characteristics	Total (n = 194)	FRAIL ≥ 3 (n = 85)	FI > 0.4 (n = 63)	CFS ≥ 5 (n = 71)
Anthropometrics/demographics				
Age (years), median (IQR)	79 (14)	82 (7)	82 (7)	82 (7)
Male, n (%)	90 (46.4)	33 (38.8)	21 (33.3)	26 (36.6)
BMI (kg/m ²), mean (SD)	23.8 (2.2)	23.9 (2.2)	23.8 (2.3)	23.7 (2.2)
CCI, mean (SD)	1.7 (1.2)	1.7 (1.3)	2.0 (1.5)	1.9 (1.4)
Main clinical features				
Operative site, n (%)				
Gastrointestinal	75 (38.7)	30 (35.3)	27 (42.9)	27 (38.0)
Cholecystic	53 (27.3)	29 (34.1)	20 (31.7)	25 (35.2)
Epityphlon	31 (16.0)	10 (11.8)	5 (7.9)	6 (8.5)
Urinary system	18 (9.3)	8 (9.4)	5 (7.9)	6 (8.5)
Gynaecology	17 (8.8)	8 (9.4)	6 (9.5)	7 (9.9)
Preoperative ADL score, median (IQR)	85 (20)	75 (10)	70 (15)	70 (15)
ASA score, median (IQR)	3 (0)	3 (0)	3 (0)	3 (0)
Operative time (hours), median (IQR)	1.8 (1.1)	1.8 (0.8)	1.8 (0.9)	1.9 (1.0)

ADL, activities of daily living; ASA, American Society of Anesthesiologists; BMI, body mass index; CCI, Charlson Comorbidity Index; CFS, Clinical Frailty Scale; FI, frailty index; IQR, interquartile range; SD, standard deviation.

Table 2 Frailty status according to the three different methods

Frailty methods	Robust, n (%)	Pre-frail, n (%)	Frail, n (%)
FRAIL	43 (22.2)	66 (34.0)	85 (43.8)
FI	75 (38.7)	56 (28.9)	63 (32.5)
CFS	66 (34.0)	57 (29.4)	71 (36.6)

CFS, Clinical Frailty Scale; FI, frailty index.

Table 3 Summary of agreement among frailty measures

Frailty methods comparison	Agreement (%)	Weighted kappa (95% CI)
FRAIL-FI	64.9	0.62 (0.54–0.69)
CFS-FI	80.9	0.79 (0.73–0.85)
FRAIL-CFS	74.2	0.71 (0.63–0.78)

CFS, Clinical Frailty Scale; CI, confidence interval; FI, frailty index.

Comparison of outcomes

90-day mortality

Nineteen patients died within 90 days after surgery. We compared 90-day mortality according to the three definitions, and 90-day mortality in the frail group was higher than that in the non-frail group regardless of the criteria used: FRAIL (15.3% versus 5.5%, $P = 0.023$), FI (23.8% versus 3.1%, $P < 0.001$) and CFS (22.5% versus 2.4%, $P < 0.001$) (Table 4). The 90-day mortality did not differ significantly between FRAIL and FI (15.3% versus 23.8%, $P = 0.191$), FRAIL and CFS (15.3% versus 22.5%, $P = 0.247$) or FI and CFS (23.8% versus 22.5%, $P = 0.861$).

Long-term hospitalization rate

In our study, at the 90-day follow-up, 19 remained hospitalized. The LTH rate was higher in frail patients than non-frail patients, regardless of which criteria were used: FRAIL (23.1% versus 1.0%, $P < 0.001$), FI (28.1% versus 2.5%, $P < 0.001$) or CFS (25.8% versus 1.8%, $P < 0.001$) (Table 4).

Table 4 Ninety-day mortality and LTH according to frailty stratified by the FRAIL, FI and CFS classification schemes

Frailty methods	Outcomes	Non-frail	Frail	<i>P</i> -value
FRAIL (%)	90-day mortality	5.5	15.3	0.023
	LTH rate	1.0	23.1	<0.001
FI (%)	90-day mortality	3.1	23.8	<0.001
	LTH rate	2.5	28.1	<0.001
CFS (%)	90-day mortality	2.4	22.5	<0.001
	LTH rate	1.8	25.8	<0.001

CFS, Clinical Frailty Scale; FI, frailty index; LTH, long-term hospitalization.

Predictive ability for 90-day mortality

Irrespective of which definition was used, frailty was independently associated with 90-day mortality even after adjusting for age, sex, operative site and CCI. For patients diagnosed with frailty by the FRAIL criteria, frailty was found to be an independent risk factor for 90-day mortality (odds ratio (OR) 2.32, 95% confidence interval (CI) 1.29–4.19, $P = 0.005$). When using the FI criteria, the OR is 1.08, and the 95% CI is 1.04–1.12; when using the CFS criteria, the OR is 3.70, and the 95% CI is 2.01–6.83 (Table 5). The corresponding area under the ROC curves for 90-day mortality for FRAIL, FI and CFS criteria was 0.723 ($P < 0.001$), 0.798 ($P < 0.001$) and 0.818 ($P < 0.001$), respectively. Compared with the FRAIL criteria, the CFS and FI had greater predictive ability for 90-day mortality (CFS versus FRAIL: $P = 0.005$; FI versus FRAIL: $P = 0.041$). However, there was no significant difference between CFS and FI ($P = 0.454$) (Fig. 1).

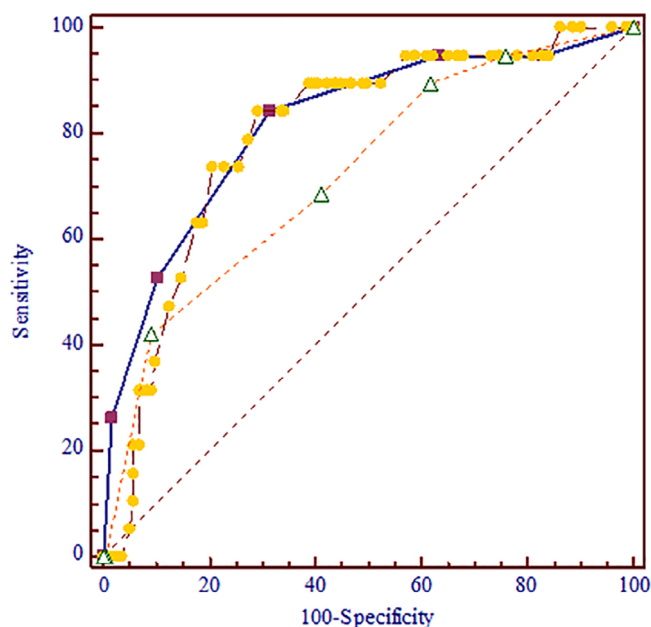
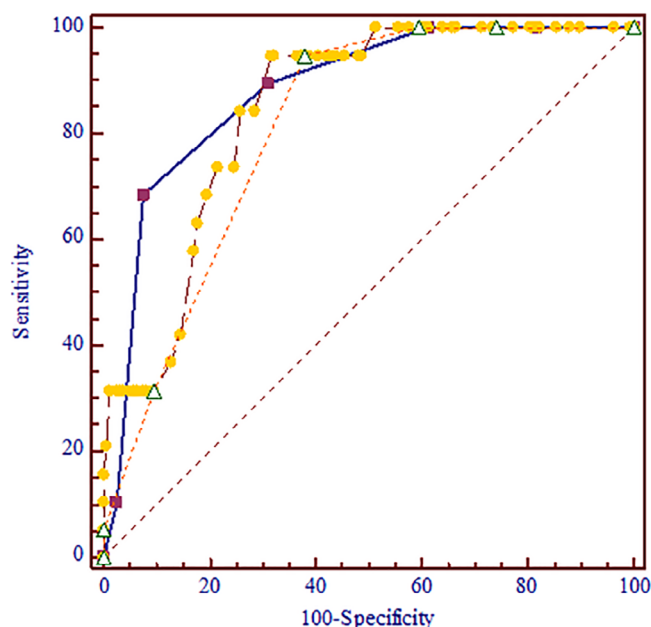
Predictive ability for long-term hospitalization

Irrespective of which definition was used, frailty was independently associated with LTH even after adjusting for the above covariates. For patients diagnosed with frailty by the FRAIL criteria, frailty was found to be an independent risk factor for LTH (OR: 4.31, 95% CI 1.95–9.50, $P < 0.001$) even after adjusting for the covariates. Similarly, when using the FI criteria, the OR is 1.10, and the 95% CI is 1.05–1.14; when using the CFS criteria, the OR is 9.52, and the 95% CI is 3.47–26.14 (Table 5). The area under the

Table 5 Association between frailty methods and outcomes at 90 days after surgery by multivariable logistic regression models

Frailty methods	Model	90-day mortality		LTH in hospital	
		Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value
FRAIL	Unadjusted	2.01 (1.28–3.17)	0.003	3.44 (1.84–6.45)	<0.001
	Adjusted†	2.32 (1.29–4.19)	0.005	4.31 (1.95–9.50)	<0.001
FI†	Unadjusted	1.06 (1.03–1.09)	<0.001	1.10 (1.05–1.14)	<0.001
	Adjusted‡	1.08 (1.04–1.12)	<0.001	1.10 (1.05–1.14)	<0.001
CFS	Unadjusted	2.87 (1.80–4.58)	<0.001	3.99 (2.24–7.11)	<0.001
	Adjusted‡	3.70 (2.01–6.83)	<0.001	9.52 (3.47–26.14)	<0.001

†Per 0.01 increase.
‡Adjusted for age, sex, operative site, and CCI.

**Fig 1.** Receiver operating characteristic curves of the preoperative FRAIL score, FI score and CFS score and comparison of the three scores with regard to their prediction of 90-day mortality. FRAIL: area under the curve 0.723 (95% CI 0.654–0.784, $P < 0.001$), FI: area under the curve 0.798 (95% CI 0.735–0.852, $P < 0.001$) and CFS: area under the curve 0.818 (95% CI 0.756–0.870, $P < 0.001$). (—), CFS (0.818); (---), FI (0.798); (· · ·), FRAIL (0.723).**Fig 2.** Receiver operating characteristic curves of the preoperative FRAIL score, FI score and CFS score and the comparison of the three scores with regard to their prediction of long-term hospitalization. FRAIL: area under the curve, 0.812 (95% CI 0.746–0.867, $P < 0.001$), FI: area under the curve, 0.846 (95% CI 0.785–0.896, $P < 0.001$) and CFS: area under the curve, 0.880 (95% CI 0.823–0.924, $P < 0.001$). (—), CFS (0.880); (---), FI (0.846); (· · ·), FRAIL (0.812).

ROC curves for LTH for the FRAIL, FI and CFS criteria was 0.812 ($P < 0.001$), 0.846 ($P < 0.001$) and 0.880 ($P < 0.001$), respectively. Compared with the FRAIL criteria, the CFS had greater predictive ability for LTH (CFS versus FRAIL: $P = 0.032$). However, there was no significant difference between the CFS and FI ($P = 0.266$) or between the FI and FRAIL criteria ($P = 0.156$) (Fig. 2).

Discussion

Within the literature, there is no consensus regarding how to evaluate the widely used term of frailty.¹⁵ Numerous studies have compared frailty and adverse outcomes in older surgical patients.¹⁶ Only a few studies have compared preoperative frailty models in predicting postoperative outcomes.¹⁷ To date and to the best of our knowledge, no study has yet performed a comparison of these three frailty evaluation methods (FRAIL, FI and CFS), especially in

China, in patients undergoing elective abdominal surgery. There are different ways to define and assess frailty, leading to prevalence rates ranging from 25% to 46%.¹⁸ In our study, frailty was diagnosed in 85 (43.8%) patients using the FRAIL classification. By the same method, Irina *et al.* found that the incidence of frailty in a Israeli group of medical patients was 40.2%,¹⁹ which is comparable to our findings. By the FI method, frailty occurred in 63 (32.5%) patients, which is similar to the findings reported by Krishnan *et al.* in their study, in which frailty occurred in 35% of patients, with a mean age of 81 years.¹⁰ By the CFS method, frailty occurred in 71 patients (36.6%), which is similar to the results reported by Goeteyn *et al.*; in that study, frailty occurred in 30.3% of patients, with a mean age of 74 years.²⁰ Our results showed that the FRAIL classification can identify more frail patients than the other two methods. The reason for this result may be because items reflecting social and cognitive deficits are not included in the FRAIL

questionnaire, while nine items are reflective of emotional and cognitive function in the FI method. When patients had no emotional or cognitive problems but reductions in activities of daily living, they were recognized as having frailty by the FRAIL method but not by the FI. While the CFS includes activity ability and mental state, it did not differ significantly from the FRAIL and the FI. Among the three frailty measures, the highest level of agreement was between the CFS and the FI. These differences and agreement may underlie the better performance of the CFS in predicting short-term adverse outcomes after surgery, which is comparable to the FI.

All three frailty measures were associated with a significantly increased risk of 90-day mortality and LTH. Compared with non-frail patients, 90-day mortality was significantly higher for frail patients using the FRAIL, FI and CFS. The 90-day mortality did not differ significantly among the three methods. The lowest 90-day mortality was predicted by the FRAIL method because the patients did not have emotional and cognitive disorders that might be recognized as frailty, but their outcomes were better than those of patients with physical and mental diseases. The CFS items included activity ability and mental state, which can describe the overall state of the patient. The FI items included activity ability, mental state, comorbidities and drugs, which can accurately identify frail patients but had poorer feasibility for surgeons. Therefore, in our study, the mortality rate of patients with frailty assessed by the FI was not higher than that of patients with frailty assessed by the CFS.

For the predictive ability of 90-day mortality using these three criteria, all were found to be significant predictors of increased 90-day mortality and LTH using multivariate analysis after adjusting for age, sex, operative site and CCI, which could explain why frailty remained an independent risk factor for 90-day mortality and LTH after surgery despite the above factors. These findings were identical to those reported in previous studies.^{21,22} However, there was no comparison of these three methods to determine which measure is more suitable for the Chinese population. In our study, we found that according to the area under the curve, compared with FRAIL, the CFS and the FI were better predictors of 90-day mortality. Compared with the FRAIL criteria, the CFS had greater predictive ability for LTH. At the beginning of the study, we suspected that the FI may be the best predictor for adverse outcomes, but ultimately, we found no difference between the CFS and FI. Mitnitski *et al.*²³ compared the ability of the FI, CFS and frailty phenotype to predict changes in cognition and mortality and showed that the frailty phenotype showed a weaker relationship with mortality than the FI and CFS. However, the FI and CFS did not significantly differ. This point is similar to ours – in our study, we also found that the CFS and the FI had the highest level of agreement and were comparable in their ability to predict 90-day mortality and LTH at 90 days post-operatively. Thus, the CFS is a simple and effective tool for predicting short-term postoperative adverse events. However, our results do not indicate that the CFS can completely replace the FI because the FI can summarize the overall state of patients in a way that can help further stratify pre-frail patients if necessary, provide advice about interventions to prevent, slow or reverse frailty in older patients and reduce or prevent

complications. Therefore, the FI has its own advantages in predicting the long-term outcomes of elderly patients.²⁴ At the same time, we should realize that each of the three indicators has its own advantages. The CFS and FRAIL method should be used in units such as emergency departments and intensive care units, while the FI is conducive to chronic disease management.

Conclusions

All three evaluation methods of frailty showed comparable associations with adverse outcomes of the patients who underwent elective abdominal surgery. Patients diagnosed with frailty had a significantly higher 90-day mortality and LTH regardless of which criteria were used. The CFS and FI were better predictors of 90-day mortality, and the CFS a better predictor of LTH. The CFS is a simple and effective tool for predicting short-term postoperative adverse events in elderly patients who undergo elective abdominal surgery.

Author Contributions

Yanyan Yin: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; visualization; writing-original draft. **Li Jiang:** Conceptualization; project administration; supervision; validation; writing-review and editing. **Lixin Xue:** Data curation; resources.

Conflicts of interest

None declared.

References

1. United Nations. *World Population Aging*. New York: United Nations, 2017.
2. Fagard K, Leonard S, Deschodt M *et al*. The impact of frailty on postoperative outcomes in individuals aged 65 and over undergoing elective surgery for colorectal cancer: a systematic review. *J. Geriatr. Oncol.* 2016; **7**: 479–91.
3. Bouillon K, Kivimaki M, Hamer M *et al*. Measures of frailty in population-based studies: an overview. *BMC Geriatr.* 2013; **13**: 64.
4. Morley JE, Malmstrom TK, Miller DK. A simple frailty questionnaire (FRAIL) predicts outcomes in middle aged African Americans. *J. Nutr. Health Aging* 2012; **16**: 601–8.
5. Mitnitski AB, Mogilner AJ, Rockwood K. Accumulation of deficits as a proxy measure of aging. *ScientificWorldJournal* 2001; **1**: 323–36.
6. Isharwal S, Johanning JM, Dwyer JG, Schmid KK, LaGrange CA. Pre-operative frailty predicts postoperative complications and mortality in urology patients. *World J. Urol.* 2017; **35**: 21–6.
7. Traven SA, Reeves RA, Slone HS, Walton ZJ. Frailty predicts medical complications, length of stay, readmission, and mortality in revision hip and knee arthroplasty. *J. Arthroplasty* 2019; **34**: 1412–6.
8. Ali TZ, Lehman EB, Aziz F. Modified frailty index can be used to predict adverse outcomes and mortality after lower extremity bypass surgery. *Ann. Vasc. Surg.* 2018; **46**: 168–77.
9. Muessig JM, Nia AM, Masyuk M *et al*. Clinical frailty scale (CFS) reliably stratifies octogenarians in German ICUs: a multicentre prospective cohort study. *BMC Geriatr.* 2018; **18**: 162.

10. Krishnan M, Beck S, Havelock W, Eeles E, Hubbard RE, Johansen A. Predicting outcome after hip fracture: using a frailty index to integrate comprehensive geriatric assessment results. *Age Ageing* 2014; **43**: 122–6.
11. Searle SD, Mitnitski A, Gahbauer EA, Gill TM, Rockwood K. A standard procedure for creating a frailty index. *BMC Geriatr*. 2008; **8**: 24.
12. Timbol CR, Baraniuk JN. Chronic fatigue syndrome in the emergency department. *Open Access Emerg. Med.* 2019; **11**: 15–28.
13. Fleiss J, Cohen J, Everitt B. *Statistical Methods for Rates and Proportions*. New York: John Wiley & Sons, 2003.
14. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics* 1988; **44**: 837–45.
15. Chen X, Mao G, Leng SX. Frailty syndrome: an overview. *Clin. Interv. Aging* 2014; **9**: 433–41.
16. Lin HS, Watts JN, Peel NM, Hubbard RE. Frailty and post-operative outcomes in older surgical patients: a systematic review. *BMC Geriatr*. 2016; **16**: 157.
17. Andreou A, Lasithiotakis K, Venianaki M *et al.* A comparison of two preoperative frailty models in predicting postoperative outcomes in geriatric general surgical patients. *World J. Surg.* 2018; **42**: 3897–902.
18. Handforth C, Clegg A, Young C *et al.* The prevalence and outcomes of frailty in older cancer patients: a systematic review. *Ann. Oncol.* 2015; **26**: 1091–101.
19. Irina G, Refaela C, Adi B *et al.* Low blood ALT activity and high FRAIL questionnaire scores correlate with increased mortality and with each other. A prospective study in the internal medicine department. *J. Clin. Med.* 2018; **7**: 386.
20. Goeteyn J, Evans LA, De Cleyn S *et al.* Frailty as a predictor of mortality in the elderly emergency general surgery patient. *Acta Chir. Belg.* 2017; **117**: 370–5.
21. Farhat JS, Velanovich V, Falvo AJ *et al.* Are the frail destined to fail? Frailty index as predictor of surgical morbidity and mortality in the elderly. *J. Trauma Acute Care Surg.* 2012; **72**: 1526–30.
22. Kim KI, Park KH, Koo KH, Han HS, Kim CH. Comprehensive geriatric assessment can predict postoperative morbidity and mortality in elderly patients undergoing elective surgery. *Arch. Gerontol. Geriatr.* 2013; **56**: 507–12.
23. Mitnitski A, Fallah N, Rockwood MR, Rockwood K. Transitions in cognitive status in relation to frailty in older adults: a comparison of three frailty measures. *J. Nutr. Health Aging* 2011; **15**: 863–7.
24. Harrison JK, Clegg A, Conroy SP, Young J. Managing frailty as a long-term condition. *Age Ageing* 2015; **44**: 732–5.