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The perioperative frailty index derived from the Chinese hospital information system: a validation study

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Abstract

Background There are various frailty assessment tools in the world, and the application choice of frailty assessment tools for the elderly perioperative population varies. It remains unclear which frailty assessment tool is more suitable for the perioperative population in China. To validate the Perioperative Frailty Index (FI-32) derived from the Chinese Hospital Information System by investigating the impact of preoperative frailty on postoperative outcomes, and ascertain the diagnostic value of FI-32 for predicting postoperative complications through comparing with the FRAIL scale and the modified Frailty Index (mFI-11).

Methods A prospective cohort study was conducted in a tertiary hospital. Elderly patients who were 60 years or older and underwent selective operation were included. The FI-32, FRAIL scale, and mFI-11 were assessed. Demographic, surgical variables and outcome variables were extracted from medical records. The data of readmission and mortality within 30 days and 90 days of surgery were ascertained by Telephone follow-up by professionally trained researchers. Multiple logistic regression was used to examine the association between frailty and complications. Receiver operating characteristic curves(ROC) were used to compare FI-32 with mFI-11 and FRAIL, to explore the predictive ability of frailty.

Results 335 patients qualified for the inclusion criteria and were enrolled in the study, and among them, 201 (60.0%) were females, and the Median(P_{25}, P_{75})age at surgery was 69 (65,74) years. The prevalence of frailty in the study population was 16.4% (assessed by FI-32). After adjusting for concomitant variables including demographic characteristics (such as gender, BMI, smoking, drinking, average monthly income and educational level) and surgical factors (such as surgical approach, surgical site, anesthesia method, operation time, intraoperative bleeding, and intraoperative fluid intake), there was a statistically significant association between frailty and the development of postoperative complication after surgery (*OR* = 3.051, 95% *CI*:1.460–6.378, *P* = 0.003). There were also significant differences in mortality within 30 days of surgery, the length of hospital stay (LOS) and the hospitalization costs. FI-32, FRAIL and mFI-11 showed a moderate predictive ability for postoperative complications, the Area Under Curves

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(AUCs) were 0.582, 0.566 and 0.531, respectively. With adjusting concomitant variables associated with postoperative complications, the AUCs of FI-32, FRAIL and mFI-11 in the adjusted prediction models were 0.824, 0.827 and 0.820 respectively.

Conclusions The FI-32 has a predictive effect on postoperative adverse outcomes in elderly Chinese patients. Compared to FRAIL and mFI-11, the FI-32 had the same ability to predict postoperative complications, and FI-32 can be extracted directly from HIS, which greatly saves the time for clinical medical staff to evaluate perioperative frailty.

Keywords Perioperative frailty index(FI-32), Frailty, Postoperative outcomes, Perioperative complication

Introduction

Frailty is defined as a non-specific state of increased vulnerability and decreased anti-stress ability caused by reductions in physiological reserves [1]. With the population aging, the number of elderly patients undergoing surgery is increasing [2]. According to previous studies, the prevalence of preoperative frailty in elderly patients is 10 -50.5% [3–8]. Previous studies have found that preoperative frailty was associated with increased mortality, postoperative complications, and prolonged length of stay [9–11]. American College of Surgeons National Surgical Quality Improvement Program and the American Geriatrics Society recommended that frailty should be included in the preoperative evaluation of elderly patients [12].

To date, a plethora of frailty assessment instruments are available globally and there are no universally recognized and unified assessment instruments for perioperative frailty at home and abroad, with the selection of these instruments differing for the perioperative period of the elderly and the prevalence of preoperative frailty in the elderly varies across different research instruments. For example, Arteaga AS et al. found that the prevalence of frailty in surgical emergency patients was 14.1%, 25%, 29.2% and 30.4% respectively by using four different frailty scales [FRAIL scale, Clinical Frailty Scale(CFS), TRST and Share-FI] [13]. Meanwhile, to promote rapid preoperative frailty screening, many researchers have developed a series of preoperative frailty screening instruments based on their medical data information system. Velanovich V et al. [14] constructed a modified Frailty Index (mFI-11) based on preoperative variables and surgical population in the American Surgical Quality Improvement Program (NSQIP) database. It has been widely used in the assessment of frailty in elderly patients undergoing perioperative surgery and has relatively good predictive efficacy [15–20]. Numerous systematic reviews conducted internationally have demonstrated that the mFI-11 is an effective tool for assessing preoperative frailty and predicting postoperative adverse outcomes in patients undergoing orthopedic, urological, head and neck tumor, and general surgical procedures [21–23]. In addition, Many foreign researchers have also developed frailty assessment tools based on their medical data information systems for a specific surgical disease, such as Emergency general surgery specific frailty index(EGSFI-15) [24], bariatric surgery specific frailty index (bFI) [25], etc.

In China, several studies have shown that the incidence of preoperative frailty in the elderly is generally at a high level, with a prevalence of 26.1-67.8% [4, 26–29]. Preoperative frailty is an independent risk factor for postoperative complications, prolonged hospital stay and mortality in elderly patients [11, 30]. At present, there is no frailty assessment tool for the Chinese medical databases modified or constructed in China. Most of the frailty screening tools used in China are from abroad, which are modified or constructed based on foreign medical databases and they would spend extra manpower and material resources on the assessment of frailty. All of these can hinder the popularization of preoperative frailty screening. Therefore, developing a perioperative frailty index for the Chinese medical information system is of great significance in promoting the development of preoperative frailty screening.

In the early stage of this study, based on the Chinese Hospital Information System (HIS), through the Literature Review method and the Expert Meeting method, we modified and formed a perioperative frailty index (FI-32) [31] following the guidelines of Searle et al. [32]. The objective of this study was to use the FI-32 for assessing preoperative frailty in elderly surgical patients, investigate the impact of preoperative frailty on postoperative outcomes (including complications, the length of hospital stay, 30-day readmission rate and mortality, as well as 90-day readmission rate and mortality), and additionally determine the diagnostic efficacy of preoperative frailty as determined by the FI-32 in predicting postoperative complications by comparing it with the FRAIL scale and mFI-11.

Methods

Study design and participants

This was a prospective cohort study of a convenience sample of patients undergoing selective operation at a tertiary hospital from February 2023 to May 2023. The inclusion criteria were as follows: (1) patients age≥60 years; (2) undergoing elective operation; (3) the

American Society of Anesthesiologists (ASA) score was I-III; (4) willingness to participate in this study and sign the informed consent form. The exclusion criteria were as follows: (1) patients with severe cognitive impairment, mental illness, dysaudia or communication obstacle; (2) patients without the ability to complete the survey; (3) patients with temporary cancellation of surgery, for example, on the day of the operation, the patient's condition suddenly worsened and the operation could not be performed on schedule. The data collection and the measurement of frailty were completed by trained researchers. The postoperative complications during the hospital stay were determined and recorded by non-study group clinicians and then collected by trained researchers. This study was approved with the permission of the Ethics Committee of Guangdong Provincial Hospital of Traditional Chinese Medicine(Ethics Document Batch number: BE2022-165). The reporting of this study conforms to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline [33]. This study was has been registered in the Chinese Clinical Trial Registry on May 17, 2023,(NO. ChiCTR2300071535).

In this study, the cohort study formula was used to calculate the sample size according to the main outcome indicators, with $\alpha=0.05$, $Z_\alpha = 1.96$, $\beta=0.10$, $Z_\beta = 1.282$. It was found in previous literature [34] that the incidence of postoperative complications in elderly patients with preoperative non-frailty was $P_0=25.5\%$, and the incidence of postoperative complications in elderly patients with preoperative frailty was $P_1=45.9\%$. The formula is used to calculate $N=111$, the sample size of the two groups is equal, and the loss rate of 20% is considered, so the total sample size is at least 267 cases.

$$N = \frac{\left(Z_\alpha\sqrt{2\bar{P}\bar{Q}} + Z_\beta\sqrt{P_0Q_0 + P_1Q_1}\right)}{(P_1 - P_0)^2}$$

Data collection

Demographic and surgical data

Extracting demographic and surgical data from the electronic medical records, (1) demographics: age, gender, body mass index (BMI), smoking and drinking, Combined chronic diseases(refers to the coexistence of 2 or more chronic conditions [35]), polypharmacy (defined as concurrent five or more drug usage [36]), average monthly income, education level; (2) surgical variables: American Society of Anesthesiologists (ASA) score, surgical approach, surgical site, anesthesia method, operation time (refers to the time from the beginning to the end of the operation), intraoperative bleeding and intraoperative fluid intake.

Assessment of frailty

In the early stage of this study, we extracted 32 items from the Chinese Hospital Information System (HIS) based on the items pool consisting of CSHA-FI [37] and the 50-variable FI [38]. We modified and formed an FI-32 following the guidelines of Searle et al. [32] through the Expert Meeting method. 32 items included in the FI-32 cover the following domains: patient comorbidities, daily activity capabilities and physical function, nutritional status and laboratory examination. Each selected item is assigned a value ranging from 0 to 1. The frailty index (FI) was calculated as FI=cumulative score of health defects / total score of health variables ($n=32$). According to Searle et al.'s [32] FI definition, frailty is defined as FI value≥0.25, that is, patients who have an FI-32 score of 8 or more are considered frail (shown in Supplementary Table 1 for details).

In addition, researchers also performed a frailty assessment using the FRAIL scale and the mFI-11. The FRAIL scale [39] contains 5 questions, which is one of the frailty assessment tools for elderly patients recommended by the Chinese Expert Consensus on Frailty Assessment and Intervention in Elderly Patients [40]. It includes fatigue, endurance, walking ability, multi-disease coexistence, and weight loss, each item is 1 point, scores≥3 are classified as frailty. Of the 11 items included in the mFI-11 [14](shown in Supplementary Table 2), 10 are related to comorbid conditions, and 1 is related to the patient's functional status. Individuals who have an mFI score of 3 or more are considered frail.

Outcome variables

Our primary outcome measure was postoperative complications. The postoperative complications were defined as one or more postoperative complications occurred during hospitalization [41], including postoperative fever (temperature≥38℃), postoperative infections (pulmonary infections, urinary tract infections, incision infection), cardiovascular complications (heart failure, arrhythmia, myocardial infarction), respiratory failure, delirium, deep vein thrombosis (DVT), hypoalbuminemia, electrolyte disturbance (including hypernatremia, hyponatremia, hypokalemia, hyperkalemia), postoperative bleeding, postoperative anemia. Secondary outcome measures were the ICU admission after surgery, readmission and mortality within 30 days of surgery, readmission and mortality within 90 days of surgery and the length of hospital stay (LOS). In this study, all objective outcome variables were collected from the electronic medical record. The data of readmission and mortality within 30 days and 90 days of surgery were ascertained by Telephone follow-up by professionally trained researchers (MxC, YdZ).

Statistical analysis

The count data was summarized with frequencies and percentages, and group comparison using the χ^2 test or Fisher exact probability method. Non-normally distributed measurement data was summarized using $M(P_{25}, P_{75})$, group comparison using Mann-Whitney U test. Univariate logistic regression analysis was used to identify the significant variables of postoperative complications and variables with a $P \leq 0.10$ were defined as concomitant variables associated with postoperative complications [24]. Multivariate logistic regression analysis, adjusted by concomitant variables associated with postoperative complications, was used to analyze the relationship between preoperative frailty and postoperative complications, calculating the odds ratio (OR) and its 95% confidence interval (CI). To determine the predictive value of FI-32 for postoperative complications, receiver operating characteristic(ROC) curve analysis was used to compare FI-32 with mFI-11 and FRAIL. Binary logistic regression analysis, adjusted by concomitant variables associated with postoperative complications, was performed to establish the diagnostic models of FI-32, mFI-11 and FRAIL, and the diagnostic efficiency was analyzed using ROC curves and calculating the area under the ROC curve (AUC). The DeLong test was used to analyze the difference in AUCs between FI-32, mFI-11 and FRAIL. $P<0.05$ was considered statistically significant. Statistical analysis was performed using SPSS version 26.0 (IBM Corporation, Armonk, NY)and MedCalc software version 22.0 (MedCalc Software, Ostend, Belgium).

Results

Baseline characteristics

335 patients qualified for the inclusion criteria and were enrolled in the study. Among these patients, 201 (60.0%) were females, and the Median (P_{25}, P_{75}) age at surgery was 69 (65,74) years. The prevalence of frailty in the study population was 16.4%(FI-32), 13.1%(FRAIL) and 10.1%(mFI-11), respectively. Significant differences were observed between the frail and non-frail groups concerning age, gender, combined chronic diseases, polypharmacy and surgical site ($P<0.05$ for all). The baseline characteristics of the study population are shown in Table 1.

Preoperative frailty and postoperative outcomes

The association between frailty and postoperative outcomes is shown in Table 2. In this study, 46.6% (156/335) of patients had postoperative complications. Among them, hypoproteinemia, electrolyte disturbance and postoperative fever were the main ones, and the distribution of complications in the non-frail and frail groups was shown in Supplementary Table 3. The incidence of postoperative complications in non-frail and frail groups was 43.2%(121/280) and 63.6%(35/55), respectively, and the between-group differences were statistically significant ($P<0.05$). At the same time, the result evidenced a statistically significant difference between non-frail and frail groups in terms of mortality within 30 days of surgery, LOS (the median: 8 and 12 days, respectively, $P<0.001$), and hospitalization costs (the median: 31365.25 and 39264.47, respectively, $P=0.003$). However, there were non-significant differences in ICU admission, 30-day readmissions, 90-day readmissions and mortality between the no-frail and frail groups ($P>0.05$).

Univariate logistic regression analysis of postoperative complications revealed that gender, BMI, smoking, drinking, average monthly income and educational level, surgical approach, surgical site, anesthesia method, operation time, intraoperative bleeding, and intraoperative fluid intake were the concomitant variables associated with postoperative complications ($P \leq 0.10$ for all) (shown in Supplementary Table 4). In addition, univariate and multivariate logistic regression analyses were used to analyze the relationship between preoperative frailty(assessed by FI-32) and postoperative complications. Univariate logistic analysis showed that the preoperative frailty was associated with postoperative complications ($OR=2.300$, 95% CI:1.264–4.182) (Model 1). On multivariate logistic regression, With adjusting concomitant variables including demographic characteristics and surgical factors, the adjusted analysis results showed that preoperative frailty was also found to be a significant predictor of postoperative complications, and it was associated with a significantly higher risk of postoperative complications($P<0.05$ for all models) (shown in Table 3). As with the above methods, we used univariate and multivariate logistic regression analysis and corrected for relevant covariates to analyze the effect of preoperative frailty on hypoproteinemia. The adjusted analysis results showed that preoperative frailty was also found to be a significant predictor of hypoproteinemia, and it was associated with a significantly higher risk of hypoproteinemia ($P<0.05$ for all models) (shown in Table 4).

Predictive ability of perioperative frailty index

To evaluate the predictive ability of FI-32 for postoperative complications, this study compared it with FRAIL and mFI-11 by ROC curve analysis. The AUC for FI-32 was 0.582 (95% CI: 0.527–0.635) and it could predict the occurrence of postoperative complications (Fig. 1). The AUCs for FRAIL and mFI-11were 0.566(95% CI: 0.511–0.620) and 0.531(95% CI: 0.478–0.586), respectively (Fig. 1). The results of the pairwise comparison of AUCs for the three frailty assessment instruments indicated that there was no statistically significant difference ($P>0.05$)(Table 5). Further, we drew the ROC of the adjusted prediction of FI-32, FRAIL and mFI-11

Table 1 Comparison of baseline characteristics between frail and non-frail participants(FI-32)

Variable	Total (*n* = 335)	Non-frail(*n* = 280)	Frail(*n* = 55)	*P* value
Age[$M(P_{25}, P_{75})$]	69(65,74)	69(65,73)	73(67,77)	0.001
Gender(n,%)				0.001
Male	134(40.0)	101(36.1)	33(60.0)	
Female	201(60.0)	179(63.9)	22(40.0)	
BMI[$M(P_{25}, P_{75})$]	24.3(22.22,26.93)	24.36(22.22,26.93)	24.21(21.74,27.24)	0.492
Smoking(n,%)				0.18
No	253(75.5)	219(78.2)	34(61.8)	
Yes	44(13.1)	31(11.1)	13(23.6)	
Have quit smoking	38(11.3)	30(10.7)	8(14.5)	
Drinking(n,%)				0.164
No	284(84.8)	242(86.4)	42(76.4)	
Yes	20(6.0)	15(5.4)	5(9.1)	
Have quit drinking	31(9.3)	23(8.2)	8(14.5)	
Combined chronic diseases(≥2)(n,%)				<0.001
No	250(74.6)	221(78.9)	29(52.7)	
Yes	85(25.4)	59(21.1)	26(47.3)	
polypharmacy(≥5)(n,%)				<0.001
No	308(91.9)	265(94.6)	43(78.2)	
Yes	27(8.1)	15(5.4)	12(21.8)	
Average monthly income(n,%)				0.092
<2500	100(29.9)	87(31.1)	13(23.6)	
2500 ~ 4999	156(46.6)	132(47.1)	24(43.6)	
5000 ~ 7499	66(19.7)	51(18.2)	15(27.3)	
≥ 7500	13(3.9)	10(3.6)	3(5.5)	
Educational level(n,%)				0.865
Primary and below	154(46.0)	129(46.1)	25(45.5)	
Junior high school	90(26.9)	76(27.1)	14(25.5)	
High or secondary school	65(19.4)	53(18.9)	12(21.8)	
College degree or above	26(7.8)	22(7.9)	4(7.3)	
ASA score(n,%)				0.076
I	5(1.5)	3(1.1)	2(3.6)	
II	241(71.9)	209(74.6)	32(58.2)	
III	89(26.6)	68(24.3)	21(38.2)	
Surgical approach(n,%)				0.746
Laparoscopic	97(29.0)	80(28.6)	17(30.9)	
Open	238(71.0)	200(71.4)	38(69.1)	
Surgical Site(n,%)				0.049
Abdomen	90(26.9)	75(26.8)	15(27.3)	
Lower back	104(31.0)	80(28.6)	24(43.6)	
Limbs	141(42.1)	125(44.6)	16(29.1)	
Anesthesia method(n,%)				0.155
local	16(4.8)	11(3.9)	5(9.1)	
general	319(95.2)	269(96.1)	50(90.9)	
Operation time[$M(P_{25}, P_{75})$, min]	130(96,180)	129(96,174.25)	130(96,203)	0.695
Intraoperative bleeding[$M(P_{25}, P_{75})$, ml]	50(30,100)	50(30, 100)	50(20, 100)	0.842
Intraoperative fluid intake[$M(P_{25}, P_{75})$, ml]	1000(500,1000)	1000(500,1000)	1000(500,1000)	0.623

Notes M : median; P_{25}: 25th percentile ; P_{75}: 75th percentile. ASA: American Society of Anesthesiologists

and analyzed the performance of the adjusted prediction models (Fig. 2). The results showed that the AUCs of FI-32, FRAIL and mFI-11 in the adjusted prediction models was 0.824 (95% *CI*:0.779–0.863), 0.827 (95% *CI*:0.783–0.866) and 0.820 (95% *CI*:0.775–0.860), respectively, which were significantly higher than the AUCs of the three predicted separately. There was no statistically significant difference in the pairwise comparison

Table 2 Comparison of postoperative outcomes between non-frailty and frailty patients(FI-32)

Variable	Total($n=335$)	Non-frail($n=280$)	Frail($n=55$)	*P* value
Postoperative complications(n,%)				0.007
No	179(53.4)	159(56.8)	20(36.4)	
Yes(≥1)	156((46.6)	121(43.2)	35(63.6)	
ICU admission after surgery (n,%)				0.058
No	329(98.2)	277(98.9)	52(94.5)	
Yes	6(1.8)	3(1.1)	3(5.5)	
Readmission within 30 days of surgery (n,%)				0.102
No	316(94.3)	267	49	
Yes	19(5.7)	13	6	
Mortality within 30 days of surgery (n,%)				0.027*
No	333(99.4)	280(100.0)	53(96.4)	
Yes	2(0.6)	0	2(3.6)	
Readmission within 90 days of surgery (n,%)				0.334
No	316(94.3)	266(95.0)	50(90.9)	
Yes	19(5.7)	14(5.0)	5(9.1)	
Mortality within 90 days of surgery(n,%)				0.164*
No	334(99.7)	280(100.0)	54(98.2)	
Yes	1(0.3)	0	1(1.8)	
Length of Hospital Stay[$M(P_{25}, P_{75})$,d]	9(7,12)	8(7,11)	12(9,15)	<0.001
Hospitalization costs [$M(P_{25}, P_{75})$,¥]	32245.13 (27436.43,61242.69)	31365.25 (25920.84,57186.66)	39264.47(30924.81,76797.37)	0.003

Notes * indicates: Fisher exact probability method; d: days; ¥: Yuan. ICU: Intensive Care Unit

Table 3 Association between preoperative frailty and postoperative complications

	Postoperative complications(≥1)				
	β	SE	Wald χ2	*P* value	OR(95%CI)
Model 1	0.833	0.305	7.446	0.006	2.300(1.264,4.182)
Model 2	0.720	0.332	4.719	0.030	2.055(1.073,3.937)
Model 3	1.116	0.376	8.795	0.003	3.051(1.460,6.378)

Notes Model 1: unadjusted;

Model 2: adjusted by demographic characteristics (gender, BMI, smoking, drinking, average monthly income, and educational level)

Model 3: adjusted for all covariates [demographic characteristics+surgical factors(surgical approach, surgical site, anesthesia method, operation time, intraoperative bleeding, intraoperative fluid intake)]

Table 4 Association between preoperative frailty and hypoalbuminemia

	β	SE	Wald χ2	*P* value	OR(95%CI)
Model 1	0.840	0.299	7.910	0.005	2.317(1.290,4.160)
Model 2	0.745	0.322	5.337	0.021	2.106(1.120,3.961)
Model 3	1.132	0.368	9.465	0.002	3.102(1.508,6.381)

Notes Model 1: unadjusted;

Model 2: adjusted by demographic characteristics (gender, BMI, smoking, drinking, average monthly income, and educational level)

Model 3: adjusted for all covariates[demographic characteristics+surgical factors(surgical approach, surgical site, anesthesia method, operation time, intraoperative bleeding, intraoperative fluid intake)]

of AUCs in the adjusted prediction models for the three frailty assessment instruments($P>0.05$). The comparisons of AUCs for three frailty assessment instruments in predicting postoperative complications are presented in Figs. 1 and 2; Table 5.

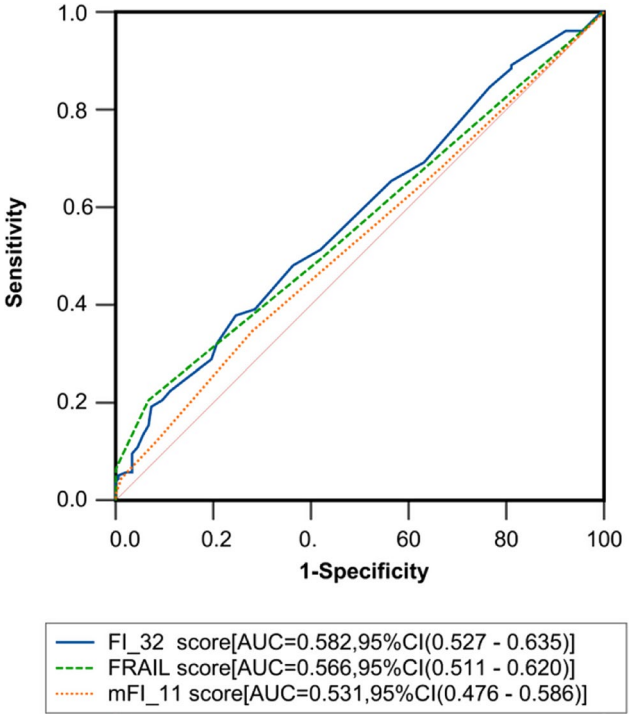

Fig. 1 An ROC curve of FI-32, FRAIL and mFI-11 predicting the postoperative complications

Discussion

To our knowledge, this is the first study to develop and validate perioperative frailty index based on the Chinese HIS. In our study, we found that the FI-32 was associated

Table 5 Results of pairwise comparison of AUCs between three frailty assessment instruments

Frailty assessment instruments	Z	*P*	Z*	*P**
FRAIL vs. mFI_11	0.995	0.3197	0.850	0.3951
FRAIL vs. FI-32	0.506	0.6130	0.443	0.6579
mFI_11 vs. FI-32	1.788	0.0738	0.404	0.6864

Notes: * indicates: adjusted by demographic characteristic(gender, BMI, smoking, drinking, average monthly income and educational level)+ surgical factors (surgical approach, anesthesia method, operation time, intraoperative bleeding, total intraoperative intake)]

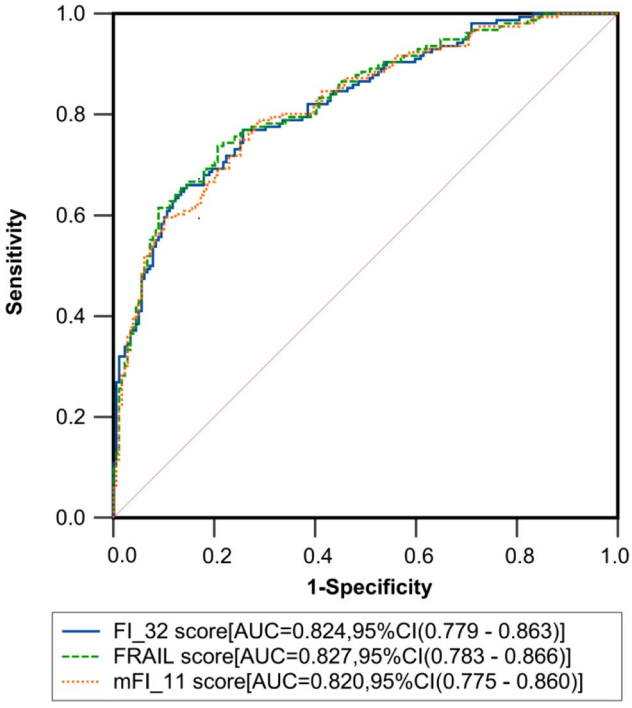

Fig. 2 An ROC curve of the adjusted prediction models of FI-32, FRAIL and mFI-11 predicting the postoperative complications. Notes: * indicates: adjusted by demographic characteristic (gender, BMI, smoking, drinking, average monthly income and educational level) + surgical factors (surgical approach, anesthesia method, operation time, intraoperative bleeding, total intraoperative intake)

with postoperative complications, and it had a predictive effect on postoperative complications. Furthermore, compared to FRAIL and mFI-11, FI-32 had the same ability to predict postoperative complications, regardless of whether the concomitant variables of postoperative complications were adjusted or not.

As the population aging, more than 50% of elderly patients are in a frailty state during the perioperative period [42]. This study demonstrated that frailty is common in Chinese elderly patients undergoing surgery, with preoperative frailty(assessed by FI-32) prevalence of 16.4%, which was comparable to that reported by Han XYA et al.(16.8%) [43]. However, this prevalence is lower than that reported among the elderly patients of thoracic and abdominal surgery in China (range, 26.2-43.2%) [4, 5], which may resulted in the different study populations and frailty assessment instruments.

In this study, we explored the association between preoperative frailty (assessed by FI-32) and postoperative outcomes after surgery in Chinese elderly patients. After adjusting for concomitant variables such as demographic characteristics and surgical factors, the results showed that the risk of postoperative complications in elderly patients in the frailty group was 3.051 times that in the non-frailty group, indicating that preoperative frailty was an independent risk factor of postoperative complications in elderly Chinese patients undergoing surgery (*OR*=3.051, 95% *CI*:1.460–6.378, *P*=0.003). Our results also found that the risk of hypoalbuminemia in elderly patients in the frailty group was 3.102 times that in the non-frailty group, indicating that preoperative frailty was an independent risk factor of hypoalbuminemia in elderly Chinese patients undergoing surgery (*OR*=3.102, 95% *CI*:1.508–6.381, *P*=0.002). The above results were consistent with those of previous studies [8, 43]. In addition, frail patients had a significantly increased incidence of mortality within 30 days of surgery compared to non-frail patients, and preoperative frailty could prolong the length of hospital stay and increase hospitalization costs($P<0.05$ for all). Frailty is a clinical syndrome characterized by a reduction in physiological reserves, resulting in patients being more vulnerable to adverse health outcomes [1]. Consistent with our findings, previous studies had also found that frail patients were at increased risk for postoperative complications and 30-day mortality [41, 44, 45]. As a strong external stressor, surgery is prone to increase the energy loss of the elderly after surgery, increase the level of inflammatory factors in the body and hemodynamic fluctuations, resulting in an increase in the utilization rate and exudation rate of albumin in the body, further aggravating the frailty of patients, and thus increasing the risk of postoperative complications and hypoproteinemia [46, 47]. In China, LEI J G.et al. found that frailty was an independent risk factor for prolonged length of hospital stay after laparoscopy in the elderly, the risk of prolonged length of hospital stay in frailty elderly patients was 5.26 times that in non-frailty elderly patients [48]. Lal S et al. [49] also demonstrated that frailty was an independent risk factor for the length of hospital stay post-cardiac surgery. Preoperative frailty also increases the risk of postoperative complications and death in elderly patients, thereby increasing the socioeconomic burden of patients and healthcare resource consumption [50, 51]. This study provides sufficient evidence that preoperative frailty was an independent risk factor or a strong predictor of adverse postoperative outcomes in elderly patients. These findings indicated that it is necessary and important to evaluate the frailty of elderly patients before operation. Therefore, we recommend that

healthcare workers should actively conduct preoperative frailty assessment, which benefits healthcare workers in identifying the frailty state and frailty risk factors of elderly patients early, and actively carry out effective preoperative frailty management to promote the rapid recovery and prognosis of elderly patients.

In addition, our study compared FI-32 with mFI-11 and FRAIL to evaluate the predictive ability of FI-32 for postoperative complications. The mFI-11 has been widely used in perioperative frailty evaluation. Prior studies have validated the ability of the mFI-11 in predicting risk for postoperative complications, it was an independent predictor for the development of any type of postoperative complications [44, 52, 53]. Previous studies have also explored the effect of preoperative frailty measured by the FRAIL on postoperative complications, indicating that it was associated with the risk of postoperative complications and it could effectively predict the postoperative adverse outcomes of patients [54, 55]. In this study, FI-32, FRAIL and mFI-11 showed a moderate predictive ability for postoperative complications before adjusted, the AUCs for them were 0.582 (95% *CI*: 0.527–0.635), 0.566(95% *CI*: 0.511–0.620) and 0.531(95% *CI*: 0.478–0.586), respectively. However, the AUCs of FI-32, FRAIL and mFI-11 in the adjusted prediction models were 0.824 (95% *CI*:0.779–0.863), 0.827 (95% *CI*:0.783–0.866) and 0.820 (95% *CI*:0.775–0.860), respectively, which were significantly higher than the AUCs of the three predicted separately. This may be because the adjusted diagnostic models controlled for concomitant variables associated with postoperative complications. The results of univariate logistic regression analysis in this study showed that the occurrence of postoperative complications in the elderly was affected by many factors, such as gender, BMI, smoking, drinking, operation time, type of surgery, anesthesia method, intraoperative bleeding, et al. Previous studies had found that gender, underweight BMI, smoking, operation time, type of surgery, anesthesia method, and intraoperative bleeding were associated with increased risks of developing a postoperative complication, which were risk factors for postoperative complications [56–59]. In this study, we corrected the relevant concomitant variables and reduced the impact of concomitant variables on the predictive performance of the three frailty assessment instruments for postoperative complications. Therefore, the prediction probability of the corrected model is higher and the AUC value is larger.

What's more notable is whether predicting separately or the adjusted prediction models, our results proved that FI-32 had the same ability to predict postoperative complications in Chinese elderly patients compared to the other two frailty assessment instruments, there was no statistically significant difference in their AUCs pairwise comparison($P>0.05$). A Recommendations for Preoperative Management suggested that frailty is a multi-dimensional state, which is affected by psychological, physiological and social factors; it also believed that compared with the frailty assessment tool of single-dimensional and single-domain variables, the frailty index covering multiple dimensions and multiple neighborhood variables is more accurate in the assessment of frailty [60]. In this study, compared to the other two frailty assessment instruments, although non-significant, the FI-32 may have a relative advantage in predicting postoperative complications in Chinese elderly patients. The FI-32 encompasses various dimensions, including comorbidities, daily activity capabilities, physical function, nutrition, laboratory examination and sleeping, indicating that the comprehensive prediction performance is relatively good. And it accurately quantifies the degree of frailty in patients numerically. Meanwhile, FI-32 is derived from the Chinese HIS and modified for the elderly surgical population in China. The information variables included in it can be retrieved and extracted in HIS, and the frailty index can be automatically generated according to the system settings, so there is no need for additional preoperative evaluation of elderly patients, which saves the evaluation time of clinical medical staff to the greatest extent and is convenient. Overall, the FI-32 is a multi-dimensional frailty assessment instrument that has good predictive value for postoperative complications and it can be widely used in preoperative screening of frailty in the elderly in China.

There are several noteworthy strengths to this study. First, this is the first study to explore the association between frailty measured by FI-32 modified and constructed according to the Chinese hospital information system and postoperative adverse outcomes in elderly Chinese patients. Second, we compared the predictive value of FI-32 with mFI-11 and FRAIL for postoperative complications, which ensured the accuracy of this study. Lastly, controlling concomitant variables such as demographic characteristics and surgical factors, reduced any type of bias. There are some limitations in our study. Firstly, our study was a single-center prospective cohort study, which may lead to selective bias and lack of representativeness in the study population. Secondly, we did not perform a detailed stratified analysis of the type of surgery and disease as influencing factors. Finally, except for hypoproteinemia, our sample size may have limited the ability to detect significant associations between frailty and a specific complication. In the future, we will conduct a multi-center, randomized, prospective trial in a larger sample size and more homogeneous cohort to verify the conclusions of this study, and study the predictive ability of FI-32 for frailty and postoperative adverse outcomes in specific elderly patients undergoing surgery.

Conclusions

The FI-32 has a predictive effect on postoperative adverse outcomes in elderly Chinese patients before surgery. Compared to FRAIL and mFI-11, the FI-32 had the same ability to predict postoperative complications, regardless of whether the concomitant variables of postoperative complications were adjusted or not. In addition, FI-32 can be extracted directly from HIS, which greatly saves the time for clinical medical staff to evaluate perioperative frailty.

Abbreviations

FI-32	Perioperative Frailty Index
mFI-11	The modified Frailty Index
ICU	Intensive Care Unit
LOS	The length of hospital stay
ROC	Receiver operating characteristic curves
OR	Odds Ratio
95%CI	95% Confidence Interval
AUC	The Area Under Curve
CFS	Clinical Frailty Scale
NSQIP	National Surgical Quality Improvement Program
HIS	Hospital Information System
CSHA-FI	Canadian Study of Health and Aging Frailty Index
BMI	Body mass index
ASA	American Society of Anesthesiologists

Supplementary Information

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Supplementary Material 1

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Author contributions

Lin Wei was responsible for design of the study and critically revising the draft. Muxin Chen, Hao Laing were responsible for the data analysis and drafting and revising of the manuscript. Lijun Lin, Ping Tan, Yiyin Xu, Shaohua Chen, Hongyun Chen were responsible for data collection. Muxin Chen, Yidi Zhao, Ruotong Liao and Jiamin Fang were responsible for data cleaning. Muxin Chen and Hao Liang contributed equally to this work.

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Data availability

The datasets generated and analysed during the current study are not publicly available because participants did not consent to the public release of their data. Further information about the analysis and supportive data is available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved with the permission of the Ethics Committee of Guangdong Provincial Hospital of Traditional Chinese Medicine (Ethics Document Batch number: BE2022-165). All subjects participated in the study voluntarily and signed informed consent.

Consent for publication

This manuscript contains information or images that could not lead to identification of a study participant, so it is not applicable.

Competing interests

The authors declare no competing interests.

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