Clinical Interventions in Aging

Dovepress
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ORIGINAL RESEARCH

Development and Validation of Nomogram to Predict Frailty for Older Patients Undergoing Abdominal Surgery

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Background: Frailty is a critical geriatric syndrome associated with adverse surgical outcomes, yet preoperative risk prediction models for older adults undergoing abdominal surgery remain underdeveloped. This study aimed to identify frailty risk factors and establish a predictive nomogram in this population.

Methods: We enrolled 790 older patients undergoing abdominal surgery at Hunan Provincial People's Hospital from February 2022 to September 2022. Frailty was assessed using the Tilburg Frailty Index. Univariate analysis, LASSO regression and multivariate analysis were used in turn to identify independent risk factors for frailty. The nomogram was developed based on the independent risk factors. The sample was randomly divided into a test group (75%) and a validation group (25%). The area under the curve (AUC) of the receiver operating characteristic (ROC) was calculated to assess the predictive performance of the nomogram.

Results: The prevalence of frailty among older patients undergoing abdominal surgery was 74.18%. Eight independent risk factors were identified: advanced age (OR=1.32), lower BMI (OR=1.28), limited education (OR=1.45), laparoscopy (OR=1.67), tumor comorbidity (OR=2.01), diabetes (OR=1.89), antihyperlipidemic drug use (OR=1.53), and elevated interleukin-6 (OR=1.76). The nomogram demonstrated acceptable discrimination, with AUCs of 0.748 (the test group) and 0.707 (the validation group).

Conclusion: Our findings demonstrate a nomogram to predict the probability of frailty for older patients undergoing abdominal with acceptable predictive performance. The nomogram is helpful in guiding further targeted and effective intervention and prevention efforts to decrease frailty and improve health outcomes.

Keywords: frailty assessment, risk assessment tool, older adults, abdominal surgery, China

Introduction

Frailty, an age-associated syndrome, is characterized by a multisystem (involving neurological, metabolic-endocrine, and immune systems) impairment of homeostasis, primarily manifesting as sarcopenia in older adults. This condition leads to reduced physiological reserve, diminished stress resilience, and a nonspecific vulnerability state, representing one of the most clinically significant geriatric syndromes. The prevalence of frailty is notably high among older populations. A global systematic review and meta-analysis[1] reported a frailty prevalence of 13.60% in community-dwelling adults aged ≥60 years. In China, frailty affects 10.00% of community-dwelling adults aged ≥60 years.[2–4] A study by Wei et al[5] involving 279 hospitalized older patients in Shanghai tertiary hospitals (surgical, medical, and geriatric departments) revealed a frailty prevalence of 34.30%. These findings highlight that hospitalized older adults exhibit higher frailty rates than their community counterparts, underscoring the need for heightened clinical attention to frailty in hospitalized older adults.

Received: 9 June 2025
Accepted: 1 December 2025
Published: 6 December 2025

Frailty arises from the cumulative decline of physiological and psychological functions, exacerbating vulnerability and impairing stress response. Minor stressors (eg, wound infections, falls, or minor surgeries) may trigger disproportionate health deterioration. Surgical interventions, inherently traumatic and stress-inducing,[6] further amplify this risk. Research[7] indicates that older surgical patients face elevated frailty risks, with prevalence reaching 30.00–50.00% in major surgeries. Frailty independently predicts postoperative complications and mortality, demonstrating high sensitivity and specificity, beyond age and the American Society of Anesthesiologists (ASA) physical status classification. Notably, abdominal surgeries—owing to the anatomical complexity of hepatobiliary and gastrointestinal systems, diverse pathophysiology, and significant surgical trauma—are associated with higher postoperative frailty rates (36.50%) compared to other procedures.[8,9]

Preoperative frailty prediction is thus critical for older patients undergoing abdominal surgery. Clinicians can leverage frailty screening to identify high-risk individuals, implement targeted interventions to mitigate or reverse frailty progression, and reduce adverse outcomes through primary, secondary, and tertiary prevention strategies. Establishing preoperative frailty risk models enables tailored interventions to improve clinical outcomes. However, no validated clinical models currently exist for predicting frailty in older abdominal surgery patients. This study aims to identify preoperative frailty risk factors and construct a predictive risk assessment nomogram, providing a scientific foundation for standardized frailty management protocols to optimize care for this vulnerable population.

Methods

Study Design, Participants, and Procedure

We have investigated 790 older patients with abdominal surgery at Hunan Provincial People's Hospital from February 2022 to September 2022. A convenience sampling method was employed to recruit eligible patients who satisfied the following inclusion criteria: (1) age ≥ 60 years; (2) undergoing abdominal surgery; (3) in stable disease condition; (4) with sufficient literacy to understand and complete the survey. Following patients were excluded: (1) severe and irreversible diseases of vital organs, such as the heart, kidneys, and gastrointestinal systems, leading to complete dependency in daily activities; (2) Alzheimer's disease or other types of dementia; (3) other severe physical or mental illness leading to inability to complete the survey.

The sample size was calculated according to the calculation method of modeling sample size.[10] The risk assessment model includes a total of 26 risk factors, each requiring 5 to 10 participants. The incidence of frailty in older patients undergoing abdominal surgery was reported as 36.5% based on previous literature. Considering an attrition rate of 15%, the sample size required for this study was calculated as 820 cases ($26 \times 10 \times (1 + 15\%) \div 36.5\%$). Therefore, a total of 820 participants were recruited for the study, 790 valid responses were obtained, yielding an impressive response rate of 96.3%. Finally, 790 responses were included and randomly distributed to a testing group (n = 592) for modeling fitting and a validation group (n = 198) for model validation with the ratio 3:1.

The study was approved by the Ethics Committee of Hunan Provincial People's Hospital (No.: [2022]-13) and was carried out in accordance with the guidelines outlined in the Declaration of Helsinki. All participants provided written informed consent before participating in the study. Eligible participants were approached and recruited by the ward nurses, who explained the study's purpose and procedures to the patients. Patients who were interested in participating in the survey were then referred to our research team, who received standard and uniform training on research conduct and data collection. All participants were fully informed about the study and assured that their participation was entirely voluntary, with the understanding that refusal or withdrawal from the study would not affect their hospital treatment. After providing written informed consent, participants were invited to complete a series of questionnaires based on face-to-face interviews conducted by the research team to collect basic information and assess their frailty and other health statuses. In addition, data on participants' demographic characteristics and laboratory-related clinical indicators were collected through the hospital's electronic medical record system.

Measurement

Patients' socio-demographic and clinical characteristics were collected through a researcher-designed questionnaire, and their laboratory-related indicators were retrieved from the electronic medical record system. Standard scales were used to assess frailty, psychological distress, cognitive impairment, and disability.

A researcher-designed questionnaire was used to collect participants' basic information, including gender, age, education level, marital status, surgical method, BMI, comorbidities, polypharmacy, etc. In addition, laboratory-related indicators were collected through the electronic medical record system, which included hemoglobin, albumin, and inflammatory factors such as IL-6, procalcitonin, white blood cells, and TNF-α.

Frailty was assessed using the Tilburg Frailty Index (TFI), a self-report standardized questionnaire developed by Gobbens.[11] The TFI comprises three domains: physical frailty (8 items), psychological frailty (4 items), and social frailty (3 items), totaling 15 items. Items 9–11 and 14 employ a three-category response format ("Yes", "Sometimes", "No"), which were subsequently dichotomized according to standardized conversion criteria. Items 1, 12, and 15 are reverse-scored. The total score ranges from 0 to 15, with scores ≥5 indicating frailty status, where higher scores reflect greater severity of frailty. The scale demonstrates excellent psychometric properties, with a Cronbach's α coefficient of 0.880, confirming strong reliability and validity.

Psychological distress was assessed using the self-administered Hospital Anxiety and Depression Scale (HADS) compiled by Snaith and Zigmond.[12] It is a 14-item scale under two subscales: anxiety (7 items) and depression (7 items). Each item is rated on a four-point Likert scale ranging from 0 to 3. The total score for each subscale ranges from 0 to 21, with a score >8 indicating the presence of anxiety or depression. The HADS showed good internal consistency with a Cronbach's α coefficient of 0.879.

Cognitive impairment was assessed using the Mini-Mental State Examination (MMSE) developed by Folstein et al.[13] It is the most widely used and well-known short screening tool for measuring cognitive impairment in clinical, research, and community settings. The MMSE includes 11 items covering time orientation, place orientation, immediate memory, attention and calculation, recall, naming, retelling, 3-level instruction, reading, writing, and tracing. The total score ranges from 0 to 30 points, with a score of 28 to 30 indicating normal cognitive function, and a score below 27 indicating cognitive impairment. The MMSE showed good internal consistency in the current study, with a Cronbach's coefficient of 0.833.

Disability was assessed using the Barthel activities of daily living (ADL) index, a widely used standardized scale in clinical, research, and community settings.[14] The Barthel ADL index comprises ten items: feeding, grooming, bathing, dressing, bowel and bladder care, toileting, ambulation, transfers, and stair climbing. The total score ranges from 0 to 100 points, with a higher score indicating lower dependency and higher ADL abilities. Based on the total score, participants are divided into the following four groups: severe dependence (≤40 points), moderate dependence (41~60 points), mild dependence (61~99 points), and no dependence (100 points). Since most participants had no dependence, participants with mild to severe dependence were combined into the disability group. ADL demonstrated good internal consistency in the current study with a Cronbach's α coefficient of 0.929.

Statistical Analysis

The data distribution of continuous variables was assessed using the Shapiro–Wilk test and presented as means ± standard deviations for normally distributed data or medians and interquartile ranges (IQRs) for data with non-normal distributions. Categorical variables were presented as numbers and percentages. Univariate logistic regression analysis, LASSO regression analysis and multivariate logistic regression analysis were used to identified the independent risk factors for frailty. The nomogram to predict the probability of frailty was developed based on the risk factors in multivariate logistic regression analysis and performed by the "rms" R package. The "ROC package" was employed to draw the Receiver Operating Characteristic curve (ROC) and calculate the area under the curve (AUC) to evaluate the predicting ability of the nomogram, with an AUC of ≥0.8 indicating good predicting performance.[15] All statistical analyses were performed using R version 4.2.2.

 https://doi.org/10.2147/CIA.S545803

Results

Patients Demographics and Characteristics

Of the 820 older patients undergoing abdominal surgery approached for participation, 790 (96.3%) completed the survey and were included in this study. The average age of the participants was 68.77 (standard deviation [SD], 5.78) years, with a balanced gender distribution (397 males, 50.25%). Most participants were married (721, 91.27%) and had attained primary school education or below (343, 43.42%), while 83 patients (10.51%) reported college-level education or higher. The average body mass index (BMI) was 22.44 kg/m^2 (SD, 3.31).

Gallstone/cholecystitis constituted the predominant diagnosis (333, 42.15%), followed by intrahepatic bile duct stones (95, 12.03%), colorectal cancer (80, 10.13%), and pancreatic cancer (45, 5.70%). Minimally invasive approaches were favored, with laparoscopy being the most common surgical intervention (561, 71.01%), followed by cholecystectomy (373, 47.22%) and liver resection (165, 20.89%). Hypertension emerged as the most prevalent comorbidity (320, 40.51%), followed by diabetes (153, 19.37%) and coronary heart disease (97, 12.28%). Pharmacological management included antihypertensive drugs (167, 21.14%), antihyperglycemic agents (97, 12.28%), Antihyperlipidemic drugs (59, 7.47%) and so on. Psychological distress was reported in 9.87% (depression, n=78) and 11.27% (anxiety, n=89) of participants, while cognitive impairment and disability each affected 36 patients (4.56%). Laboratory indicators such as interleukin-6, procalcitonin and other details were described in Table 1.

Table 1 Patient Demographics and Characteristics

Characteristics	N=790
Demographics	
Age (M±SD)	68.77±5.78
Gender (male, n, %)	397(50.25%)
Education (n, %)	
Illiterate	38(4.81%)
Primary school	305(38.61%)
Middle school	232(29.37%)
High School	132(16.71%)
College and above	83(10.51%)
Marital status	
Not married	69(8.73%)
Married	721(91.27%)
BMI (kg/m2, M±SD)	22.44±3.31
Disease type (n, %)	
Gallstones/cholecystitis	333(42.15%)
Stomach cancer	18(2.28%)
Common bile duct stones	85(10.76%)
Intrahepatic bile duct stones	95(12.03%)
Liver cancer	64(8.10%)
Biliary system tumors	25(3.16%)
Colorectal cancer	80(10.13%)
Pancreatic cancer	45(5.70%)
Pancreatitis	9(1.14%)
Surgery type (n, %)	
Laparoscopy	561(71.01%)
Liver resection	165(20.89%)
Cholecystectomy	373(47.22%)
Colorectal resection	75(9.49%)
Pancreaticoduodenectomy	62(7.85%)

(*Continued*)

Table 1 (Continued).

Characteristics	N=790
Comorbidities (n, %)	
Lung disease	22(2.78%)
Hypertension	320(40.51%)
Coronary heart disease	97(12.28%)
Cerebrovascular disease	37(4.68%)
Hepatitis	42(5.32%)
Tumor	51(6.46%)
Diabetes	153(19.37%)
Medication (n, %)	
Antihyperglycemic drugs	97(12.28%)
Antihypertensive drugs	167(21.14%)
Antihyperlipidemic drugs	59(7.47%)
Heart disease drugs	27(3.42%)
Sleeping drugs	5(0.63%)
Antithrombotic drugs	40(5.06%)
Lab indicators (M±SD)	
Interleukin-6 (pg/mL)	17.40±80.35
Procalcitonin (ng/mL)	0.73±5.63
White blood cell count (109/L)	6.45±2.92
Tumor necrosis factor-α (pg/mL)	9.36±14.18
Hemoglobin (g/L)	120.24±16.60
Albumin (g/L)	38.52±4.99
Psychological distress (n, %)	
Depression	78(9.87%)
Anxiety	89(11.27%)
Cognitive impairment (n, %)	36(4.56%)
Disability (n, %)	36(4.56%)

Independent Factors for Frailty

Of all patients, 586 (74.18%) patients were assessed as frailty. First, we performed univariate analysis and found that age, education, marital status, BMI, disease type, surgery type, tumor, diabetes, antithrombotic drugs, interleukin-6, hemoglobin, albumin, depression, anxiety, cognitive impairment, and disability were associated with frailty (Table 2). All risk factors identified in the univariate analysis were included in the LASSO logistic regression model.

Ten factors (age, BMI, education, marital status, surgical method, tumor, diabetes, antihyperlipidemic drugs, interleukin-6, and hemoglobin) with nonzero coefficients were retained in the LASSO analysis (Figure 1) and were included in the further multivariate regression analyses (Figures 2 and 3). Finally, eight variables were identified as independent risk factors for frailty: age, BMI, education, surgical method, tumor, diabetes, antihyperlipidemic drugs and interleukin-6 (Table 3).

Predictive Nomogram for Frailty

We developed a nomogram to predict the frailty probability of older patients with abdominal surgery based on independent risk factors for frailty, the nomogram is illustrated in Figure 3. For example, a 70 years old patients with BMI 22kg/m^2, college education, antihyperlipidemic drugs, non-laparotomy, non-tumor, non-diabetes and Interleukin-6 0 pg/mL would score of 92.5 points (22 points for 70 years old, 30 points for BMI 22kg/m^2, 0 point for college education, 40.5 points for antihyperlipidemic drugs, 0 point for non-laparotomy, non-tumor, non-diabetes and Interleukin-6 0 pg/mL), which corresponded to 83.5% probability of frailty.

Table 2 The Univariate Logistic Regression Analysis of Frailty

Characteristics	Non-Frail (n=204)	Frail (n=586)	χ2/Z	P-value
Demographics				
Age (M±SD)	66.91 ± 4.63	69.42 ± 6.01	−5.44	<0.0001
Gender (male, n, %)	98 (48.04%)	299 (51.02%)	0.54	0.494
Education (n, %)				
Illiterate	7 (3.43%)	31 (5.29%)	26.54	<0.001
Primary school	51 (25.00%)	254 (43.34%)		
Middle school	72 (35.29%)	160 (27.30%)		
High School	48 (23.53%)	84 (14.33%)		
College and above	26 (12.75%)	57 (9.73%)		
Marital status				
Not married	8 (3.92%)	61 (10.41%)	8.21	0.002
Married	196 (96.08%)	525 (89.59%)		
BMI (kg/m2, M±SD)	23.24±3.12	22.17±3.34	4.04	<0.001
Disease type (n, %)				
Gallstones/cholecystitis	99 (48.53%)	234 (39.93%)	4.59	0.033
Stomach cancer	2 (0.98%)	16 (2.73%)	2.08	0.023
Common bile duct stones	14 (6.86%)	71 (12.12%)	4.35	0.548
Intrahepatic bile duct stones	26 (12.75%)	69 (11.77%)	0.13	0.57
Liver cancer	22 (10.78%)	42 (7.17%)	2.66	0.05
Biliary system tumors	4 (1.96%)	21 (3.58%)	1.3	0.273
Colorectal cancer	15 (7.35%)	65 (11.09%)	2.32	0.011
Pancreatic cancer	8 (3.92%)	37 (6.31%)	1.61	0.852
Pancreatitis	1 (0.49%)	8 (1.37%)	1.03	0.049
Surgery type (n, %)				
Laparoscopy	166 (81.37%)	395 (67.41%)	14.34	0.002
Liver resection	53 (25.98%)	112 (19.11%)	4.32	0.037
Cholecystectomy	107 (52.45%)	266 (45.39%)	3.03	0.082
Colorectal resection	15 (7.35%)	60 (10.24%)	1.47	0.226
Pancreaticoduodenectomy	8 (3.92%)	54 (9.22%)	5.86	0.016
Comorbidities (n, %)				
Lung disease	7 (3.43%)	15 (2.56%)	0.42	0.515
Hypertension	76 (37.25%)	244 (41.64%)	1.21	0.272
Coronary heart disease	18 (8.82%)	79 (13.48%)	3.05	0.081
Cerebrovascular disease	5 (2.45%)	32 (5.46%)	3.07	0.08
Hepatitis	14 (6.86%)	28 (4.78%)	1.31	0.253
Tumor	6 (2.94%)	45 (7.68%)	5.63	0.018
Diabetes	27 (13.24%)	126 (21.50%)	6.62	0.01
Medication (n, %)				
Antihyperglycemic drugs	20 (9.80%)	77 (13.14%)	1.56	0.211
Antihypertensive drugs	36 (17.65%)	131 (22.35%)	2.01	0.156
Antihyperlipidemic drugs	6 (2.94%)	53 (9.04%)	8.16	0.004
Heart disease drugs	5 (2.45%)	22 (3.75%)	0.78	0.378
Sleeping drugs	0 (0.00%)	5 (0.85%)	1.75	0.186
Antithrombotic drugs	6 (2.94%)	34 (5.80%)	2.58	0.108
Lab indicators (M±SD)				
Interleukin-6 (pg/mL)	6.96 ± 16.74	21.03 ± 92.65	−2.16	0.031
Procalcitonin (ng/mL)	0.25 ± 1.38	0.90 ± 6.48	−1.42	0.157
White blood cell count (109/L)	6.36 ± 2.80	6.48 ± 2.96	−0.49	0.625
Tumor necrosis factor-α (pg/mL)	9.37 ± 14.77	9.36 ± 13.92	0.01	0.994
Hemoglobin (g/L)	124.67 ± 16.66	118.70 ± 19.02	3.98	<0.001
Albumin (g/L)	39.24 ± 4.97	38.27 ± 4.98	2.4	0.016

(*Continued*)

Table 2 (Continued).

Characteristics	Non-Frail (n=204)	Frail (n=586)	χ2/Z	P-value
Psychological distress (n, %)				
Depression	2 (0.98%)	76 (12.97%)	24.44	<0.001
Anxiety	7 (3.43%)	82 (13.99%)	16.89	<0.001
Cognitive impairment (n, %)	3 (1.47%)	33 (5.63%)	6.02	0.014
Disability (n, %)	1 (0.49%)	35(5.97%)	11.36	<0.001

We randomly selected 75% of the total sample as the test group and the remaining 25% as the validation group. The AUC of the nomogram for predicting the probability of frailty was 0.748 in the test group and 0.707 in the validation group, indicating acceptable predictive performance (Figure 4).

Discussion

Summary of the Findings

This study represents the first effort to develop and validate a frailty risk assessment model tailored to older Chinese adults undergoing abdominal surgery. We identified a striking frailty prevalence of 74.18% in this population, substantially higher than rates reported in prior Chinese and international cohorts. Through univariate logistic regression, LASSO logistic regression and multivariate logistic regression, eight independent predictors of frailty were established: age, BMI, education, surgical method, tumor comorbidity, diabetes, antihyperlipidemic drug use, and interleukin-6 elevation. The nomogram demonstrated clinically acceptable predictive performance, with AUC values of 0.748 (test group) and 0.707 (validation group). This model provides clinicians with a practical tool to stratify perioperative risks, optimize surgical decision-making, and implement targeted interventions to mitigate postoperative complications and mortality.

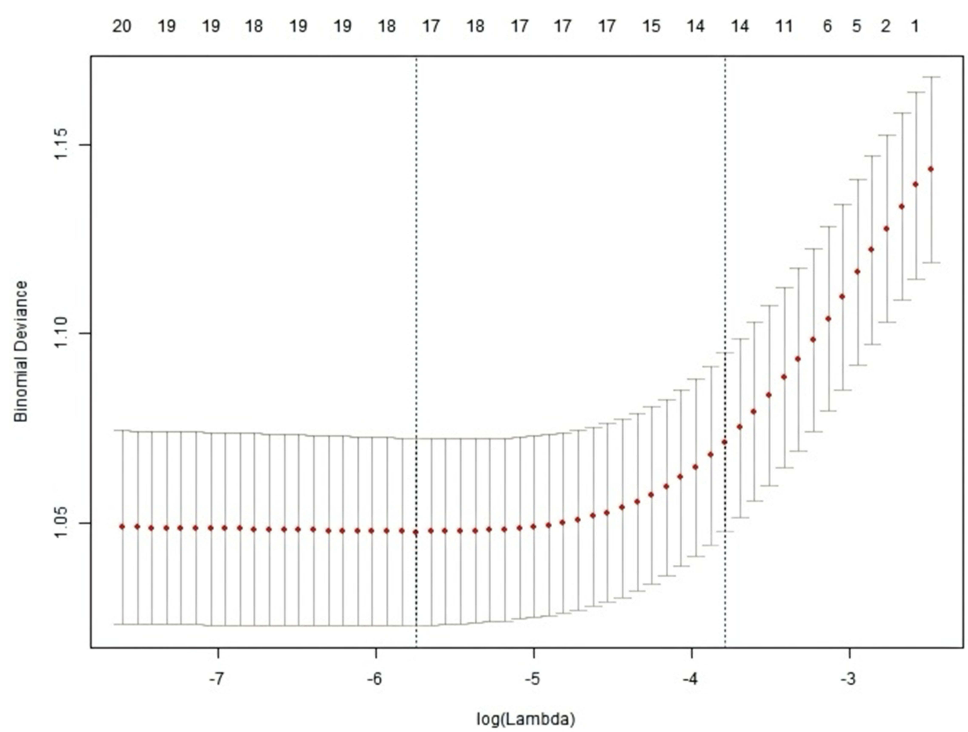

Figure 1 Cross-validation plot of LASSO regression analysis.

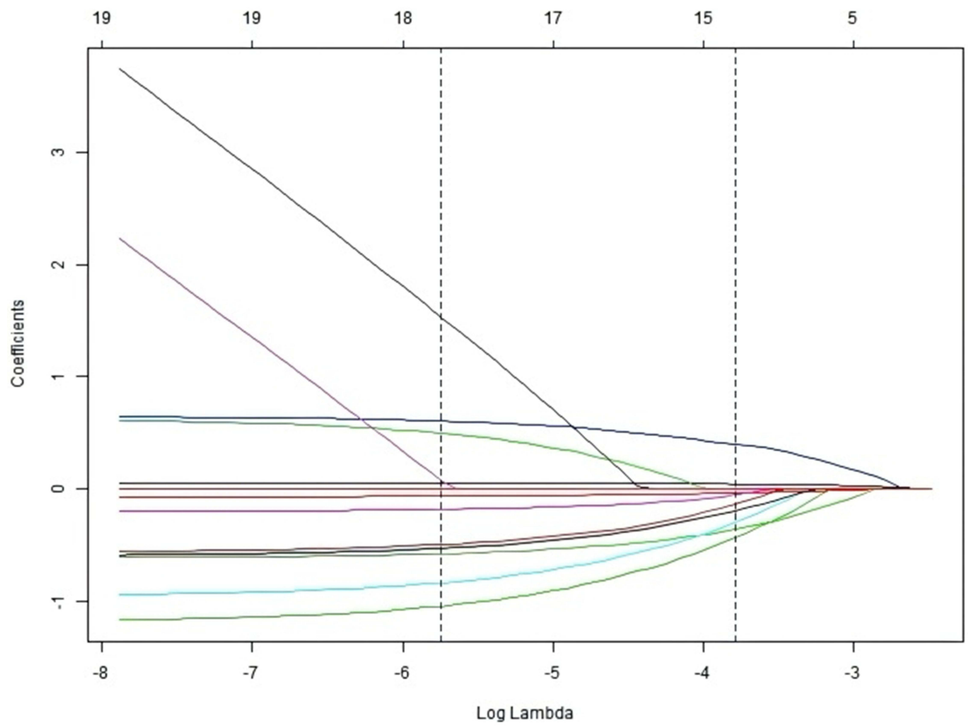

Figure 2 LASSO coefficient regularization path plot.

Prevalence of Frailty

The frailty prevalence of 74.18% observed in our cohort markedly exceeds rates from comparable studies. For instance, Liang et al[16] reported frailty rates of 19.2–35.1% in mixed surgical and non-surgical hospitalized older adults, while Han et al[17] and Cao[18] documented rates of 26.12% and 36.50%, respectively, in thoracic/abdominal surgery populations. Globally, frailty prevalence in non-cardiac surgical patients ranges from 10.60% (US)[19] to 25.70% (UK emergency surgeries).[20] This discrepancy likely stems from two key factors: (1) our cohort had a higher mean age (68.77 years vs 60–65 years in prior studies) and included a substantial proportion of cancer patients (10.13% colorectal cancer, 5.70% pancreatic cancer), both recognized frailty accelerators; (2) unlike studies using generic frailty tools (eg, Fried phenotype), the TFI's multidimensional design (physical, psychological, social domains) may capture subtler deficits prevalent in abdominal surgery candidates.

In the present study, the use of the established TFI cutoff (≥5) for defining frailty resulted in a high prevalence rate of 47.1% among community-dwelling older adults. This high rate may reflect the inherent design of the TFI as a multidimensional screening instrument aimed at maximizing sensitivity rather than specificity. A high sensitivity is desirable in community and primary care settings to ensure that the majority of at-risk individuals are identified early, thereby allowing for timely interventions to prevent or delay adverse outcomes such as disability, increased healthcare use, and reduced quality of life. However, the trade-off for high sensitivity is often a lower specificity, which may lead to overidentification of individuals as "frail" who might not experience the outcome of interest (eg, mortality). This is supported by our findings, where the AUC values for mortality prediction using the TFI cutoff, though significant, were moderate (eg, unadjusted AUC = 0.627 for total frailty), indicating limited discriminatory accuracy.[21] Therefore, while the TFI is a valuable tool for initial screening and comprehensive frailty assessment, clinicians and researchers should be aware of its operational characteristics—prioritizing broad detection over precise prognostic stratification—when implementing it in practice or interpreting results in relation to specific outcomes like mortality.

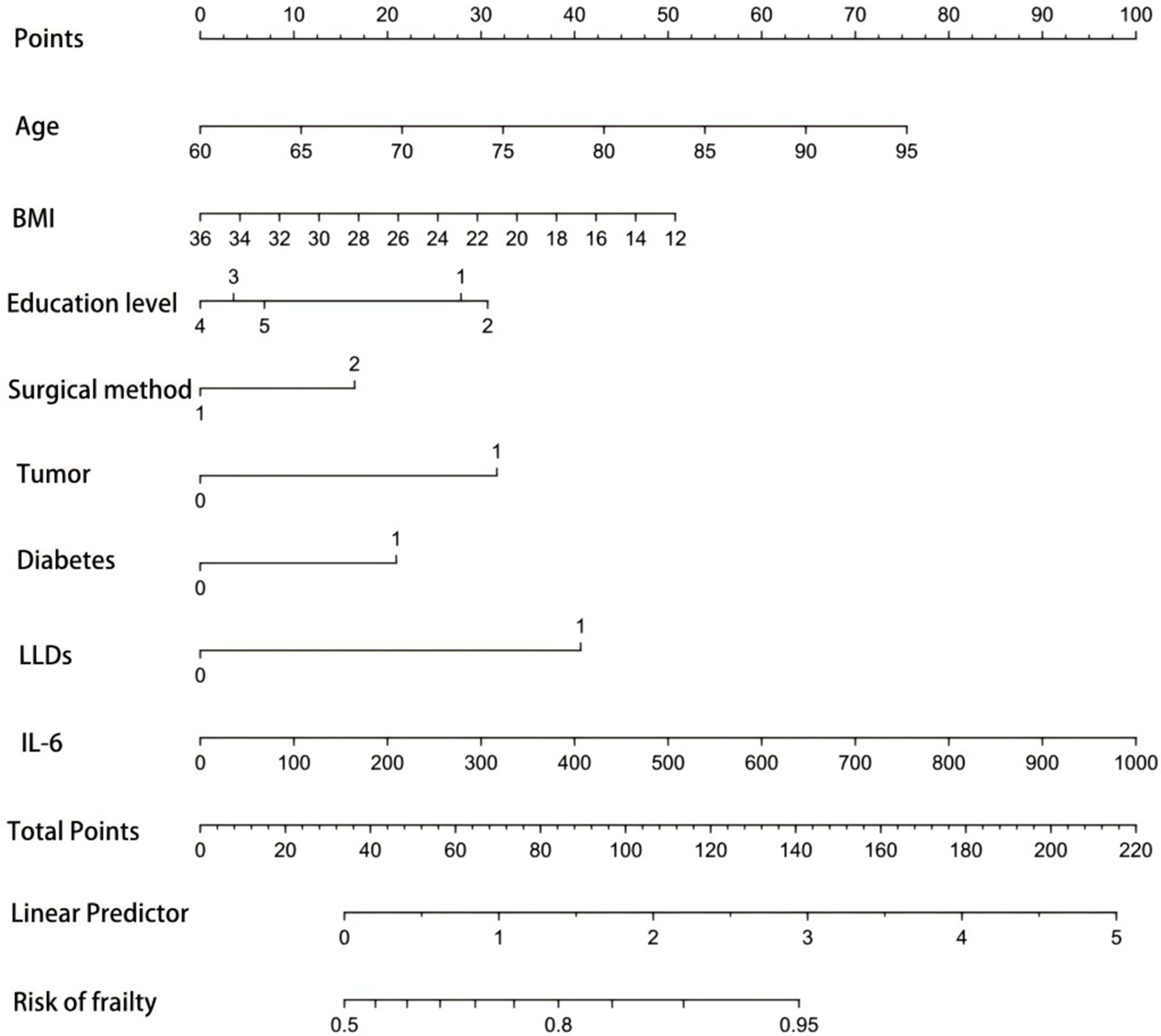

Figure 3 Nomogram of frailty risk.

Risk Factors of Frailty

Frailty is a geriatric syndrome resulting from multiple interacting factors that collectively influence its development. Therefore, the risk prediction of frailty should be based on multiple factors rather than a single factor. In this study, we

Table 3 The Multivariate Logistic Regression Analysis of Frailty

Variables	β	OR (95% CI)	*P*-value
Age	0.06	1.06 (1.02, 1.10)	0.002
BMI	−0.06	0.94 (0.89, 1.00)	0.06
Education (Illiterate as reference)			
Primary school	0.08	1.08 (0.37, 3.14)	0.886
Middle school	−0.67	0.51 (0.18, 1.48)	0.216
High school	−0.77	0.46 (0.15, 1.39)	0.171

(*Continued*)

Table 3 (Continued).

Variables	β	OR (95% CI)	*P*-value
College and above	−0.58	0.56 (0.18, 1.78)	0.325
Laparotomy	0.45	1.57 (0.98, 2.53)	0.061
Tumor (no as the reference)			
Yes	0.87	2.39 (0.89, 6.45)	0.085
Diabetes (no as the reference)			
Yes	0.58	1.78 (1.03, 3.08)	0.039
Antihyperlipidemic drugs (no as the reference)			
Yes	1.12	3.06 (1.15, 8.16)	0.025
Interleukin-6	0.01	1.00 (0.99, 1.01)	0.255

developed a predictive nomogram for frailty based on eight independent risk factors including demographic characteristics, disease, treatment, and laboratory indicators, thereby further corroborating the multidimensional concept of frailty.

Demographic and physiological factors:

Consistent with previous researches,[22–24] advancing age and low BMI (a proxy for sarcopenia and malnutrition[25,26]) emerged as central frailty drivers. The protective effect of higher education aligns with Huibregtse et al's[27] observations, likely mediated by enhanced health literacy and proactive self-management behaviors in educated populations.

Surgical and comorbidity profiles:

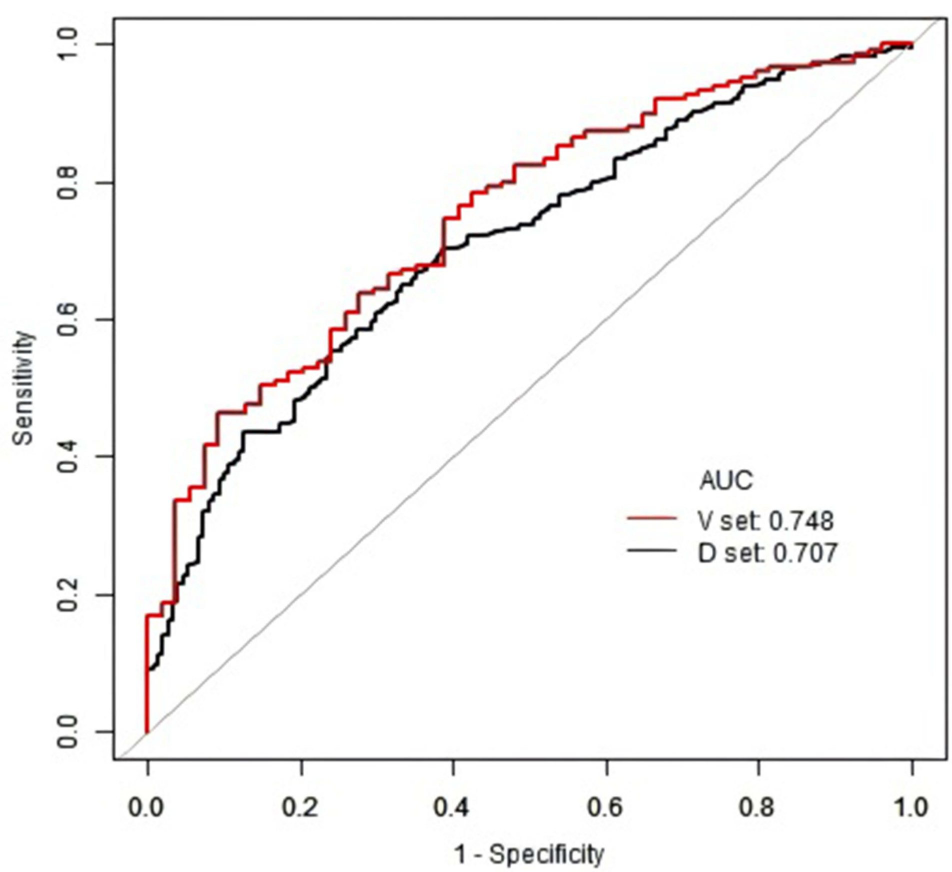

Figure 4 Receiver operating characteristic (ROC) curves show the predictive ability of the risk assessment model for frailty.

Our study found that the surgical procedure was associated with frailty status, with patients undergoing laparoscopy being less likely to be frail compared to those undergoing open surgery. This finding was consistent with Sioutas et al's[28] literature review and Mosquera et al's[29] study, which showed a higher prevalence of frailty among patients undergoing open surgery compared to those undergoing laparoscopy. Compared to traditional open surgeries, laparotomy has multiple advantages, such as smaller surgical incisions, more rapid postoperative recovery, and fewer complications related to the internal organs, leading to a lower risk of frailty.[30,31]

The strong frailty association with tumors and diabetes corroborates mechanistic links between chronic metabolic stress (eg, insulin resistance, cachexia) and accelerated functional decline.[32,33] Notably, 42.15% of our cohort had gallstone/cholecystitis—a condition often accompanied by chronic inflammation and nutritional malabsorption—potentially synergizing with comorbidities to amplify frailty.

Pharmacological and inflammatory mediators:

The use of antihyperlipidemic drugs was shown to be associated with an increased risk of frailty in our study, which may be related to the adverse effects of these drugs, especially statin-associated muscle symptoms (SAMS). SAMS often manifests as fatigue, muscle pain, cramps, or muscle weakness, with or without an increase in creatine kinase (CK).[34] In severe cases, rhabdomyolysis may occur, causing severe skeletal muscle damage.[34] Studies show that the use of antihyperlipidemic drugs may exacerbate age-related loss of muscle function and muscle weakness, leading to frailty.[35,36]

Finally, the results of this study showed that elevated interleukin-6 was associated with an increased risk of preoperative frailty. The inflammatory response is a potential pathophysiological change closely related to the occurrence and development of frailty. Interleukin-6 is an important pro-inflammatory cytokine that can lead to muscle atrophy by promoting skeletal muscle proteolysis, inducing insulin resistance, and promoting phosphorylation of myocyte growth factor.[37] Xu et al[38] conducted a systematic review and meta-analysis of 53 cross-sectional studies on the relationship between chronic inflammation and frailty, showing that the peripheral blood inflammatory marker interleukin-6 was related to frailty.

Limitations

The study has several limitations. First, the cross-sectional study design cannot verify the causal relationships between risk factors and frailty. Although the nomogram demonstrated good diagnostic performance in this study, its predictive ability requires further validation in longitudinal study designs. Second, this was a single-center study, which may lack representativeness for a broader population. Although we had a large sample size of 790 older patients undergoing abdominal surgery, further multicenter studies are needed to obtain a more representative sample and enhance the external validity of our model. Third, the model only collects data within a fixed period of time, and its long-term prediction effect needs to be confirmed by further research. In subsequent studies, time periods can be added for follow-up, and the nomogram can be compared with other frailty assessment scales to explore its clinical adaptability.

Conclusions

This study establishes that 74.18% of older adults undergoing abdominal surgery exhibit frailty, driven by a confluence of demographic, surgical, metabolic, and inflammatory factors. The nomogram showed good performance in predicting the probability of frailty. The nomogram can help clinicians to identify patients at high risk of frailty and make informed and effective decisions on further management, such as targeted and effective intervention and prevention efforts which can decrease frailty and improve patients' outcomes. In addition, the nomogram can guide shared decision-making in borderline surgical candidates. Prior to any clinical application, our findings necessitate external validation and further investigation in higher-level clinical studies to assess their impact.

Statement

An unauthorized version of the Chinese MMSE was used by the study team without permission, however this has now been rectified with PAR. The MMSE is a copyrighted instrument and may not be used or reproduced in whole or in part, in any form or language, or by any means without written permission of PAR (www.parinc.com).

Disclosure

The authors report no conflicts of interest in this work.

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