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Predictive Model for Frailty in the Elderly Based on Fat Infiltration of the Para vertebral Muscles of the Thoracic Spine

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Abstract

Objectives

This study aimed to examine the predictive value of thoracic para vertebral muscle fat infiltration for frailty in older adults.

Methods

A total of 390 patients elderly patients in the Geriatric Medicine and Orthopedic Departments of the Second Affiliated Hospital of Dalian Medical University between January 2020 and June 2024 were enrolled. Basic patient information, laboratory data, imaging findings, and Morse scale during hospitalization; general health status, activities of daily living, and other relevant scales through Telephone follow-up were collected.

1.Using 3D Slicer software, measured and calculated T5 and T10 Skeletal muscle cross-sectional area, corrected T5-T10 para vertebral muscle volume, fat volume of T5-T10 thoracic para vertebral muscles, then calculated T5 and T10 Skeletal muscle mass index (SMI) and Thoracic para vertebral muscle fat infiltration (MFI).

2. Based on telephone follow-up outcomes, all patients were categorized into three groups, Including the effective follow-up group (n=301), loss to follow-up group(n=143), and deceased group(n=35). Characteristics between effective follow-up group and deceased group were analyzed.

3. The effective follow-up group patients were divided into quadrilles by thoracic para vertebral MFI , then analyzing baseline and follow-up data.

4. Predictors of frailty was determined using binary logistic regression, and constructed nomogram based on these predictors. Bootstrap with 1000 resamples was used for internal validation of nomogram, Model discrimination, calibration, and clinical value were assessed using ROC curves, calibration curves, and decision curve analysis (DCA), respectively.

Results

1.Comparing with the effective follow-up group, the deceased group exhibited higher thoracic para vertebral MFI.

2. Comparing with the first quartile group, the patients with para vertebral MFI exceeding 20.75% exhibited higher FRAIL score.

3. Multivariate binary logistic regression analysis for frailty revealed positive correlations between thoracic para vertebral MFI and frailty.

4. Nomogram was constructed based on binary logistic predictors. The AUC of validation set ROC curve was 0.785, sensitivity was 0.744, and specificity was 0.723. Calibration curve indicated that probabilities predicted by the nomogram agreed well with the actual observation. Decision curve analysis (DCA) revealed that the net benefit curves exceeded the All and None curves, indicating superior clinical net benefit.

Conclusions

1. There is positive correlations between thoracic para vertebral MFI and frailty.

2. Patients with thoracic para vertebral MFI exceeding 20.75% are more prone to developing frailty.

Introduction

Frailty, as a geriatric syndrome, has increasingly become a central topic in geriatric medicine. It is not merely a result of ageing but a clinical state reflecting diminished physiological reserve and reduced stress resilience. This can render an individual significantly more vulnerable to adverse health outcomes, such as falls, disability, increased hospitalization rates, and mortality—when confronted with minor internal or external stressors, thus exacerbating healthcare system and socioeconomic burden[1]. As China's aging problem becomes more severe, early identification, risk warning, and effective interventions for frailty are of utmost importance for achieving healthy ageing and alleviating the burden on the society and also family caregivers.

At present, frailty assessment primarily relies on clinical scales, for example, the Fried Phenotype Model and the FRAIL scale. While these tools are widely used in research and clinical practice, they remain heavily dependent on patient's subjective reports as well as healthcare professional's judgments. Furthermore, they struggle to reveal underlying physiological changes in advance, before significant functional decline manifests.

Among frailty, the progressive decline in skeletal muscle mass and sarcopenia plays an essential role. Muscles serve as the core organ for sustaining bodily functions, metabolic equilibrium, and energy reserves. In recent years, researchers have increasingly recognized that skeletal muscle health depends not only on its volume but, more critically, on its quality[2]. Muscle fat infiltration (MFI), as a core hallmark of deteriorating muscle quality, has drew significant attention. MFI denotes the abnormal deposition of adipose tissue within skeletal muscle. This alteration directly impairs muscle contraction efficiency, reduces muscle strength, and may exacerbate local and systemic inflammatory states through pro-inflammatory factor secreteeeion, thereby establishing a vicious cycle of functional decline[3] .

Extensive research had focused on muscle mass reduction and increased MFI in limb muscles, both closely linked to functional decline and mortality in the elderly[4]. However, the para vertebral muscles constitute a vital core muscle group whose functional status directly influences postural control, gait stability, and fall risk. Given that even minor functional impairments in the elderly can rapidly manifest through weakened core strength and diminished balance, it merits consideration whether para vertebral MFI may more sensitively predict bodily functional decline and the onset of frailty than limb muscle parameters.

The widespread clinical availability of chest CT images in geriatric patients facilitate large-scale retrospective studies using pre-existing CT data to explore their potential predictive value for frailty.

Currently, studies directly examining the association between thoracic para vertebral muscle fat infiltration and frailty remain scarce. Therefore, this retrospective analysis aims to objectively and comprehensively assess frailty using clinical and relevant scales. It utilizes routine chest CT imaging to quantitatively measure the fat infiltration in the thoracic para vertebral muscles of elderly patients and investigate its association with frailty.

Methods

Study population and design

A random sampling method was employed to select elderly patients aged 60 years and above admitted to the Geriatric Medicine and Orthopedic Departments of Second Affiliated Hospital of Dalian Medical University in China between January 2020 and June 2024. Basic clinical data, biochemical parameters, imaging findings, and post-discharge follow-up information were collected during hospitalization. Follow-up occurred between April and June 2025. Inclusion criteria: (1) Age≥60 years; (2) Complete clinical records; (3) All patients underwent chest CT examination; (4) All patients provided informed consent. Exclusion criteria: (1) Patients with multiple fractures; (2) Patients with conditions potentially causing secondary osteoporosis, such as hyperthyroidism, hyperparathyroidism, Cushing's syndrome, or autoimmune diseases; (3) Patients with spinal deformities; (4) Patients who had used bone metabolism-affecting medications, such as steroids or oestrogens, in six months.

Measurements

1. General Data: Patients' age, gender, height (cm), weight (kg), and history of fundamental conditions (hypertension, type 2 diabetes, coronary heart disease) , Body Mass Index (BMI) = weight (kg) / height (m)² were collected .

2. Laboratory parameters: Serum albumin (Alb), serum prealbumin (PA), creatinine (Cr), serum calcium (Ca), serum phosphorus (P), serum sodium (Na), haemoglobin (Hb), white blood cells (WBC), absolute neutrophil count (N), Absolute lymphocyte count (L), platelets (Plt) , neutrophil-lymphocyte ratio (NLR) = absolute neutrophil count (N)/absolute lymphocyte count (L) were collected . Other scale：MORSE fall scale[5].

3. Para vertebral Muscle Measurement: The CT threshold range for skeletal muscle is 29HU to 150HU, while that for fat is -190HU to -30HU[6] . Using 3D Slicer software, measured the volume of the para vertebral posterior muscle group (thoracic spinous muscles, thoracic semispinal muscles, multifidus muscles, thoracic rotator muscles, and cervical intertransversal muscles) at the T5-T10 vertebral levels, the area of the para vertebral posterior muscle group (thoracic spinous muscles, thoracic semispinal muscles, multifidus muscles, thoracic rotator muscles, and cervical intertransversal muscles) at the T5 vertebral level, area of the para vertebral posterior muscle group at the T10 vertebral level (thoracic serratus, thoracic semispinalis, multifidus, thoracic rotator brevis), and fat infiltration volume of the para vertebral posterior muscle group at the T5-T10 vertebral levels (see Figure 1).(1) Thoracic para vertebral muscle fat infiltration (MFI) = fat volume of T5-T10 thoracic para vertebral muscles / muscle volume of T5-T10 thoracic para vertebral muscles; (2) T5 and T10 Skeletal muscle mass index (SMI) = T5 and T10 para vertebral muscles cross-sectional area /height $(cm)^2$; (3) Corrected T5-T10 para vertebral muscle volume=T5-T10 para vertebral muscle volume/height $(cm)^2$; Corrected T5-T10 para vertebral muscle fat volume(cm^3/m^2) =T5-T10 para vertebral muscle fat volume/height $(cm)^2$

4. Follow-up Data

The patients were followed up through telephone, include: (1) General health status: death, bedridden status, post-discharge fractures/re-fractures, social isolation, level of consciousness, types of long-term medication, and daily medication frequency; (2) Activities of daily living: BADL score[7], IADL score[8]; (3) Geriatric syndromes: physical pain, visual impairment, hearing loss, urinary incontinence, urinary retention, constipation, faecal incontinence, insomnia; (4) Other relevant scales: FRAIL frailty scale[9], MNA-SF nutritional scale[10]. Based on FRAIL score, patients in the pre-frailty (1-2 points) and frailty (3-5 points) groups , they were classified as frail, while those in the robust group (0 points) were classified as non-frail.

Statistical analyses

Statistical analysis of all data was performed using SPSS 25.0. All quantitative data underwent K-S normality testing. Data meeting normality criteria were expressed as mean ± standard deviation ($\bar{x} \pm s$), while non-normally distributed data were presented as median and inter-quartile range [M(Q1,Q3)]. Categorical data were reported as frequencies and percentages. Data meeting normality assumptions underwent analysis of variance (ANOVA) with LSD post hoc testing for multiple comparisons; non-normally distributed data employed non-parametric tests with Bonferroni post hoc test. Categorical variables were compared using chi-square tests, whilst binary logistic regression analysed associations between variables and frailty. Variables with $P<0.1$[10]were included in a multivariate binary logistic regression analysis to identify primary factors influencing frailty. Nomograms were originated using RStudio. Based on the logistic regression results, the nomogram served as an effect model, calculating each patient's risk of developing frailty using points associated with each risk factor. The predictive model's efficacy was assessed. $P < 0.05$ was considered statistically significant.

Results

Baseline characteristics

1. A total of 390 elderly individuals were included in this study, with a median age of 69(64, 77) years. There were 146 males (37.4%) and 244 females (62.6%). After a mean follow-up of 3.63 years, 336 patients were followed up, follow-up rate was 86.2%. Effective follow-up was achieved in 301 patients, with 35 deaths occurring (mortality rate: 10.4%). The loss-to-follow-up group (n=54) had a mean age of 73 (64, 81) years, comprising 22.2% hip fracture patients and 33.3% had spinal fractures. A total of 301 patients were included in subsequent analyses. The median age of the effectively followed-up cohort was 68 (63, 74) years, comprising 193 women (64.1%) and 108 men (35.9%). Baseline characteristics were analysed and compared between the effective follow-up group (n=301) and the deceased group (n=35). Results indicated that compared with the effective follow-up group, the deceased group exhibited higher age, WBC, N, NLR, thoracic para vertebral MFI, and MORSE score($P<0.05$);while BMI, Alb, PA, Ca, P, Na, Hb, L, Plt, corrected T5-T10 para vertebral muscle volume, T5 para vertebral muscle SMI, and T10 para vertebral muscle SMI were lower ($P<0.05$). Gender, hypertension, coronary heart disease, diabetes mellitus, Cr, and corrected T5-T10 para vertebral muscle fat volume showed no statistically significant differences between the two groups ($P > 0.05$). (Table 1)

2. Comparison of baseline characteristics among four groups of subjects stratified by para vertebral MFI quadrilles

The 301 patients were divided into four quadrilles based on para vertebral MFI: the first quartile (0.89% ≤ para vertebral MFI< 7.05%), the second quartile (7.05% ≤ para vertebral MFI<12.21%), the third quartile (12.21%≤para vertebral MFI < 20.75%),and the fourth quartile group (20.75% ≤ para vertebral MFI < 64.53%). Compared with the first quartile group, patients in the fourth quartile group (para vertebral MFI ≥ 20.75%) exhibited greater age, higher BMI, larger corrected T5-T10 para vertebral muscle fat volume, higher MORSE score, and lower albumin levels ($P<0.05$). No statistically significant differences were observed across the four groups for hypertension, coronary heart disease, diabetes, or corrected T5-T10 para vertebral muscle volume ($P> 0.05$). (Table 2).

3. Comparison of follow-up data among four groups stratified by thoracic para vertebral MFI quadrilles

Compared with the first quartile group, patients in the fourth quartile group had lower BADL and IADL scores; higher bedridden rates, social isolation rates, and FRAIL scores ($P < 0.05$). No statistically significant differences were observed across quadrilles for: falls in the past year, fractures/re-fractures post-discharge, living arrangements, hospitalizations in the past year, types of long-term medications, frequency of long-term medication use, MORSE score, MNA-SF score ($P > 0.05$). (Table 3)

4. Univariate and multivariate analysis of predictors for frailty

4.1 The univariate model identified 13 predictors associated with frailty, including age, osteoporosis, MORSE score, and thoracic para vertebral MFI, which were positively correlated with frailty and thus risk factors for frailty; Alb, PA, Ca, Hb, T10 para vertebral muscle SMI, and corrected T5-T10 para vertebral muscle volume were negatively correlated with frailty, representing protective factors ($P<0.05$). (Table 4.1)

4.2 The multivariate logistic regression model revealed that age, MORSE score, and thoracic para vertebral MFI were positively correlated with frailty, constituting risk factors for frailty ($P<0.05$). In contrast, T10 para vertebral muscle SMI was inversely associated with frailty, representing a protective factor against frailty ($P<0.05$). (Table 4.2)

5. Construction and performance evaluation of a nomogram for predicting frailty

5.1 Based on the results of multivariate logistic regression analysis, a nomogram incorporating four independent predictive factors was constructed to forecast frailty occurrence in elderly patients (Figure 2). Each factor's value is assigned a score on the score axis. By summing individual scores and projecting the total score onto the bottom risk axis, the probability of frailty in elderly patients can be estimated.

5.2 The 301 patients with valid follow-up were randomly divided into a training set (n=211) and a validation set (n=90) in a 7:3 ratio for internal validation. The AUC of training set was 0.754, sensitivity was 0.644, and specificity was 0.802 (Figure 3A), while the AUC of validation set was 0.785, sensitivity and specificity were 0.744 and 0.723 respectively (Figure 3B). This nomogram demonstrated favourable discriminatory performance. Calibration curves indicated that both the training and validation sets demonstrated close alignment with the ideal reference line , indicating satisfactory model calibration and a high degree of consistency between the predicted probabilities of frailty and the actual observed outcomes. (Figures 4A and 4B). Furthermore, decision curve analysis (DCA) of the columnar plot revealed that the predicted model's net benefit curves consistently exceeded both the All curve and None curve, demonstrating superior clinical net benefit (Figure 5).

Discussion

This study initially enrolled 390 patients. 301 patients were effectively followed up through telephone, while 54 loss to follow-up, the effective follow-up rate was 86.2%. Among effectively followed-up patients, the median age was 68 years, while female 64.1% and male 35.9%. Furthermore in the effectively followed cohort, hip fractures and spinal fractures accounted for 14.6% and 15.0% respectively; in the loss-to-follow-up group, hip fractures and spinal fractures accounted for 22.2% and 33.3% respectively. This suggested that loss to follow-up group may be associated with poorer outcomes or even mortality among fracture patients.

Analysis of follow-up data revealed that the deceased group exhibited higher age, lower BMI, elevated absolute white blood cell and neutrophil counts, increased NLR, and reduced lymphocyte, platelet, serum albumin, and

prealbumin levels. This suggested inflammatory activation and sub-optimal nutritional status in the deceased group[12] . Concurrently, the deceased group demonstrated generally lower serum sodium, calcium, phosphorus, and haemoglobin levels. The patients in this group exhibited higher MORSE score, moreover, the corrected T5-T10 para vertebral muscle volumes and SMI of the T5 and T10 levels were smaller, with more fat infiltration.

This study found that the median age of patients in the fourth quartile (para vertebral MFI > 20.75%) was 72 years, higher than that in other groups. Research indicated that para vertebral MFI began to increase in women at age 40 and men at age 50, while muscle mass declining with age[13] . This study additionally observed that T10 para vertebral muscle SMI was smaller and MORSE score were higher in the patients with para vertebral MFI > 20.75%. These alterations impaired muscle function and thereby diminish spinal stability, which increased the risk of adverse events such as falls and fractures[14] . Research found that muscle cross sectional area, as a crucial indicator for assessing muscle mass and function, was closely associated with frailty, increased fall risk, and higher disability rates in the elderly[15] .In this study, the patients with thoracic para vertebral MFI exceeding 20.75% exhibited higher BMI and lower albumin levels. This signified that even with normal or elevated total body weight or BMI, significant skeletal muscle mass decline and muscle fat infiltration may persist, leading to reduced muscle function and metabolic disorders[16] . In fact, sarcopenic obesity needs be recognized in clinical practice.

This study revealed that in patients with fat infiltration surpassing 20.75%, they expressed higher FRAIL scores, BADL scores, IADL scores, bedridden days, and social isolation than other groups, indicating a positive correlation between para vertebral MFI and frailty status. Further uni-variate analysis identified thoracic para vertebral MFI is a risk factor for frailty. After adjusting for confounding variables via multivariate logistic regression, thoracic para vertebral MFI remained statistically significant, indicating 7.3% increased risk of frailty per 1% increase in thoracic para vertebral MFI. This finding indicated that increased para vertebral MFI substantially elevates frailty risk in elderly patients. Adipose tissue can secreteee pro-inflammatory cytokines such as TNF-α and IL-6 to induce systemic low grade inflammation. This chronic inflammation can directly speed up muscle protein catabolism and promotes multi-organ dysfunction by affecting neuro-endocrine systems and immune systems, thereby contributing to frailty[17] . Fat infiltration disrupts normal insulin signalling pathways, exacerbating insulin resistance and afterwards weakening protein synthesis and energy metabolism balance in muscle tissue. Research indicated that a significant positive correlation between pancreatic fat infiltration and the risk of developing type 2 diabetes[18] . This metabolic disorder further impairs muscle function, because fat infiltration reduces muscle cross-sectional area and induces alterations in muscle fibre type, in the meantime , reduces mitochondrial function, and impaires muscle contractility[19]. Fat infiltration can diminish muscle strength and physical capacity, thereby increasing frailty risk[20] . This study also found that patients with high fat infiltration exhibited lower BADL and IADL scores, higher bedridden rate , and more social isolation.

A nomogram incorporating comorbidities, depression, and social support predicted frailty trajectories among elderly gastric cancer survivors[21].Compared to previous studies, the innovation of this research lies in introducing an objective, quantifiable imaging metric—the thoracic para vertebral MFI. This study developed a frailty prediction nomogram based on thoracic para vertebral MFI, age, MORSE score during hospitalization, and T10 para vertebral muscle SMI. The model demonstrated that training set AUC is 0.754 (sensitivity is 0.644, specificity is 0.802) and validation set AUC is 0.785 (sensitivity is 0.744, specificity is 0.723). The model exhibited an intermediate discrimination. The calibration curve showed high concordance between predicted probability and actual risk, indicating a favourable model calibration.

This model set up a clinical tool for frailty risk assessment, integrating imaging and clinical indicators, enabling early risk stratification based on routine chest CT. It provides an objective screening tool for precision prevention and control of frailty in the elderly.

This study identified that patients with thoracic para vertebral muscle MFI exceeding 20.75% exhibited increased susceptibility to frailty. Thoracic para vertebral MFI, age, MORSE score and T10 para vertebral muscle SMI were found to be efficient predictors of frailty onset. Consequently, clinicians may employ these objective indicators for early frailty screening, thereby enabling timely interference to effectively prevent adverse health consequence such as disability, bedridden status, and social isolation. Prospective studies are required to prove the predictive value of thoracic para vertebral MFI for frailty.

Several limitations of this study should be acknowledged. First, the absence of external validation limits the generalizability of the model, which requires confirmation through multicenter studies.Second, psychosocial factors such as cognitive function, depression, and social support were not included in the analysis. Third, death may act as a competing event affecting the estimation of bedridden status and disability; future studies should consider applying competing risk models for further analysis.

Conclusions

1.The fat infiltration of the para vertebral muscles of the thoracic spine positively correlates with frailty; patients with fat infiltration exceeding 20.75% are more prone to developing frailty.

2. Fat infiltration in the thoracic para vertebral muscles, age, MORSE score, and T10 para vertebral muscle SMI effectively predict the occurrence of frailty.

Abbreviations

MFI
Muscle fat infiltration
Alb
Serum albumin
PA
serum prealbumin
Cr
creatinine
Ca
serum calcium
P
serum phosphorus
Na
serum sodium
Hb
haemoglobin
WBC
white blood cells

N
absolute neutrophil count
L
Absolute lymphocyte count
Plt
platelets
NLR
neutrophil-lymphocyte ratio
SMI
Skeletal muscle mass index
BADL core
Basic activities of daily living
IADL scores
Instrumental activities of daily living
MNA-SF score
mini-nutritional assessment short-form

Declarations

Ethics approval and consent to participate

This is a retrospective single-institution series analysis study which is clinically conducted at Second Affiliated Hospital of Dalian Medical University. The study adhered to the principles of the Declaration of Helsinki and was authorized by the Ethics Committee of Second Affiliated Hospital of Dalian Medical University [KY2025-700-01], which granted a waiver of informed consent due to the retrospective nature of the study and the use of anonymized clinical and imaging data.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from Second Affiliated Hospital of Dalian Medical University but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the corresponding author upon reasonable request and with the permission of the Institutional Review Board of Second Affiliated Hospital of Dalian Medical University.

Competing Interests

The authors declare no conflicts of interest.

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Authors' contributions

Study design and revision: Chunyu Zhang; Formal analysis, writing review and editing: Andi Tian；Data collection: Lanfeng Zhang, Hussain Muthasim Adnan, Bo Jin, Xiaoyun Gao, Yanan Liu, Shuwen Tan, Jiaxin Tong, Guangchan Li. All authors have read and agreed to the published version of the manuscript.

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Tables

Table 1 Comparison of data from 390 patients with differing follow-up outcomes

	Patients with effective follow-up (n=301)	Deceased patients (n=35)	*P*
Gender Male	108 (35.9%)	17 (48.6%)	0.222
Female	193 (64.1%)	18 (51.4%)	
Age (years)	68 (63, 74)	78.26±7.20*	<0.001
BMI (kg/m²)	24.79±3.11	22.81±4.08*	0.004
Number of Hypertensive Cases (%)	162 (53.8%)	20 (57.1%)	0.387
Cases of coronary heart disease (%)	41 (13.6%)	4 (11.4%)	0.846
Diabetes cases (%)	104 (34.6%)	15 (42.9%)	0.490
Normal bone masscases (%)	75 (24.9%)	3 (8.6%)	<0.001
Number of cases with reduced bone mass (%)	73 (24.3%)	1 (2.9%)	
Osteoporosis Non-fracture cases (%)	64 (21.3%)	4 (11.4%)	
Number of hip fractures (%)	44 (14.6%)	11 (31.4%)*	
Spinal fractures (%)	45 (15.0%)	16 (45.7%)	
Alb (g/L)	41.05±4.10	37.65±4.28*	0.001
PA (mg/L)	258.34±62.31	216.29±71.97*	0.001
Cr (μmol/L)	61.09 (52.78, 72.62)	64.05(55.43,88.80)	0.116
Ca (mmol/L)	2.32 ± 0.12	2.25±0.15*	0.001
P(mmol/L)	1.18 (1.07, 1.28)	1.01±0.22*	0.010
Na (mmol/L)	140.73±2.45	139.15±3.51*	0.005
Hb (g/L)	136.00(125.00,146.00)	121.06±22.99*	0.001
WBC (* 10^9/L)	6.27 (5.17, 7.80)	7.69±2.36*	0.013
N(* 10^9/L)	3.90(3.00,5.26)	5.50(4.18,7.57)*	0.001
L(* 10^9/L)	1.63(1.31,2.09)	1.29(0.95,1.67)*	0.001
Plt(* 10^9/L)	209.00(178.50,255.50)	176.00(150.00, 217.00)*	0.003
NLR	2.20(1.63,3.72)	4.00(2.79,8.55)*	0.001
MORSE during hospitalisation score	35(35, 40)	40(35,60)*	0.016
Thoracic paravertebral MFI (%)	12.21 (7.05, 20.75)	17.06(10.76,27.00)*	0.037

Corrected T5-T10 paravertebral fat volume (cm^3/m^2)	8.75(5.07,14.93)	11.20(5.32,18.24)	0.908
Corrected T5-T10 paravertebral muscle volume (cm^3/m^2)	71.36 (61.92, 81.44)	61.97±15.37 *	<0.001
T5 paravertebral muscle SMI (cm^2/m^2)	3.78 (3.37, 4.38)	3.39±0.85*#	0.005
T10 paravertebral muscle SMI (cm^2/m^2)	7.34±1.66	5.61(4.98, 6.86)*#	<0.001

Note: MORSE score：MORSE score during hospitalisation ：Compared with the effective follow-up patient group, *P<0.05, BMI: Body Mass Index; Alb: Serum Albumin; PA: Serum Prealbumin; Cr: Serum Creatinine; Ca: Serum Calcium; P: Serum Phosphorus; Na: Serum Sodium; Hb: Haemoglobin; WBC: White blood cells; N: Absolute neutrophil count; L: Absolute lymphocyte count; Plt: Platelets; NLR: Neutrophil-lymphocyte ratio; SMI: Skeletal muscle index.

Table 2 Comparison of baseline characteristics among 301 elderly patients with thoracic vertebral paravertebral MFI quadrilles

Indicator	First quartile (n=76)	Second quartile (n=75)	Third quartile (n=75)	Fourth Quartile (n=75)	*P*
Gender Male	38 (50.0%)	35 (46.7%)	21 (28.0%)	14 (18.7%)	<0.001
Female	38 (50.0%)	40 (53.3%)	54 (72.0%) [ab]	61 (81.3%)[c]	
Age (years)	66 (62, 71)	66 (62, 69)	69 (64, 75)	72 (68, 78)[abc]	<0.001
BMI (kg/m²)	23.87±2.60	24.76±3.16	25.1±2.68	25.6±3.55[a]	0.006
Number of hypertension cases (%)	40 (52.6%)	40 (53.3%)	41 (54.7%)	41 (54.7%)	0.993
Number of coronary heart disease cases (%)	6 (7.9%)	11 (14.7%)	16 (21.3%)	8 (10.7%)	0.088
Number of diabetes cases (%)	40 (52.6%)	41 (54.7%)	40 (53.3%)	37 (49.3%)	0.927
Number of non-osteoporotic cases (%)	38 (50.0%)	45 (60.0%)	35 (46.7%)	30 (40.0%)	0.008
Number of non-fracture osteoporosis cases (%)	23 (30.3%)	15 (20.0%)	13 (17.3%)	13 (17.3%)	
Number of hip fractures (%)	3 (3.9%)	9 (12.0%)[a]	14 (18.7%)[a]	18 (24.0%) [bc]	
Number of spinal fractures (%)	12 (15.8%)	6 (8.0%)	13 (17.3%)	14 (18.7%)	
Alb (g/L)	41.76±3.98	42.02±4.23	40.90±3.44	40.40 (37.1, 42.5)[ab]	0.004
MORSE score	35(35, 35)	35(35, 35)	35 (35, 45)	35 (35, 45)[a]	0.032
Corrected T5-T10 paravertebral fat volume (cm³/m²)	3.30±1.38	7.28±1.86	11.44±2.79	20.00 (16.77,29.27)	<0.001
Corrected T5-T10 paravertebral muscle volume (cm³/m²)	71.8±13.58	71.12(61.25, 82.75)	71.10±13.99	73.14±16.50	0.841
T5 paravertebral muscle SMI (cm²/m²)	3.73±0.65	3.73 (3.29, 4.35)	3.73 ±0.78	4.11±1.03	0.049
T10 paravertebral muscle SMI (cm²/m²)	7.44±1.58	7.42 (6.25, 8.51)	7.41±1.39	6.91±1.78[b]	0.019

Note: Compared with the first quartile group, [a]$P < 0.05$; compared with the second quartile group, [b]$P < 0.05$; compared with the third quartile group, [c]$P < 0.05$.

Table 3 Comparison of follow-up data for 301 elderly patients grouped by thoracic paravertebral MFI quadrilles

Indicator	First quartile (n=76)	Second Quartile (n=75)	Third Quartile (n=75)	Fourth quartile (n=75)	*P*
Number of bedridden cases (%)	1 (1.3%)	2 (2.7%)	2 (2.7%)	12 (16.0%) [abc]	<0.001
Social isolation	0 (0, 1)	0 (0, 0)	0 (0, 1)	1(0, 1)[ab]	<0.001
IADL score	8(8, 8)	8(8, 8)	8 (7, 8)	6.5 (3, 8)[abc]	<0.001
BADL score	100 (100, 100)	100 (100, 100)	100 (97, 100)	100 (85, 100)[abc]	0.001
MNA-SF score	14 (12, 14)	14 (13, 14)	14 (13, 14)	14 (12, 14)	0.691
FRAIL score	0(0, 1)	0(0, 0)	0 (0, 2)b	2 (0, 3)abc	<0.001

Note: Compared with the first quartile group,[a]*P* < 0.05; compared with the second quartile group,[b]*P* < 0.05; compared with the third quartile group, [c]*P* < 0.05.

Table 4.1 Results of univariate binary logistic regression analysis

Variables		β	S. E.	OR values (95 % CI)	*P*
Age(years)		0.093	0.018	1.098(1.059-1.137)	<0.001
Bone Osteoporosis	None	Reference			
	Yes	0.564	0.235	1.759(1.110-2.786)	0.016
Alb (g/L)		-0.105	0.030	0.900(0.848-0.956)	0.001
PA(mg/L)		-0.007	0.002	0.993(0.989-0.997)	0.001
Ca (mmol/L)		-4.007	1.057	0.018(0.002-0.145)	<0.001
P(mmol/L)		-1.228	0.675	0.293(0.078-1.101)	0.069
Hb (g/L)		-0.015	0.007	0.985(0.972-0.998)	0.022
N ($\times 10^9$/L)		0.112	0.058	1.119(0.998-1.254)	0.054
NLR		0.095	0.051	1.099(0.996-1.214)	0.061
MORSE score		0.031	0.008	1.031(1.014-1.048)	<0.001
Area of paravertebral muscles at T10 (cm^2)		-0.110	0.025	0.896(0.852-0.941)	<0.001
T10 paravertebral muscle SMI (cm^2/m^2)		-0.380	0.081	0.684(0.584-0.801)	<0.001
Thoracic paravertebral MFI(%)		0.048	0.011	1.049(1.027-1.072)	<0.001
Corrected T5-T10 paravertebral muscle volume (cm^3/m^2)		-0.020	0.008	0.980(0.965-0.996)	0.013

Table 4.2 Multivariate binary logistic regression analysis results for frailty

Variables	β	S.E.	OR values (95 % CI)	*P*
Age (years)	0.071	0.020	1.073(1.031- 1.117)	0.001
MORSE score	0.026	0.010	1.026(1.007-1.046)	0.008
T10 paravertebral muscle SMI (cm^2/m^2)	-0.322	0.088	0.725(0.610-0.860)	<0.001
Thoracic paravertebral MFI (%)	3.602	1.189	1.037(1.013-1.061)	0.002
Constant	-4.303	1.610	0.014(1.031-1.117)	0.008

Note：MORSE score：MORSE score during hospitalisation

Figures

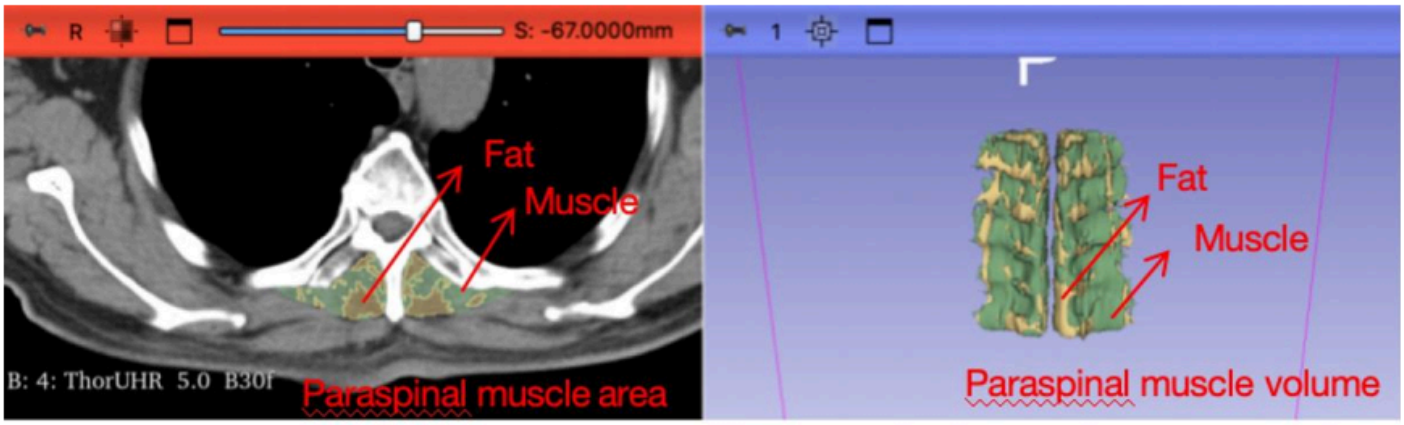


Figure 1

Figure 1

Legend not included with this version.

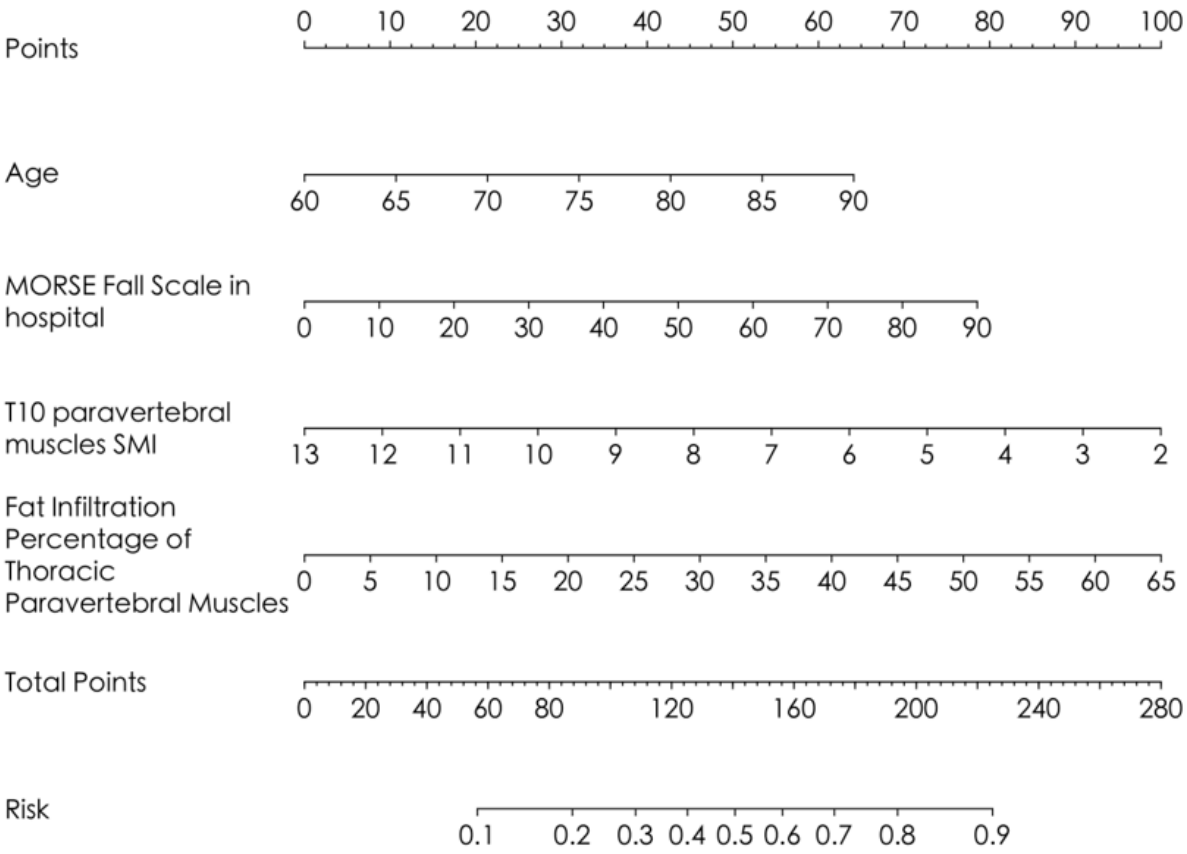


Figure 2

Frailty nomogram

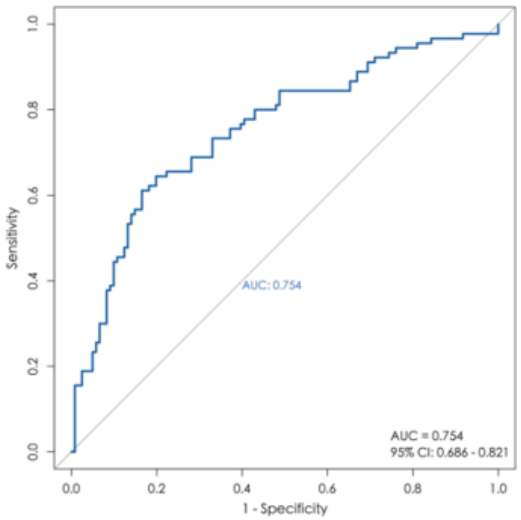


Figure 3A

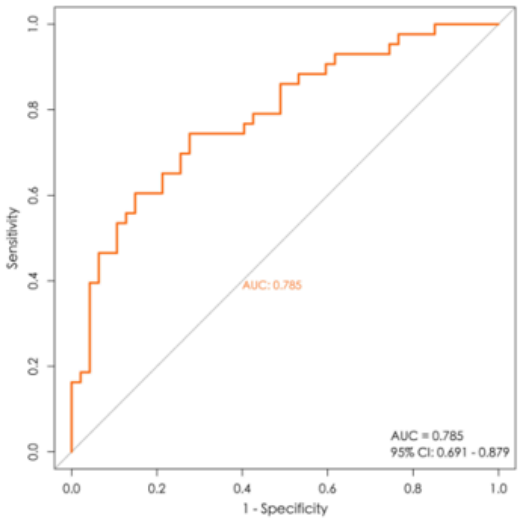


Figure 3B

Figure 3

A Training set AUC

B validation set AUC

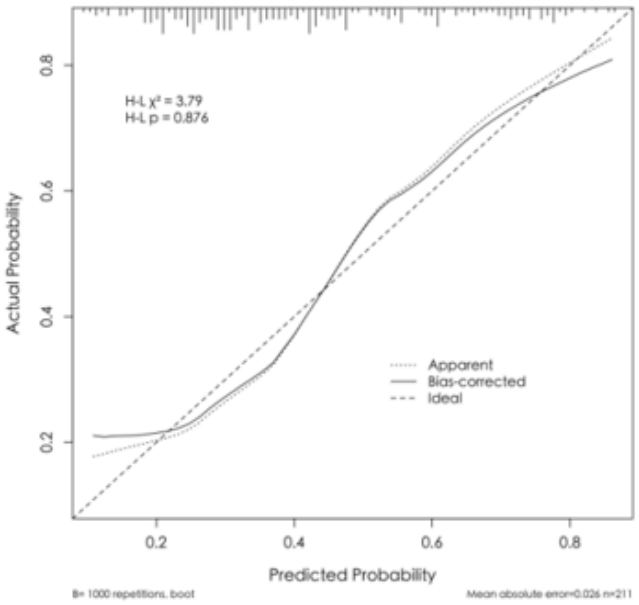


Figure 4A

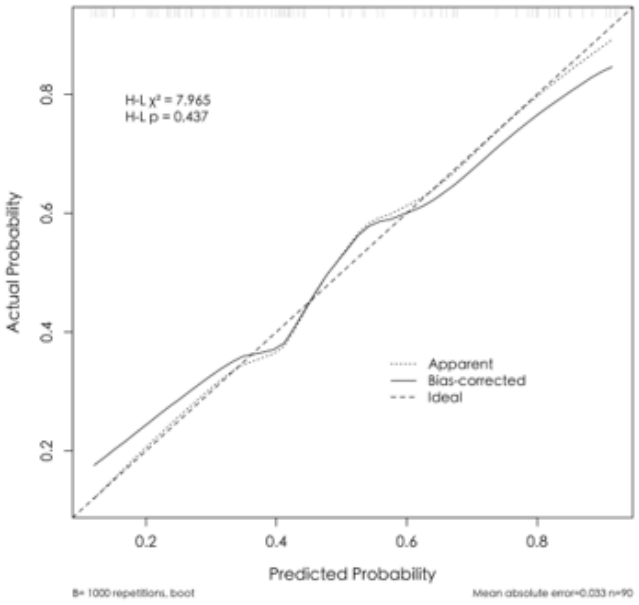


Figure 4B

Figure 4

A Training set Calibration curves

B validation set Calibration curves

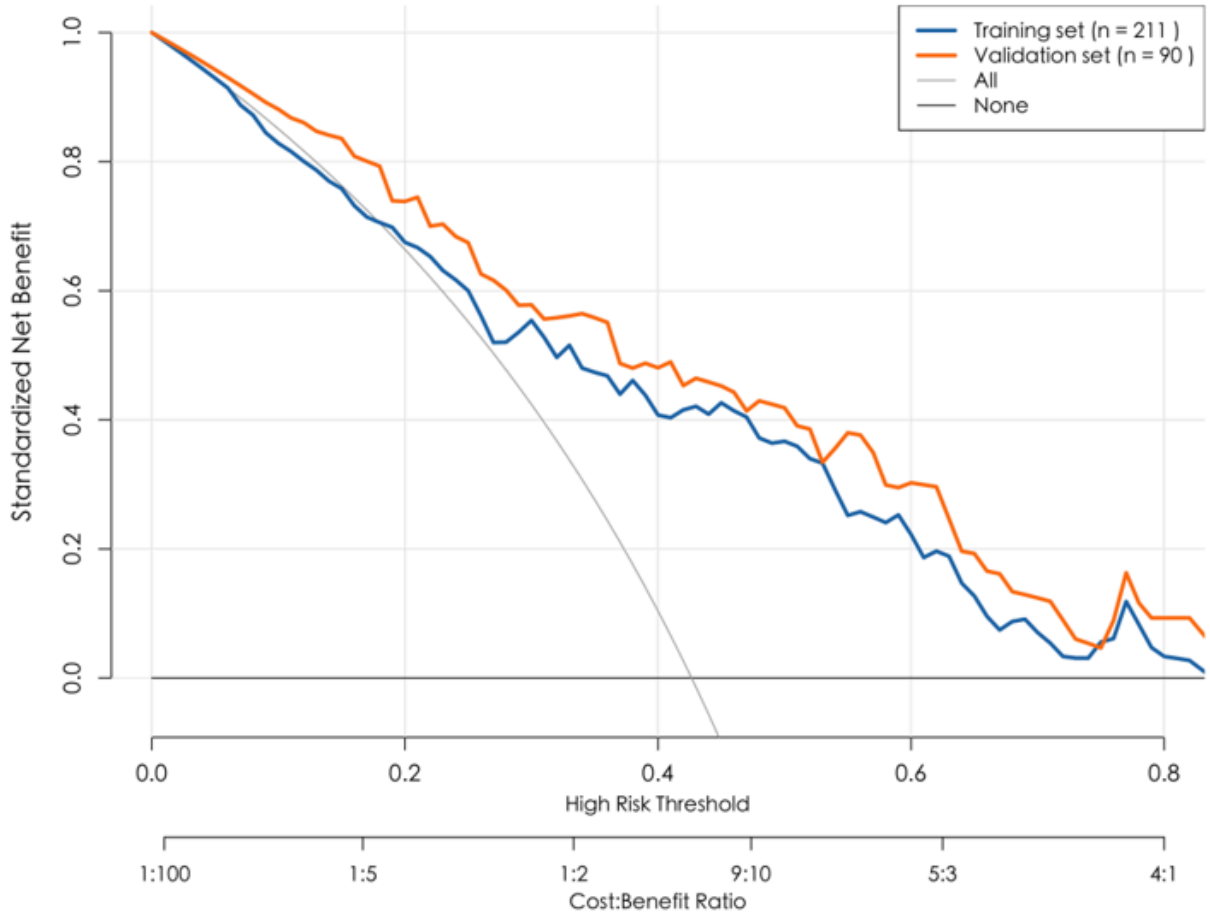


Figure 5

Decision curve