Heliyon 10 (2024) e24017

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Correlation of ultrasound measurement of limb muscle thickness and echo intensity with frailty assessment in elderly patients undergoing malignancies surgery

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ARTICLE INFO

Keywords:
Ultrasound
Frailty
Elderly
Muscle thickness
Echo intensity
Prognosis

ABSTRACT

Introduction: It remains controversial which frailty score correlates with adverse outcomes. Instead of these subjective and time consuming scores, we studied whether ultrasound guided lower extremity thickness measurements more closely are associated with adverse outcomes.
Method: Patients undergoing gastrointestinal malignancy surgery were included as study subjects. Frailty was identified using the FRAIL scale assessment. Ultrasound measured the muscle thickness and echo intensity of the patient's upper and lower limbs. ANOVA was used to analyze the relationship between muscle data and frailty assessment. Significant indicators from the one-way analysis were included in the multivariate logistic regression equation.
Results: A total of 160 study subjects were included, 52 in the normal group, 78 in the prefrailty group, and 30 in the frailty group. The ANOVA showed that there were significant differences in age, hemoglobin, albumin, history of hypertension, history of coronary artery disease, the history of cerebrovascular disease, rate of postoperative complications, rate of transferring to intensive care unit, time out of bed, length of hospitalization, thickness and echo intensity of quadriceps femoris the vastus lateralis and the tibialis anterior, echo intensity of the medial gastrocnemius among the three groups ($P < 0.05$). Pearson's correlation analysis showed FRAIL score was correlated with muscle thickness and echo intensity of the lower limbs. Multifactor logistic regression analysis showed that the prefrailty group was positively correlated with age ($\beta = 0.146$, $P = 0.004$) , echo intensity of the medial gastrocnemius ($\beta = 0.055$, $P = 0.031$), and rate of postoperative complications ($\beta = 1.439$, $P = 0.021$) , also negatively correlated with muscle thickness of the tibialis anterior ($\beta = -2.124$, $P = 0.007$) . The frailty group was positively correlated with age ($\beta = 0.22$, $P = 0.005$) , tibialis anterior echo intensity ($\beta = 0.082$, $P = 0.015$), medial gastrocnemius echo intensity ($\beta = 0.089$, $P = 0.026$), cerebrovascular disease history ($\beta = 2.311$, $P = 0.04$), and postoperative complication rate ($\beta = 2.684$, $P = 0.003$). It was negatively correlated with albumin ($\beta = -0.26$, $P = 0.017$), quadriceps muscle thickness ($\beta = -2.257$, $P = 0.017$), and tibialis anterior muscle thickness ($\beta = -5.408$, $P = 0.001$).

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https://doi.org/10.1016/j.heliyon.2024.e24017
Received 1 April 2023; Received in revised form 7 December 2023; Accepted 2 January 2024
Available online 3 January 2024

Conclusion: Ultrasound measurement of lower (not upper) extremity muscle thickness and echo intensity was significantly associated with discriminating severity of frailty and postoperative outcomes than frailty scores in elderly patients.

1. Introduction

Frailty is a complex clinical condition that is characterized by muscle loss, nutritional deficiency, hormonal changes, and increased inflammation leading to decreased function of different organs and decreased tolerance to stimulation [1]. In recent years, it has been recognized that frailty is diverse and complex, encompassing physical, cognitive, psychological and social domains, and is gradually becoming a biopsychosocial syndrome [1]. Physiological factors in the elderly lead to a decrease in muscle strength and loss of muscle function, which promotes the occurrence of falls and disability [2], making them in low spirits [3], less socializing [4], and triggering psychological disorders such as depression, which ultimately leads to frailty [5]. It is the biological basis of frailty and is the most important and relevant factor in assessing frailty. Along with the aggregate of population ageing and the growth of average life expectancy, there is a clear trend of increasing the rate of anesthesia operations in the elderly. Previous studies have shown that preoperative frailty increases perioperative risks and the incidence of postoperative complications in surgical patients [6]. Moreover, frailty will also increase medical costs and the medical burden of patients [7]. Identifying frailty can contribute to identifying high-risk elderly patients for appropriate surgical and anesthetic management.

Sarcopenia is the basis of physical frailty, which accelerates the progression of frailty, recognized as an important and relevant factor in frailty. In recent years, due to the convenience of ultrasound, it has been widely used by anesthesiologists in the perioperative period [8]. However, the relationship between muscle thickness, muscle mass, frailty and postoperative outcomes is unclear. Therefore, the purpose of this study was to investigate the correlation between ultrasound measurement of muscle thickness and echo intensity with the FRAIL scale assessment, providing a rational basis for ultrasound measurement of muscle thickness to assess frailty and perioperative applications.

2. Method

2.1. Study participants

Data on hospitalized patients in gastrointestinal malignancies surgery from June 2022 to December 2022 were collected. Inclusion criteria: elective gastrointestinal malignancies surgery; age $\geq$65 years; ASAII-III grade. Exclusion criteria: emergency operation in patients with acute heart failure, acute stroke, acute myocardial infarction, severe pneumonia, and other critical diseases; amputation, paralysis, neuromuscular disease, spinal cord injury, brain atrophy, cognitive impairment, dementia, mental abnormalities, inability to cooperate with study, inability to obtain informed consent and obesity (male BMI$\geq$35, female $\geq$34); Patients with capillary leak syndrome or moderate to severe edema; Patients who did not agree to participate in this study.

2.2. Frailty assessment

Frailty status was assessed by the FRAIL scale [9], including fatigue, resistance, ambulation, illnesses, and weight loss. (1) Patients were asked how exhausted they felt in the previous month to determine their level of fatigue. One point was given if they were exhausted all the time or most of the time. (2) Resistance was tested by asking whether it was difficult to ascend a flight of stairs without rest or assistance. If the response was yes, one point was given. (3) Ambulation was evaluated by questioning if it was hard to walk 300 m without additional help. If the response was yes, one point was given. (4) Illness was examined by inquiring if they had hypertension, diabetes, cancer, chronic lung disease, heart attack, congestive heart failure, angina, asthma, arthritis, stroke, or renal disease. It was given one point if they had five or more diseases at the time of the response. (5) Loss of weight was given one point if the patients had dropped more than 5 % of their weight in the previous year. Patients who met 1–2 of the five criteria were considered prefrailty; if they met three of the five criteria, they were considered frailty; The rest is defined as normal.

2.3. Ultrasound measurements

A B-mode ultrasound (SonoSite M-Turbo) with a linear transducer (5–12 Mhz) was used to evaluate muscle thickness (MT)and echo intensity (EI). Except for harmonic tissue imaging, all image optimization modes were turned off to avoid changing image characteristics through software processing. The gain was set to 50, the dynamic range at 66 dB, the frequency at 10 Mhz and all of them were kept constant throughout the examination. The depth was set at 4 cm for upper limb muscles, 6 cm for rectus quadriceps and vastus lateralis muscles, and 4 cm for other muscles. We ensured that different muscles are compared at the same depth [10,11]. The probe direction was perpendicular to the long axis of the muscle. When measuring the muscles of the upper limbs, the patients were in a supine position with elbows extended and relaxed. The probe was placed at the anatomical location corresponding to the largest diameter of the muscles examined described in previous studies [12,13]. The biceps muscle was measured at 2/3 of the distance from the acromion to the antecubital crease (Fig. 1A). The flexor carpi radialis was measured from the midline of the elbow to the upper middle 1/3 of the distal radius (Fig. 1B). When measuring the muscles of the lower limbs, the patients were in a supine position, with their legs extended and relaxed. The quadriceps muscle was measured at the superior border of the patella to the middle and lower 1/3 of the line of the anterior superior iliac spine (Fig. 1C). When measuring the vastus lateralis muscle, the probe was placed at the junction of the middle and lower 1/3 between the greater trochanter and the lateral condyle of the tibia (Fig. 1D). When measuring the anterior tibial muscle, the probe was placed at the inferior border of the patella and the mid-superior 1/3 of the lateral ankle. The long axis of the probe was perpendicular to the long axis of the fibula (Fig. 1E). When measuring the medial gastrocnemius, the probe was placed at the lateral fibula and the mid-superior 1/3 of the lateral tibial condyle (Fig. 1F). When measuring the muscle echo intensity, the same part of the muscle was selected. A 5 mm*5 mm sampling frame was selected to obtain the region of interest (ROI) , and Image-J constructed a pixel intensity histogram to measure the echo intensity. The EI of each muscle was expressed as a value between 0 (black) and 255 (white). In order to reduce measurement errors, couplers were used extensively during the measurements to minimize the contact between the probe and the skin while the measurement points were marked and recorded. The images of each site were measured intermittently three times by the same physician. The average was taken for further analysis.

2.4. Statistical analysis

SPSS 25.0 statistical software was employed to analyze the data. The Shapiro-Wilk test was performed to test the normality. Descriptive data were presented as the means ± SDs. Qualitative variables were expressed as frequencies and percentages (%). The associations between the FRAIL scale and muscle data were examined using Pearson's correlation analysis. Comparison between multiple groups was performed by one-way ANOVA. The indexes that were significant in one-way ANOVA were included in the multiple logistic regression equation. If $P < 0.05$ was considered statistically significant.

3. Results

3.1. Demographics and characteristics

The demographics and characteristics of the participants are shown in Table 1. A total of 160 participants (105 men and 55 women) were enrolled in the study. FRAIL assessments were used as the reference standard. Ultrasound assessments were used as index tests.

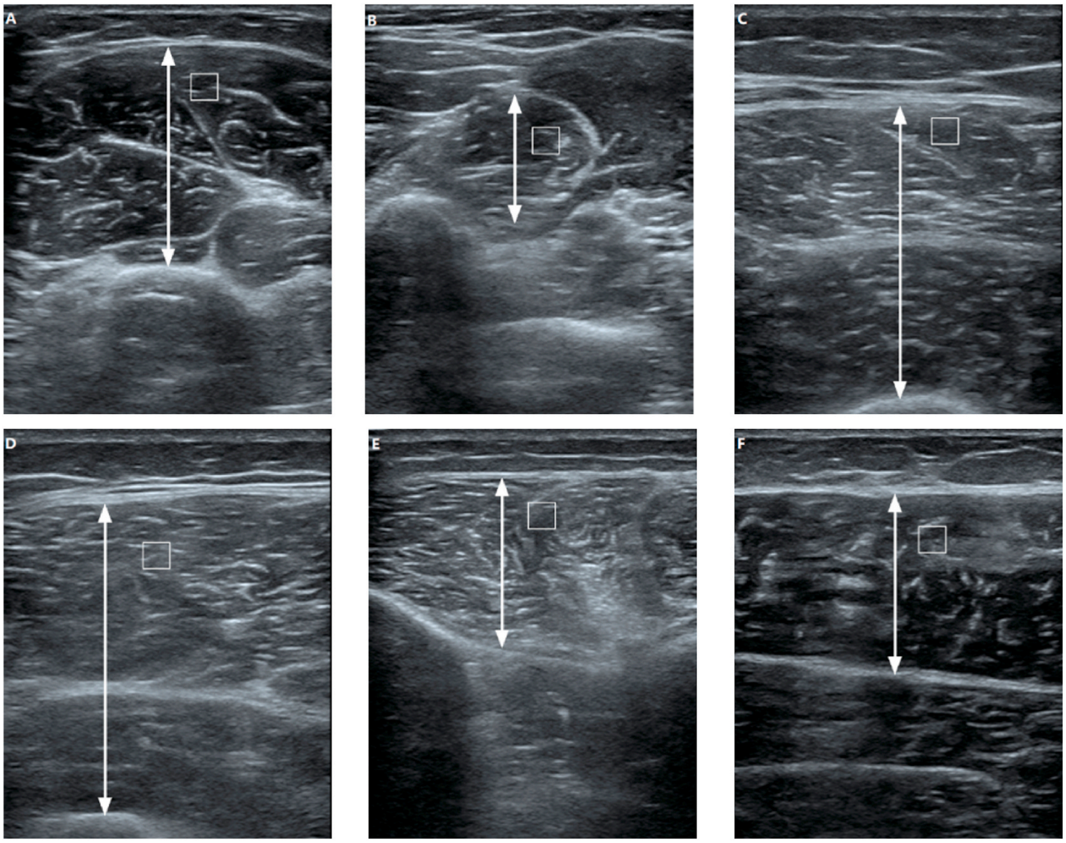

Fig. 1. Typical ultrasound images of the thickness and Echo Intensity of the biceps brachii muscle, flexor carpi radialis, quadriceps femoris, vastus lateralis muscle, tibialis anterior muscle, and medial gastrocnemius muscle.

They were divided into three groups according to the FRAIL scale, including 52 cases (32.5 %) in the normal group, 78 cases (48.75 %) in the prefrailty group, and 30 cases (18.75 %) in the frailty group. One-way ANOVA revealed that age, hemoglobin, albumin, history of hypertension, history of coronary disease, history of cerebrovascular disease, incidence of postoperative complications, incidence of transferring to the intensive care unit, time out of bed, and length of hospitalization were statistically different among the three groups ($P < 0.05$), in which the age of the prefrailty group was higher than that of the patients in the normal group ($P < 0.05$). There were statistical differences between the frailty group and the normal group in age, hemoglobin, albumin, history of hypertension, history of coronary disease, history of cerebrovascular disease, incidence of postoperative complications, incidence of transferring to the intensive care unit, and length of hospitalization ($P < 0.05$). The remaining indicators were not statistically significant among the three groups ($P > 0.05$).

3.2. Analysis of upper and lower extremity muscle thickness and echo intensity with frailty assessment

Muscle thickness and echo intensity of the biceps brachii, flexor carpi radialis, quadriceps femoris, vastus lateralis, tibialis anterior, and medial gastrocnemius were measured by ultrasound in all patients. It could be seen from the data in Table 2 that the thickness and echo intensity of quadriceps femoris, vastus lateralis, tibialis anterior, and medial gastrocnemius were statistically different among the three groups ($P < 0.05$). The thickness of the tibialis anterior in the prefrailty group and the thickness of quadriceps femoris, vastus lateralis, and tibialis anterior in the frailty group were all lower than those in the normal group ($P < 0.05$). The echo intensity of the medial gastrocnemius in the prefrailty group and the quadriceps femoris, vastus lateralis, tibialis anterior, and medial gastrocnemius in the frailty group were higher than those in the normal group ($P < 0.05$). The thickness of the quadriceps and lateral femoris in the frailty group was lower than in the prefrailty group ($P < 0.05$). (Fig. 2A and B). However, the ANOVA showed that these results of upper limb muscles were not statistically significant ($P > 0.05$).

There was no correlation between FRAIL scale with thickness and echo intensity of biceps (thickness: $R = -0.98$ $P = 0.218$; gray value: $R = 0.142$ $P = 0.073$) (Fig. 3A and B), flexor carpi radialis (thickness: $R = -0.128$ $P = 0.106$; gray value: $R = 0.133$ $P = 0.095$) (Fig. 3C and D)and thickness of medial gastrocnemius (thickness: $R = -0.112$ $P = 0.158$) (Fig. 3K). However, it was significantly correlated with muscle thickness and echo intensity of the lower limbs, including the quadriceps (thickness: $R = -0.260$ $P = 0.001$; gray value: $R = 0.220$ $P = 0.005$) (Fig. 3E and F), lateral femoris (thickness: $R = -0.241$ $P = 0.002$; gray value: $R = 0.225$ $P = 0.004$) (Fig. 3G and H), anterior tibialis (thickness: $R = -0.280$ $P < 0.001$; gray value: $R = 0.196$ $P = 0.013$) (Fig. 3I and J), and medial gastrocnemius (gray value: $R = 0.253$ $P = 0.001$) (Fig. 3L).

Table 1
General data of patients in different groups.

	normal	Prefrailty	frailty	χ2/F	P
N	52	78	30		
Gender(N)					
Male	37 (71.2)	51 (65.4)	17 (56.7)	1.77	0.412
Female	15 (28.8)	27 (34.6)	13 (43.3)		
Age (years)	70.13 ± 4.15	73.08 ± 5.62*	73.27 ± 5.86**	5.76	**0.004**
Creatinine (mmol/L)	62.42 ± 13.22	62.73 ± 17.50	68.50 ± 36.40	0.94	0.393
Hemoglobin (mmol/L)	126.25 ± 25.13	117.05 ± 24.02	111.27 ± 21.56*	4.20	**0.017**
Albumin (mmol/L)	37.10 ± 3.28	35.62 ± 3.72	34.33 + 3.78**	5.96	**0.003**
BMI(kg/m2)	22.92 ± 3.15	23.18 ± 3.41	24.30 ± 3.42	1.74	0.180
Hypertension(N)					
Yes	19 (36.5)	29 (37.2)	19 (63.3)	7.00	**0.030**
No	33 (63.5)	49 (62.8)	11 (36.7)		
Diabetes(N)					
Yes	7 (13.5)	12 (15.4)	8 (26.7)	2.61	0.272
No	45 (86.5)	66 (84.6)	22 (73.3)		
Coronary disease (N)					
Yes	4 (7.7)	12 (15.4)	11 (36.7)	11.63	**0.003**
No	48 (92.3)	66 (84.6)	19 (63.3)		
Cerebrovascular disease(N)					
Yes	3 (5.8)	8 (10.3)	12 (40)	20.21	< **0.001**
No	49 (94.2)	70 (89.7)	18 (60)		
Postoperative outcome					
Time out of bed (days)	1.33 ± 0.59	1.45 ± 0.73	2.33 ± 1.03**##	19.06	< **0.001**
Postoperative complication(N)					
Yes	8 (15.4)	25 (32.1)	20 (66.7)	22.66	< **0.001**
No	44 (84.6)	51 (67.9)	10 (33.3)		
transferring to Intensive care unit (N)					
Yes	2 (3.8)	9 (11.5)	10 (33.3)	14.84	**0.001**
No	50 (96.2)	69 (88.5)	20 (66.7)		
Length of hospitalization (days)	14.13 ± 3.84	15.70 ± 5.23	17.10 ± 6.88*	3.22	**0.043**

Note: compared with the normal group, * means $P < 0.05$; ** indicates $P < 0.01$; compared with the prefrailty group, # means $P < 0.05$; ## indicates $P < 0.01$.

Table 2
Muscle quality of upper and lower limbs of patients in different groups.

	Muscle quality	Normal	Prefrailty	Frailty	F	P
Muscle thickness (cm)	Biceps brachii	2.80 ± 0.46	2.74 ± 0.45	2.68 ± 0.51	0.74	0.481
	Flexor carpi radialis	1.49 ± 0.24	1.41 ± 0.24	1.38 ± 0.35	1.99	0.140
	Quadriceps femoris	2.23 ± 0.69	2.04 ± 0.58	1.71 ± 0.55**#	6.88	**0.001**
	Vastus lateralis	2.18 ± 0.58	2.08 ± 0.57	1.78 ± 0.45**#	4.88	**0.009**
	Tibialis anterior	1.88 ± 0.30	1.74 ± 0.32*	1.60 ± 0.22**	8.49	< **0.001**
	Medial gastrocnemius	1.41 ± 0.25	1.33 ± 0.35	1.31 ± 0.26	1.56	0.213
Echo intensity (au)	Biceps brachii	32.95 ± 8.55	35.73 ± 11.90	38.45 ± 10.83	2.60	0.77
	Flexor carpi radialis	20.47 ± 4.37	20.60 ± 5.22	22.44 ± 4.85	1.84	0.163
	Quadriceps femoris	48.89 ± 14.47	54.95 ± 16.69	59.33 ± 10.88**	5.026	**0.008**
	Vastus lateralis	46.76 ± 13.71	52.54 ± 15.74	56.30 ± 8.96*	4.92	**0.009**
	Tibialis anterior	50.11 ± 14.21	55.23 ± 13.59	58.87 ± 8.66*	4.78	**0.01**
	Medial gastrocnemius	51.32 ± 7.40	56.62 ± 11.70*	58.76 ± 8.27**	6.75	**0.002**

Note: compared with the normal group, * means $P < 0.05$; ** indicates $P < 0.01$; compared with the prefrailty group, # means $P < 0.05$; ## indicates $P < 0.01$.

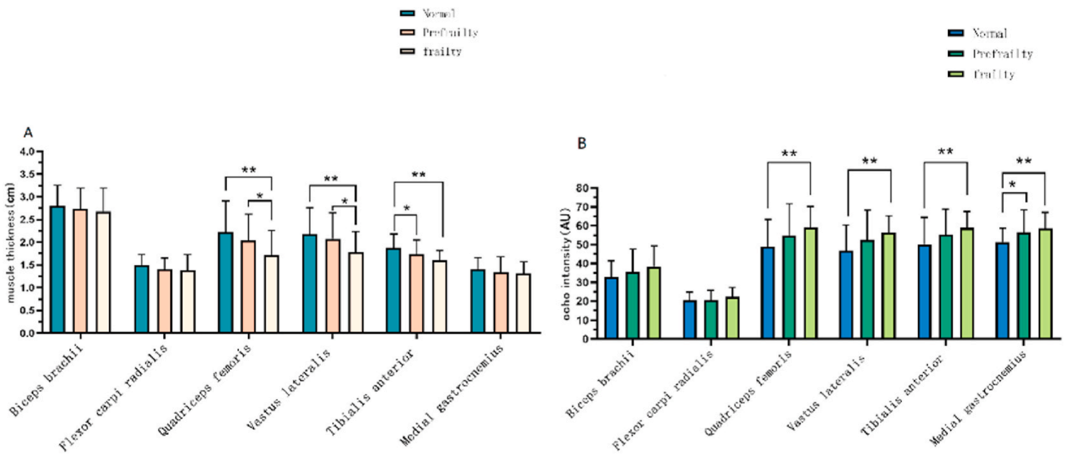

Fig. 2. Comparision of muscle quality in different groups
A: Comparision of thickness in different groups; B: Comparision of echo intensity in different groups
Note: * means $P < 0.05$; ** means $P < 0.01$.

3.3. Multiple logistic regression analysis of FRAIL score, muscle data, and postoperative outcome

Owing to the obvious relationship between age, hemoglobin, albumin, past medical history, and frailty in this study, multivariate regression analysis was performed with the FRAIL score as the dependent variable and the meaningful variables from univariate analysis as the independent variables, as shown in Table 3. The results of this study indicated that age, tibialis anterior thickness, medial gastrocnemius echo intensity, and postoperative complication rate were closely related with prefrailty ($P < 0.05$). Prefrailty was positively correlated with age ($\beta = 0.146$, $P = 0.004$), echo intensity of the medial gastrocnemius ($\beta = 0.055$, $P = 0.031$), and postoperative complication rate ($\beta = 1.439$, $P = 0.021$), and negatively correlated with muscle thickness of the tibialis anterior ($\beta = -2.124$, $P = 0.007$). Significantly, age, albumin, quadriceps thickness, tibialis anterior thickness and echo intensity, medial gastrocnemius echo intensity, cerebrovascular disease history, and postoperative complication rate were observed as the risk factors for the frailty group ($P < 0.05$). The frailty group was positively correlated with age ($\beta = 0.22$, $P = 0.005$) , tibialis anterior echo intensity ($\beta = 0.082$, $P = 0.015$) medial gastrocnemius echo intensity ($\beta = 0.089$, $P = 0.026$), cerebrovascular disease history ($\beta = 2.311$, $P = 0.04$), and postoperative complication rate ($\beta = 2.684$, $P = 0.003$). It was negatively associated with albumin ($\beta = -0.26$, $P = 0.017$), quadriceps thickness ($\beta = -2.257$, $P = 0.017$), and tibialis anterior thickness ($\beta = -5.408$, $P = 0.001$).

4. Discussion

In this study, we measured upper and lower limb thickness and echo intensity by ultrasound in elderly surgical patients over 65 years old with gastrointestinal malignancies. We found that lower limb muscle thickness and echo intensity were significantly correlated with frailty and postoperative outcomes. It indicated that the great potential of lower limb muscles in the assessment of frailty and the great advantages of ultrasound in frailty assessment and perioperative. At the same time, the results of this study suggested improving the preoperative status of patients will help reduce the perioperative risk of patients.

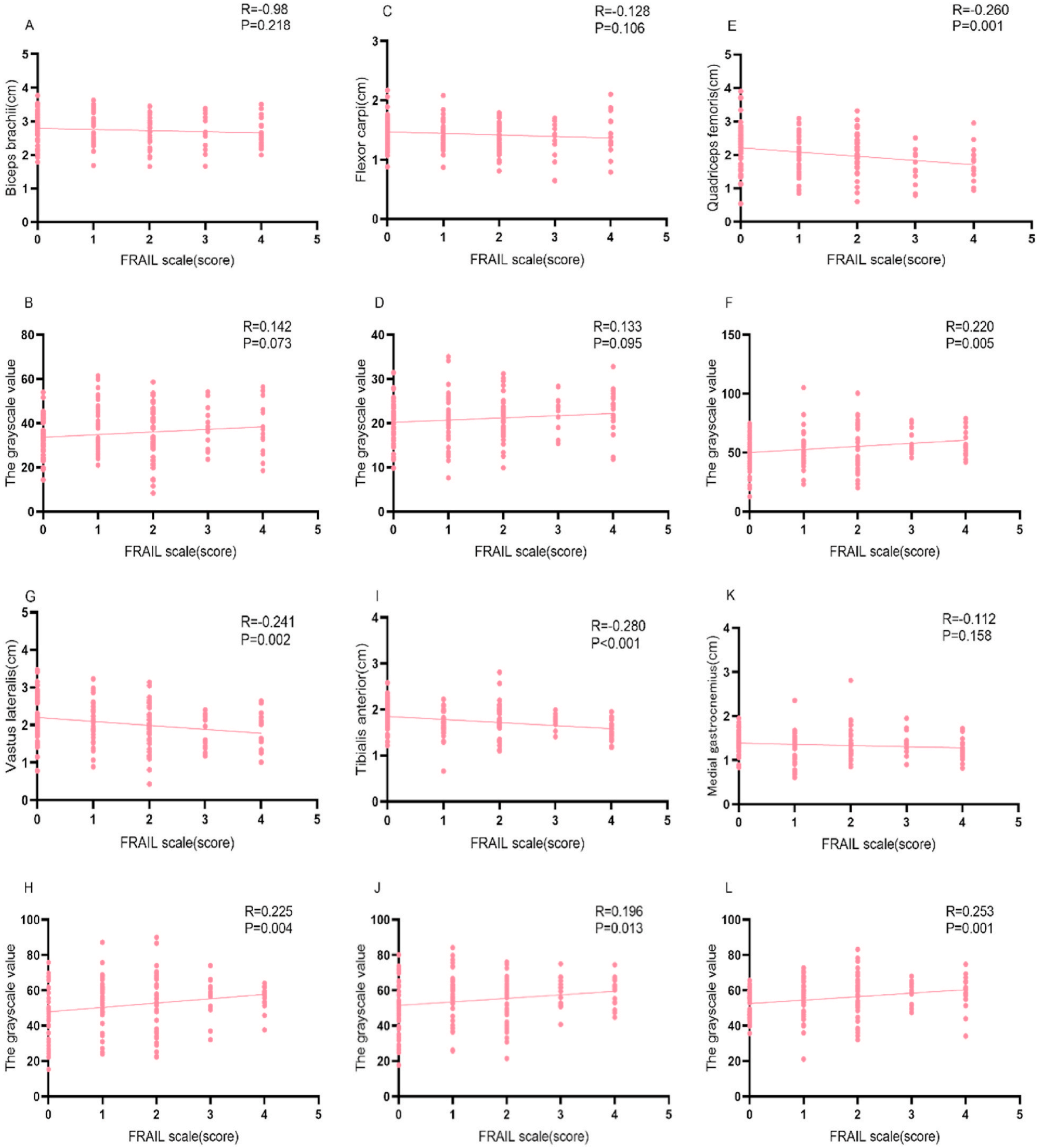

Fig. 3. Correlation between FRAIL scale and limb muscle thickness and echo intensity.

The results of this study showed that the thickness and echo intensity of the lower limb muscles in the frailty group were significantly different compared with the normal and prefrailty groups. As the degree of frailty progresses, the thickness of quadriceps, lateral femoral, and anterior tibial gradually decreased, and the echo intensity increased. Pearson's correlation analysis showed it was significantly correlated with muscle thickness and echo intensity of the lower limbs. With aging, muscle function decreases in older people due to a decline in muscle composition and infiltration of adipose tissue, which may account for the increased of muscle echo intensity [14]. In contrast, the muscle thickness and echo intensity of the upper limb had no statistical significance. These results were consistent with previous studies [10,15], At the same time, based on the research of Canales et al. [16], we found that the thickness and echo intensity of the vastus lateralis and tibialis anterior muscles were also closely related to the assessment of frailty. It provides more

Table 3
Multiple Logistic regression analysis of frailty score, muscle data, and postoperative outcome of patients in different groups.

Prefrailty		B	Wald	P	OR	95%CI
	Age	0.146	8.143	**0.004**	1.157	1.047–1.279
	Hemoglobin	−0.009	0.935	0.334	0.991	0.973–1.009
	Albumin	−0.102	2.27	0.132	0.903	0.79–1.031
	Quadriceps femoris					
	MT	−0.465	1.566	0.211	0.628	0.303–1.301
	EI	0.029	3.024	0.082	1.029	0.996–1.063
	Vastus lateralis					
	MT	0.101	0.057	0.812	1.106	0.483–2.535
	EI	0.009	0.271	0.603	1.009	0.976–1.043
	Tibialis anterior					
	MT	−2.124	7.311	**0.007**	0.12	0.026–0.557
	EI	0.033	2.759	0.097	1.033	0.994–1.074
	Medial gastrocnemius					
	EI	0.052	4.646	**0.031**	1.054	1.005–1.105
	Time out of bed	0.095	0.07	0.792	1.1	0.541–2.237
	Length of hospitalization	0.035	0.421	0.517	1.036	0.931–1.153
	Hypertension	−0.14	0.072	0.788	0.869	0.313–2.415
	Coronary disease	0.52	0.434	0.51	1.682	0.358–7.906
	Cerebrovascular Disease	0.302	0.108	0.743	1.352	0.223–8.187
	Postoperative complication	1.439	5.308	**0.021**	4.215	1.24–14.33
	Transferring to Intensive care unit	0.273	0.068	0.794	1.315	0.169–10.214
	Age	0.22	7.98	**0.005**	1.246	1.07–1.451
	Hemoglobin	−0.005	0.068	0.794	0.995	0.962–1.03
Frailty	Albumin	−0.257	5.662	**0.017**	0.773	0.625–0.956
	Quadriceps femoris					
	MT	−1.425	4.707	**0.03**	0.24	0.066–0.871
	EI	0.038	2.059	0.151	1.039	0.986–1.094
	Vastus lateralis					
	MT	−0.923	1.22	0.269	0.397	0.077–2.045
	EI	0.05	2.564	0.109	1.052	0.989–1.118
	Tibialis anterior					
	MT	−5.408	11.178	**0.001**	0.004	0–0.107
	EI	0.082	5.953	**0.015**	1.086	1.016–1.16
	Medial gastrocnemius					
	EI	0.089	4.931	**0.026**	1.093	1.011–1.183
	Time out of bed	1.018	3.578	0.059	2.769	0.964–7.955
	Length of hospitalization	−0.004	0.003	0.954	0.996	0.862–1.151
	Hypertension	1.107	1.671	0.196	3.024	0.565–16.197
	Coronary disease	1.149	1.245	0.264	3.156	0.419–23.749
	Cerebrovascular Disease	2.311	4.212	**0.04**	10.081	1.11–91.601
	Postoperative complication	2.684	9.097	**0.003**	14.643	2.56–83.771
	Transferring to Intensive care unit	0.955	0.571	0.45	2.599	0.218–30.955

muscle choices for the follow-up research on sarcopenia and frailty. Although there was a trend of decrease in the upper limb muscle mass, the observed difference in this study was insignificant. These results may be due to the muscle mass declining at inconsistent rates in different body areas. With advancing age and lack of physical activity, the muscle decline rate of the lower limbs is faster than that of the upper limbs; Sometimes the upper limb muscle mass of the elderly will even increase due to compensation [17]. This may be the reason why the thickness and echo intensity of the biceps brachii and flexor carpi radialis made no significant difference to frailty. The thickness of the medial gastrocnemius was not statistically significant between the frailty group and the normal group, which is inconsistent with previous research [11]. It was possible that the echo intensity of the medial gastrocnemius was more relevant for frailty assessment. At the same time, our research found that frailty patients had worse postoperative outcomes (such as time out of bed, postoperative complications, intensive care unit stay and length of hospitalization), were older and had more underlying diseases. It is recommended to actively treat the basic disease of the patient before the operation, incorporating moderate exercise [18], improving nutrition, addressing patients' concerns about their illnesses, reducing preoperative anxiety, and enhancing the overall state of patients [19]. During the operation, efforts should be made to minimize surgical trauma, individualize the anesthesia plan, reduce stress in frail elderly patients, and prevent the occurrence of complications such as cognitive dysfunction [20]. Postoperatively implementing the patients' multimodal analgesia, encouraging early mobilization and respiratory function exercises, providing adequate nutritional support, and prioritizing humanistic nursing care is crucial. Therefore, by analyzing the muscle mass of limb muscles, it is possible to detect sarcopenia at an early stage, correct the patient's frail state, and adjust the surgical and anesthesia protocols, which is vital for improving the prognosis and quality of life in the elderly.

Currently, preoperative frailty is assessed mainly through the Fried Frailty Scale [21], the Frailty Index (FI) [22], the Clinical Frailty Scale (CFS) [23], and so on. The current scoring scales heavily rely on patients' subjective information, and the scoring items are complex, making it difficult to conduct rapid preoperative assessments. Sarcopenia is the biological basis of frailty and is the most important and relevant factor in assessing frailty. Muscle thickness measured by ultrasound was found to have a strong correlation with muscle mass measured by dual-energy X-ray absorptiometry, which is considered the gold standard [24]. Ultrasound has several advantages over other imaging tools, such as CT and MRI, including safety, convenience, non-invasiveness, and no radiation exposure. In addition, ultrasound can continuously, dynamically, and repeatedly measure muscle thickness and mass. There are many studies examining muscle mass by ultrasound in emergency medicine [25]and intensive care medicine [26,27], but few studies in the perioperative period. The echo intensity increase in the elderly is caused by the decrease of muscle fibers and the increase of fat tissue infiltration. It leads to muscle mass decrease. Muscle thickness and mass are closely related to muscle strength and function and are a reliable indicator for early detection of sarcopenia [14,28]. Muscle thickness and mass also play a crucial role in the physiological function of older adults [29]. Therefore, lower muscle thickness and higher echo intensity indicate poorer muscle mass, which associated with sarcopenia and an adverse prognosis. In recent years, anesthesiologists have widely used ultrasound in the perioperative period due to its convenience. Additionally, ultrasound has shown good reliability and validity in quantitatively measuring muscles [30]. A study found that after a brief 20-min training session, the intraclass correlation coefficients (ICC) for ultrasound echo intensity of the flexor carpi radialis and rectus femoris were $\geq$0.85, which correlated with the measurements made by experienced sonographers (ICC $\geq$0.84) [31]. It suggests that non-medical personnel can quickly learn ultrasound measurement technology after simple training, which is significant for the early identification of sarcopenia and frailty evaluation. In elderly surgical patients, ultrasound can be used as an additional auxiliary means to assess frailty. Ultrasound can evaluate the muscle mass of patients and according to the muscle mass to appropriate surgery and anesthesia plans [32]. At the same time, muscle mass provides early targeted intervention, such as nutritional support [33] and rehabilitation [34], to reduce the patient's muscle loss and improve the postoperative outcome of the frail patient. Early detection of frailty, the prodromal state of the need for nursing care, and the extension of healthy life expectancy are important [35].

Several limitations need to be noted regarding the present study. Firstly, data were collected only from gastrointestinal malignancy patients and Non-tumor surgical patients were not collected. Secondly, it is unfortunate that the study was not included the cross-sectional muscle area and fascicle angle data. In future studies, the sample population could be expanded to include other indicators of muscle for further evaluation. Frailty is a diverse and complex syndrome encompassing various physical, cognitive, psychological, and social domains. However, this study focuses solely on the physiological aspects and does not consider the psychological and social factors. Future research should aim to incorporate a comprehensive evaluation of multiple systems and include larger sample sizes and more measurement data. Additionally, conducting numerous horizontal and longitudinal studies will be necessary to establish a standardized muscle measurement criterion and develop practical frailty assessment and intervention programs.

In conclusion, muscle thickness and echo intensity measured by ultrasound were significantly associated with frailty, especially quadriceps femoris, vastus lateralis, and tibialis anterior, and significantly associated with worse postoperative outcome (such as time out of bed, postoperative complications, intensive care unit stay and length of hospitalization). Due to the subjective and time-consuming frailty score, it was not suitable for emergency and coma patients. Therefore, we suggested that ultrasound measurement of lower limb muscles (not upper limbs) should be used to evaluate the patients' degree of frailty and predict the adverse outcomes. The intervention measures according to the measurement results of the patients to improve the basic condition, minimize the perioperative risk and reduce postoperative complications. As a reliable and gradually maturing research method, ultrasound-derived limb muscle thickness and echo intensity have a promising future in assessing frailty and perioperative period.

Ethics statement

All patients provided written informed consent to participate in this study and they were informed that they could refuse to participate at any stage. This clinical study was approved by the Ethics Committee of Yantai Yuhuangding Hospital【2021-631】(Registration number: ChiCTR2300068307).

Funding statement

Scientific Research Fund of Yantai Yuhuangding Hospital affiliated with Qingdao University and Special Fund for Clinical Research of Shandong Medical Association (No: YXH2021ZX023).

Data availability statement

The data associated with this study has not been deposited into a publicly available repository.
Data will be made available on request.

CRediT authorship contribution statement

Chengjian Xin: Writing – original draft, Software, Methodology, Formal analysis, Data curation. **Mengzhuo Ma:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Qian Wang:** Writing – original draft, Software, Formal analysis, Data curation. **Tao Li:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Qiaoxia Sun:** Visualization, Validation, Resources. **Meiru Jiang:** Software, Project administration, Methodology. **Juan Du:** Resources, Funding acquisition. **Zhi Li:** Writing – review & editing, Validation, Resources, Project administration. **Jiahai Ma:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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