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Original article

Associations between skeletal muscle mass index, nutritional and functional status of patients with oesophago-gastric cancer

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SUMMARY

Background and aims: Cancer patients frequently suffer from disease-related malnutrition and functional decline. The aim of the current study is to investigate the association between traditional methods of nutritional assessment (unintentional weight loss, Patient Generated-Subjective Global Assessment, anthropometric measurements), functional assessment and muscle mass assessment in oesophago-gastric cancer patients prior to surgery.

Methods: A cross-sectional study was performed in 108 consecutive patients with oesophageal and gastric cancer who were admitted for surgery in the First Department of Surgery, Laikon General Hospital, Athens, Greece. The assessment of muscle mass was based on preoperative Skeletal Muscle Mass Index (SMI) values. The assessment of malnutrition was based on the Patient Generated Subjective Global Assessment, whereas laboratory markers and anthropometric measurements were also recorded. Muscle strength and physical performance were evaluated by measuring patients' handgrip strength and gait speed respectively.

Results: 76.8% of the study sample were severely malnourished and moderately or suspected of being malnourished, while the prevalence of low muscle mass was 49.1%. Age was significantly higher in low SMI patients compared to normal SMI individuals (67.2 ± 9.2 vs 60 ± 10.8, $p < 0.001$). Albumin was significantly lower in low SMI compared to normal SMI patients, as well as BMI, mid-upper arm circumference, calf circumference and corrected mid arm muscle area. Moreover, malnourished patients exhibited higher rates of low muscle mass (57.8% vs 42.2%, $p = 0.022$) than well-nourished patients. SMI was also significantly correlated with patients' handgrip strength and gait speed.

Conclusions: Low muscle mass is strongly correlated with malnutrition and should be taken into consideration when evaluating the nutritional status of patients with oesophago-gastric cancer.

1. Introduction

Cancer patients frequently suffer from disease-related malnutrition, the severity of which is strongly linked to the type of the disease and the therapeutic regimens. The majority of cancer patients are not able to achieve a positive energy balance and in many cases, they cannot maintain their initial body weight, resulting in tissue wasting and muscle degradation [1]. In particular, oesophago-gastric cancer patients have markedly poor nutritional status due to tumour location that often impedes adequate nutritional intake, contributing to earlier manifestation of malnutrition. Current research emphasizes on various factors regarding nutritional status, functional status and body composition that are related to short-and long-term cancer outcomes and potentially affect quality of life of cancer patients [2–4].

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Perioperative nutritional assessment is of great significance, since clinicians have the opportunity to detect patients in need of perioperative nutritional support. Among the various methods of nutritional assessment, anthropometric measurements, body mass index (BMI) values and the percentage of unintentional weight loss are commonly used criteria of malnutrition in the clinical setting, as well as biochemical markers that reflect patients' nutritional status and give information on body composition of these patients [5,6]. In addition, there are extensive questionnaires, such as the Patient Generated Subjective Global Assessment (PG-SGA) which is a practical tool for nutritional screening and assessment in malnourished hospital patients with cancer.

Muscle mass assessment has garnered considerable attention as an emerging method of nutritional assessment. Low muscle mass is frequently seen in oncologic patients, ascribed mainly to the catabolic nature of cancer [7–9]. Low muscle mass is associated with higher incidence of postoperative pulmonary complications in oesophageal cancer patients [10], while it is also associated with poor long-term prognosis for patients undergoing surgery for oesophagogastric cancer junction or upper gastric cancer [11]. These findings suggest that the assessment of muscle mass is a clinically useful tool that should be taken into consideration when evaluating the nutritional status of patients with oesophago-gastric cancer.

Nevertheless, little is known about the relationship between traditional methods of preoperative nutritional status evaluation, functional status and muscle mass in oesophago-gastric cancer patients. The aim of our study is to investigate the association between traditional methods of nutritional assessment (unintentional weight loss, PG-SGA, anthropometric measurements), functional assessment (handgrip strength, gait speed) and skeletal muscle mass assessment in oesophago-gastric cancer patients prior to surgery.

2. Methods

2.1. Study population

One hundred and twenty five consecutive patients (≥18 years old) with primary oesophageal and gastric cancer, were admitted for surgery in the First Department of Surgery, Laikon General Hospital, Athens, Greece between September 2015 and September 2018. Participants were recruited after cancer diagnosis was made and data were collected before surgery. Seventeen patients were excluded from this study due to a lack of suitable CT image for the evaluation of skeletal muscle mass index (SMI) within 90 days before surgery. Consequently, the study sample consisted of 108 patients with oesophageal (n = 60) and gastric (n = 48) cancer. Informed written consent was obtained from all patients prior to study commencement. The study protocol was approved by the Human Research Ethics Committee of Laikon General Hospital.

2.2. Demographic and clinical data

At inclusion, demographic characteristics of the patients included age and gender, whereas clinical data included preoperative treatment and laboratory markers. Preoperative laboratory data included fasting blood sample analyzed for haemoglobin (Hb), haematocrit (HCT), albumin (alb), total lymphocyte count (TLC), neutrophil count and platelet count. The neutrophil-to-lymphocyte ratio (NLR) was calculated as the absolute neutrophil count divided by the absolute lymphocyte count. The platelet-to-lymphocyte ratio (PLR) was calculated as the absolute platelet count divided by the absolute lymphocyte count.

2.3. Anthropometric measurements

Patients wearing light clothing without shoes were weighed using a Seca digital scale, graduated to 0.1-kg intervals. Body height was measured to the nearest 1.0 cm with a mechanical wall tape, graduated at 1-mm intervals. BMI was calculated as weight (kg) divided by the square of height (m^2). Patients were classified according to the World Health Organization criteria as underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25.0–29.9) or obese (BMI >30). Mid-upper arm circumference (MAC) was measured at the midpoint between the olecranon and the acromial process using a non-extensible measuring tape. Skinfold measurements were obtained using a caliper (Lange Skinfold Caliper). Triceps skinfold (TSF) was measured directly over the triceps muscle on the posterior midline of the upper arm, at the midpoint between the acromial process of the scapula and the olecranon of the ulna. Mid-arm muscle circumference (MAMC) was calculated using the following equation: $MAMC = MAC - \pi \times [TSF / 10]$. Mid-arm muscle area (MAMA) was recorded using the following equation: $MAMA = MAMC^2/4\pi$, whereas corrected mid-arm muscle area (cMAMA) derived from the following equation: MAMA-10 (males) and MAMA-6.5 (females) [12,13]. Calf circumference was measured with a measuring tape at the point of greatest circumference.

2.4. Clinical assessment of nutritional status

The assessment of malnutrition was based on the PG-SGA questionnaire. The scored PG-SGA is an extensive questionnaire divided into two sections. The first section (Weight history, Symptoms, Food intake, Activities and Function) was completed by the patients, whereas the second section (Disease, Metabolic Demands and Physical Exam) was completed by a trained and expert dietitian. Numerical values were also recorded with higher PG-SGA scores demonstrating greater risk of malnutrition [14]. Patients were classified as A) well nourished, B) moderately malnourished/suspected malnutrition and C) severely malnourished according to PG-SGA. Moreover, information on unintentional weight loss 6 months prior to surgery were also collected.

2.5. Functional assessment

Muscle strength was evaluated by handgrip strength measured with the hand-held dynamometer (Takei 5401 Digital Dynamometer). Three measurements were collected from each hand and the mean value is used in all analyses [15]. Physical performance was assessed by measuring patients' gait speed on a 4-m course.

2.6. Skeletal muscle mass assessment

Routine computed tomography (CT) scans conducted for cancer staging before surgery were used to assess the total cross-sectional areas of skeletal muscle (cm^2) at the caudal end of the third lumbar vertebra. The L3 region contains psoas, para-spinal muscles (erector spinae, quadratus lumborum), and the abdominal wall muscles (transversus abdominus, external and internal obliques, rectus abdominus). These muscles were identified based on their anatomic features by a trained researcher. Muscle mass was quantified within a Hounsfield unit (HU) range of −29 to +150 HU using Slice-O-Matic software (v.4.3; Tomovision, Montreal, Quebec, Canada). As a measure of skeletal muscle mass, the total cross sectional skeletal muscle area (cm^2) was normalized for stature divided by squared height (m^2) and expressed as SMI (cm^2/m^2). The sex-specific cut-offs for low muscle mass (52.4 cm^2/m^2 for males

and 38.5 cm^2/m^2 for females) were used, in order to classify study participants as low or normal SMI patients [16].

2.7. Statistical analysis

Descriptive statistics were used to analyze the frequencies, means and standard deviations (SDs) of the study variables, regarding clinical, laboratory, nutritional, and anthropometric data, as well as SMI assessment for the overall study sample. Normal distribution was tested using the Shapiro–Wilk test. We compared baseline characteristics of participants between low and normal SMI patients using chi-square or Fisher's exact test for categorical variables and independent samples t-test for continuous variables. Pearson correlation coefficient was performed to assess the relationship between continuous variables. Missing data were excluded from the analysis. The level of significance was set at p-values $\leq$0.05. The statistical analysis was performed with SPSS (SPSS Inc., Chicago, IL) statistical software package version 20.0.

3. Results

3.1. Baseline data of study participants

Patients' baseline data are summarized in Table 1. The mean age of the patients was 63.6 ± 10.6 years. 83.3% of the study participants were males, while 55.6% and 44.4% suffered from oesophageal and gastric cancer respectively (Table 1). 23.1% of the study sample were well nourished (PG-SGA grade A), 29.6% of patients were moderately or suspected of being malnourished (PG-SGA grade B), whereas 47.2% of the study sample were severely malnourished (PG-SGA grade C). The prevalence of low muscle mass, according to SMI, was 49.1%. The mean unintentional weight loss was 8.75 ± 10.92%, while 63.9% of the patients reported ≥5% unintentional weight loss (Table 1).

Table 1
Baseline data of study participants.

Characteristic	Total sample (n = 108)
Age (years)	63.6 ± 10.6
Sex	n (%)
Male	90 (83.3)
Female	18 (16.7)
Type of cancer	n (%)
Oesophageal	60 (55.6)
Gastric	48 (44.4)
Neoadjuvant chemotherapy	n (%)
Yes	26 (24.1)
No	82 (75.9)
Neoadjuvant radiotherapy	n (%)
Yes	2 (1.9)
No	106 (98.1)
Hb (g/dL)	12.66 ± 1.99
HCT (%)	37.87 ± 5.33
Albumin (g/dL)	4.05 ± 0.47
TLC (K/μL)	1.71 ± 0.67
NLR	3.03 ± 2.04
PLR	163 ± 84.64
BMI (kg/m^2)	27.18 ± 5.2
BMI categories	n (%)
<18.5	4 (3.7)
18.5–24.9	32 (29.6)
25.0–29.9	43 (39.8)
>30	29 (26.9)
MAC (cm)	30.42 ± 4.05
cMAMA (cm)	44.99 ± 13.00
Calf circumference (cm)	35.72 ± 3.83
PG-SGA	9.20 ± 5.97
PG-SGA Grades	n (%)
A	25 (23.1)
B	32 (29.6)
C	51 (47.2)
Unintentional Weight Loss (%)	8.75 ± 10.92
Unintentional Weight Loss (%)	n (%)
0.1–5	16 (14.8)
≥5	69 (63.9)
Handgrip strength (kg) (Dominant hand)	34.10 ± 10.1
Handgrip strength (kg) (Non-dominant hand)	31.77 ± 9.54
Gait speed (m/s)	1.02 ± 0.30
SMI (cm^2/m^2)	50.43 ± 10.32
Low skeletal muscle mass	n (%)
Yes	53 (49.1)
No	55 (50.9)
Low skeletal muscle mass & Obesity	n (%)
Yes	7 (6.5)
No	101 (93.5)

Hb, Haemoglobin; HCT, Haematocrit; TLC Total lymphocyte count; NLR neutrophil-to- lymphocyte ratio; PLR, platelet-to-lymphocyte ratio; SMI, Skeletal Muscle Mass Index; PG-SGA, Patient Generated Subjective Global Assessment; BMI, Body Mass Index; MAC, Mid-upper arm circumference; cMAMA, Corrected Mid-arm muscle area.
Mean ± standard deviation (SD).

3.2. Associations between demographic, clinical data and low muscle mass

Age was significantly higher in low SMI patients compared to normal SMI individuals (67.2 ± 9.2 vs 60 ± 10.8, p < 0.001). The rate of low muscle mass did not differ between males and females. Albumin was significantly lower in low SMI compared to normal SMI patients (3.9 ± 0.49 vs 4.2 ± 0.4, p = 0.001), whereas haematocrit, haemoglobin TLC, NLR and PLR did not differ between the two groups (Table 2).

3.3. Associations between anthropometric, nutritional, functional data and muscle mass

Low SMI patients had lower BMI compared to normal SMI patients (25.32 ± 4.47 vs 28.92 ± 5.26, p < 0.001). Low muscle mass in conjunction with obesity was observed in 6.5% of the study sample. Among the other anthropometric measurements, MAC, calf circumference and cMAMA were lower in low SMI patients compared to their normal SMI counterparts. Moreover, low SMI patients had significantly higher PG-SGA scores compared to patients with normal muscle mass levels (11.08 ± 6.28 vs 7.40 ± 5.09, p = 0.001 respectively), while moderately and severely malnourished patients (PG-SGA grade B and C) had higher rates of low muscle mass (57.8% vs 42.2%, p = 0.022) than well-nourished patients. Unintentional preoperative weight loss did not differ between the two groups of patients (Table 3).

Regarding functional assessment, handgrip strength of dominant and non-dominant hand was significantly higher in normal SMI patients compared to low SMI patients (36.8 ± 10.3 vs 31.2 ± 9.1, p = 0.004 and 34.0 ± 10.0 vs 29.19 ± 8.4, p = 0.011 respectively), as well as gait speed (1.09 ± 0.28 vs 0.95 ± 0.30, p = 0.014) (Table 3).

3.4. Correlations between SMI, PG-SGA scores and clinical, anthropometric, and functional data

Correlations of the PG-SGA scores and SMI values with clinical and anthropometric parameters, as well as with nutritional status and muscle function, are shown in Table 4. There was a significant negative correlation between the PG-SGA scores and SMI. Albumin, Hb, HCT, MAC, cMAMA, calf circumference, gait speed, and handgrip strength of dominant and non-dominant hand were significantly correlated with SMI, whereas PLR was negatively correlated with SMI.

Table 2
Differences in the demographic and clinical data of patients with and without low muscle mass.

Characteristic	Normal SMI (n = 55)	Low SMI (n = 53)	p- value
Age (years)	60 ± 10.8	67.2 ± 9.2	<0.001
Sex	n (%)	n (%)	0.441
Male	44 (48.9)	46 (51.1)	
Female	11 (61.1)	7 (38.9)	
Type of cancer	n (%)	n (%)	0.699
Esophageal	32 (53.3)	28 (46.7)	
Gastric	23 (47.9)	25 (52.1)	
Neoadjuvant chemotherapy	n (%)	n (%)	0.655
Yes	12 (46.2)	14 (53.8)	
No	43 (52.4)	39 (47.6)	
Neoadjuvant radiotherapy	n (%)	n (%)	0.743
Yes	1 (50)	1 (50)	
No	54 (51)	52 (49)	
Hb (g/dL)	12.88 ± 1.97	12.42 ± 2.00	0.231
HCT (%)	38.39 ± 5.18	37.33 ± 5.48	0.302
Albumin (g/dL)	4.2 ± 0.4	3.9 ± 0.49	0.001
TLC (K/μL)	1.75 ± 0.66	1.67 ± 0.68	0.526
NLR	2.72 ± 1.30	3.36 ± 2.57	0.104
PLR	158.14 ± 88.63	168.04 ± 80.92	0.105

Hb, Haemoglobin; HCT, Haematocrit; TLC Total lymphocyte count; NLR neutrophil-to- lymphocyte ratio; PLR, platelet-to-lymphocyte ratio.
Mean ± standard deviation (SD).

Table 3
Differences in the anthropometric, nutritional and functional data of patients with and without low muscle mass.

Characteristic	Normal SMI (n = 55)	Low SMI (n = 53)	p-value
BMI (kg/m^2)	28.92 ± 5.26	25.32 ± 4.47	<0.001
MAC (cm)	26.75 ± 3.49	25.16 ± 2.78	0.011
cMAMA (cm)	48.18 ± 14.25	41.55 ± 10.60	0.008
Calf circumference (cm)	36.79 ± 3.79	34.57 ± 3.56	0.002
PG-SGA	7.40 ± 5.09	11.08 ± 6.28	0.001
Moderately and severely malnourished[a]	n (%)	n (%)	0.022
Yes	35 (42.2)	48 (57.8)	
No	20 (80)	5 (20)	
Unintentional Weight Loss (%)	7.56 ± 12.25	10.04 ± 9.21	0.483
Handgrip strength (kg) (Dominant hand)	36.8 ± 10.3	31.2 ± 9.1	0.004
Handgrip strength (kg) (Non-dominant hand)	34.0 ± 10.0	29.19 ± 8.4	0.011
Gait speed (m/s)	1.09 ± 0.28	0.95 ± 0.30	0.014

SMI, Skeletal Muscle Mass Index; PG-SGA, Patient Generated Subjective Global Assessment; BMI, Body Mass Index; MAC, Mid-upper arm circumference; cMAMA, Corrected Mid-arm muscle area.
Mean ± standard deviation (SD).
[a] PG-SGA Grade B and C vs Grade A.

Table 4
Correlation coefficients and P-values for the association between SMI, PG-SGA score, clinical, anthropometric and functional data.

Clinical and Anthropometric data (total sample, n = 108)	SMI (cm^2/m^2)		PG-SGA score	
	Correlation	p-value	Correlation	p-value
Albumin (g/dL)	0.318	0.001	−0.507	<0.001
Hb (g/dL)	0.268	0.005	−0.168	0.081
HCT (%)	0.260	0.006	−0.232	0.016
TLC (K/μL)	0.129	0.184	−0.172	0.075
NLR	−0.111	0.255	0.247	0.010
PLR	−0.238	0.013	0.300	0.002
BMI (kg/m^2)	0.577	<0.001	−0.251	0.009
MAC (cm)	0.574	<0.001	−0.334	<0.001
cMAMA (cm)	0.668	<0.001	−0.382	<0.001
Calf circumference (cm)	0.570	<0.001	−0.339	<0.001
PG-SGA score	−0.379	<0.001	–	–
Gait speed (m/s)	0.255	0.008	−0.484	<0.001
Handgrip strength (kg) (Dominant hand)	0.583	<0.001	−0.369	<0.001
Handgrip strength (kg) (Non-dominant hand)	0.536	<0.001	−0.275	0.005
Unintentional Weight Loss (%)	−0.145	0.139	0.412	<0.001

Hb, Haemoglobin; HCT, Haematocrit; TLC Total lymphocyte count; NLR neutrophil-to- lymphocyte ratio; PLR, platelet-to-lymphocyte ratio; SMI, Skeletal Muscle Mass Index; PG-SGA, Patient Generated Subjective Global Assessment; BMI, Body Mass Index; MAC, Mid-upper arm circumference; cMAMA, Corrected Mid-arm muscle area.

4. Discussion

This study investigated the nutritional status of oesophago-gastric cancer patients prior to surgery, as well as the association between traditional methods of nutritional assessment, functional status and low muscle mass. More specifically, in our study patients with low muscle mass were older compared to normal SMI patients. Aging process is associated with changes in muscle mass and muscle strength mainly due to decreased muscle turnover and repair capacity [17,18]. Furthermore, 49.1% of the study participants were characterized by low skeletal muscle mass. According to a recent systematic review, the overall prevalence of pre-therapeutic low muscle mass in cancer patients was 38.6%, while oesophageal cancer patients presented the highest prevalence of low muscle mass [19]. The high rate of low muscle mass in our study could be attributed to the high prevalence of malnutrition, since low SMI patients had more impaired nutritional status compared to normal SMI patients.

In our study, the prevalence of severe malnutrition (PG-SGA Grade C) was 47.2%, while the prevalence of moderate/suspected malnutrition was 29.6% (PG-SGA Grade B), according to the PG-SGA. Oesophago-gastric cancer patients often complain of preoperative unintentional weight loss due to anorexia, early satiety, dysphagia and malabsorption of nutrients, symptoms that are often exacerbated due to neoadjuvant chemoradiotherapy treatment [6,20]. The current study demonstrated that BMI was significantly lower in low SMI patients, but preoperative unintentional weight loss, although higher in the low SMI group, did not reach statistical significance. This result indicates that the physiological reserve of patients might be more important when it comes to muscle mass loss. Consequently, weight loss alone cannot sufficiently predict low muscle mass in oesophago-gastric cancer patients.

On the other hand, 66.7% of our study participants were overweight and obese. This finding indicates that we cannot rely only on BMI when assessing patients' nutritional status. Malnutrition and low muscle mass are frequently masqued by obesity, thus making difficult to detect patients in need of intervention. Additionally, the combination of obesity and low muscle mass was observed in 6.5% of the study sample. Even though not frequently seen in our study, these patients constitute a special group of patients that warrants further attention, since current literature supports that the coexistence of low muscle mass and high BMI values is significantly associated with worse postoperative and oncologic outcomes [21,22].

Moreover, low muscle mass was significantly associated with lower levels of preoperative albumin. Even though the use of albumin as a reliable indicator of patients' nutritional status has been questioned, albumin -as a measure of systemic inflammation-is considered a significant outcome predictor in cancer patients [23]. Therefore, our results support the potential relationship between low muscle mass and inflammation, which is in accordance with the results of previous studies in oncologic patients [24–26]. None of the other laboratory parameters were significantly associated with low muscle mass. However, when no cut-off point for skeletal muscle mass was used, SMI was positively correlated with haemoglobin and haematocrit and negatively associated with PLR. Miyake et al. showed that PLR was inversely correlated with psoas muscle index in patients with muscle-invasive bladder cancer who underwent radical cystectomy [27]. Similarly, recent findings support that higher PLR increased the risk of decreased muscle mass in community-dwelling older adults [28]. Since platelets play a key role in the inflammatory process, PLR is considered to be an important indicator of systemic inflammation, which in turn, induces muscle wasting and alters protein catabolism, affecting also muscle mass [29].

Regarding the relationship between classic anthropometric parameters (mid-upper arm circumference, corrected mid-arm muscle area and calf circumference) and skeletal muscle mass, low SMI patients had significantly lower values compared to normal SMI patients. Moreover, low SMI patients had more impaired functional status in terms of handgrip strength and gait speed, demonstrating that inadequate nutritional intake leads not only to muscle loss, but to profound muscle dysfunction as well. This association is also supported by recent studies in patients with several malignancies. More specifically, low SMI patients with haematological malignancies had lower scores of physical functioning than patients with normal muscle mass levels [7], while sub-maximal strength was positively correlated with SMI in patients with advanced pancreatic and gastrointestinal cancers [30]. Although PG-SGA was negatively correlated with the anthropometric measurements and functional performance, SMI was positively associated with these parameters to a greater extent. This finding indicates that muscle mass loss might be accompanied by a greater functional compromise rather than malnutrition alone.

Finally, the prevalence of low muscle mass did not differ between male and female patients, neither did among the different type of cancers (ie. oesophageal and gastric cancer). Interestingly, neoadjuvant therapy did not influence the rate of low muscle mass. Several studies indicated that both chemotherapy and radiation therapy affect patients' body composition and functional status [31,32]. Nonetheless, the small number of patients that underwent neoadjuvant therapy in our study may not be adequate to detect significant differences between the two groups of patients.

Current literature supports the incorporation of muscle mass assessment to conventional risk scores in order to identify high risk patients. Pre-therapeutic low muscle mass is significantly and independently associated with increased risk for postoperative complications, chemotherapy-induced toxicity and poor survival in cancer patients [19,33,34]. A recent meta-analysis reported that loss of skeletal muscle mass was independently associated with increased all-cause mortality and tumour recurrence in patients with hepatocellular carcinoma [8], while Wagner at al. demonstrated that low skeletal muscle mass outperforms the Charlson Comorbidity Index in risk prediction in patients undergoing pancreatic resections [35]. Moreover, low muscle mass has emerged as a significant prognostic factor for the decline in health related quality of life in many types of cancer [36–38]. Since low muscle mass is closely related to malnutrition in cancer patients, preoperative assessment of SMI seems necessary in order to prevent further deterioration of their nutritional and functional status [2,39].

Whilst SMI is a useful tool for the assessment of patients' muscle mass, it is also subject to several limitations. The quantification of muscle mass based on computed tomography is not an easily accessible method to the majority of clinicians and researchers and requires highly qualified personnel. Other disadvantages of CT scans are the considerably high cost and radiation exposure [40]. Moreover, even though low muscle mass was the primary component of sarcopenia, recent data focus on low muscle strength as a key characteristic of sarcopenia, as well as on the importance of SARC-F questionnaire in the diagnosis of sarcopenia [41]. The definition of sarcopenia has long been a serious bone of contention due to the different cut-off points and different methods of assessment between studies, thus making the results not easily comparable. Further studies incorporating measurements of muscle strength and physical function are warranted to determine whether inclusion of both parameters better predicts adverse outcomes than use of muscle mass only.

Preoperative evaluation of patients' nutritional status and timely nutritional support are key components of the

appropriate support therapy for oesophago-gastric cancer patients. Prehabilitation programs are designed to facilitate a patient's ability to withstand operative stress. These programs include nutritional support and preoperative muscular exercises, aiming to strengthen the musculoskeletal system and ameliorate patients' nutritional status and their implementation should be considered in the clinical setting [42,43].

Several limitations of our study warrant consideration. First, the cut-off points used in this study are based on predefined thresholds and are not specific for our study sample. Last, but not least, the relatively small sample size of our study limits the generalizability of our results. A large-scale, multi-institutional study is needed, in order to validate our findings.

In conclusion, a great percentage of oesophago-gastric cancer patients is affected by low muscle mass levels, while a notable proportion of our study sample was malnourished. Furthermore, low muscle mass is associated with more compromised nutritional and functional status. Given than the gold standard of nutritional assessment has yet to be determined, muscle mass assessment provides clinicians with a good insight into patients' body composition. Consequently, our results support the use of skeletal muscle mass assessment as an objective method of nutritional assessment in oesophago-gastric cancer patients. Additional research should focus on the impact of SMI, alone or as a part of a composite index, on short-and long-term outcomes of cancer patients in order to develop effective treatment strategies for the improvement of patients' nutritional and functional status.

Statement of authorship

Irene Lidoriki: conceived and designed the study, analyzed the data, interpreted the data, wrote the paper and reviewed the content of the paper.

Dimitrios Schizas: designed the study, analyzed the data, interpreted the data and reviewed the content of the paper.

Efstratia Mpaili: analyzed the data and reviewed the content of the paper.

Michail Vailas: analyzed the data and reviewed the content of the paper.

Maria Sotiropoulou: analyzed the data and reviewed the content of the paper.

Alexandros Papalampros: interpreted the data and reviewed the content of the paper.

Evangelos Misiakos: interpreted the data, contributed to the drafting of the paper and reviewed the content of the paper.

Ioannis Karavokyros: interpreted the data, contributed to the drafting of the paper and reviewed the content of the paper.

Emmanouil Pikoulis: interpreted the data, contributed to the drafting of the paper and reviewed the content of the paper.

Theodoros Liakakos: conceived the study, interpreted the data, contributed to the drafting of the paper and reviewed the content of the paper.

Conflict of interest

The authors declare no conflict of interest.

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