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ORIGINAL ARTICLE

Skeletal muscle mass and quality as risk factors for postoperative outcome after open colon resection for cancer

B. C. Boer[1,2] · **F. de Graaff**[1,3] · **M. Brusse-Keizer**[4] · **D. E. Bouman**[5] · **C. H. Slump**[3] · **M. Slee-Valentijn**[6] · **J. M. Klaase**[1]

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Abstract

Background The prevalence of colorectal cancer in the elderly is increasing and, therefore, surgical interventions with a risk of potential complications are more frequently performed. This study investigated the role of low skeletal muscle mass (sarcopenia), muscle quality, and the sarcopenic obesity as prognostic factors for postoperative complications and survival in patients with resectable colon cancer.

Methods We conducted a retrospective chart review of 91 consecutive patients who underwent an elective open colon resection for cancer with primary anastomosis between 2011 and 2013. Skeletal muscle mass was measured as total psoas area (TPA) and total abdominal muscle area (TAMA) at three anatomical levels on the preoperative CT scan. Skeletal muscle quality was measured using corresponding mean Hounsfield units (HU) for TAMA. Their relation with complications (none vs one or more), severe complications, and survival was analyzed.

Results The study included 91 patients with a mean age of 71.2 ± 9.7 years. Complications were noted in 55 patients (60 %), of which 15 (16.4 %) were severe. Lower HU for TAMA, as an indicator for impaired skeletal muscle quality, was an independent risk factor for one or more complications (all $P \leq 0.002$), while sarcopenic obesity (TPA) was an independent risk factor for severe complications (all $P \leq 0.008$). Sarcopenia was an independent predictor of worse overall survival (HR 8.54; 95 % confidence interval (CI) 1.07–68.32).

Conclusion Skeletal muscle quality is a predictor for overall complications, whereas sarcopenic obesity is a predictor for severe postoperative complications after open colon resection for cancer. Sarcopenia on itself is a predictor for worse overall survival.

Keywords Sarcopenia · Colon cancer

✉ J. M. Klaase
j.klaase@mst.nl

1 Department of Surgery, Medisch Spectrum Twente, Enschede, Netherlands

2 Faculty of Medical Sciences, University of Groningen, Groningen, Netherlands

3 Faculty of Science and Technology, University of Twente, Enschede, Netherlands

4 Medical School Twente, Medisch Spectrum Twente, Enschede, Netherlands

5 Department of Radiology, Medisch Spectrum Twente, Enschede, Netherlands

6 Department of Internal Medicine–Section of Gerontology and Geriatrics, VU University Medical Center, Amsterdam, Netherlands

Introduction

Colorectal cancer (CRC) is the third most common malignant neoplasm worldwide, with nearly 1.4 million new cases in 2012 [1]. Surgical resection is the cornerstone of treatment for CRC. However, there is a reported postoperative severe complication rate of approximately 25 % [2].

Several patient characteristics have been used in the past to identify those patients who are at an increased risk of perioperative complications and mortality, such as the American Society of Anesthesiologists Score (ASA), Charlson index, and body mass index (BMI).

There is increasing evidence that skeletal muscle mass interferes with the outcome after surgery. Low muscle mass, referred to as sarcopenia, in cancer patients is associated with increased morbidity, length of hospital stay, and increased mortality [3, 4]. Furthermore, it has been associated with postoperative infections and a delayed recovery after colorectal resection for cancer [5].

Sarcopenia can occur either independently or along with adiposity. Sarcopenic obesity, in which excessive body fat and low muscle mass and muscle quality occur simultaneously, has been shown to be associated with poorer performance status and decreased survival [4, 6, 7].

Objective measures to assess patients preoperatively for their risk of postoperative morbidity and mortality are needed.

In this study, we investigated the relation between skeletal muscle mass, muscle quality, and sarcopenic obesity with postoperative complications and survival in patients with resectable colon cancer.

Patients and methods

Study population

Data from 594 patients treated with resection for colorectal cancer (CRC) at Medisch Spectrum Twente, Enschede, Netherlands, in the period of January 2011 till December 2013 were retrieved from the Dutch Surgical Colorectal Audit (DSCA). From this cohort, patients with an elective open colon resection with primary anastomosis were selected, bringing in 125 patients. Patients were excluded if they had tumors with histology other than adenocarcinoma ($n=7$), neoadjuvant chemotherapy or radiotherapy ($n=2$), simultaneous liver resection ($n=20$), and/or absent preoperative CT scan ($n=4$). One patient was additionally excluded because of impossibility of performing muscle mass measurements due to significant scoliosis. Our final study population consisted of 91 patients.

Data collection

Patient medical data, including patient demographics, tumor stage, perioperative details, duration of hospital stay, perioperative morbidity, and mortality, were obtained from the electronic patient systems. If patients had not visited the hospital for 3 months or cause of death was unknown, information was requested from their general practitioner. All patients were followed until the latest included patient had reached follow-up of 2 months.

Patients were staged according to the seventh edition of the American Joint Committee on Cancer (AJCC) Colon and Rectum Staging Manual [8]. We defined overweight as BMI >25 kg m^{-2} [9]. Charlson classification was used to describe comorbidity and has been validated in various larger populations [10].

Outcome measures

Any deviation of the ideal postoperative course was interpreted as an overall complication and defined as Clavien-Dindo Classification (CDC) grade I or higher. Severe complications, such as reintervention under local or general anesthesia, organ failure with ICU admittance, or death, were defined as CDC grade IIIa or higher [11]. Complications were defined as in-hospital morbidity or mortality occurring within 30 days of surgery.

Muscle mass measurements and definitions

Preoperative venous phase abdominal CT scans were performed for staging workup for colon cancer, with slice thickness ranging from 1 to 5 mm. Scans were imported in TeraRecon (TeraRecon Aquarius; TeraRecon, USA). Muscle mass was measured at three levels [12–14], namely, cross sections at the third lumbar vertebra (L3) where both transverse processes were visible, and at both the superior and inferior border of the fourth lumbar vertebra (L4).

Total abdominal muscle area (TAMA) was manually detected, and a threshold of −29 to +150 Hounsfield units (HU) was applied to this region to discriminate between skeletal muscle and other tissues [15]. Muscle area and average Hounsfield unit (HU) were then calculated automatically. Total psoas area (TPA) was measured by manually tracing left and right psoas area, and cross-sectional areas (cm^2) of both psoas muscles were added. Muscle areas were normalized for patient height to calculate the muscle index for TPA and TAMA in cm^2 m^{-2}. The investigator who performed the measurements (FdG) was blinded for postoperative outcome.

Skeletal muscle mass was treated as a continuous variable, since there are no standardized cutoff values determined. Sarcopenia was defined as sex-specific cutoff value below the median. The mean HU of TAMA was considered to be related to the overall muscle quality since lower HU values correspond with fatty infiltration of muscle (myosteatosis) [16]. Sarcopenic obesity was defined as BMI above 25 kg/m^2 combined with skeletal muscle mass measures, TPA, or TAMA, below the sex-specific median, and comparison was made with the rest of the cohort. [17]

Statistical methods

Continuous data are presented as mean ± SD or median (range) as appropriate. Normality of the data was visually tested. Categorical data are presented as numbers with corresponding percentages.

The relation between the skeletal muscle mass measurements (TPA, TAMA, and corresponding mean HU of TAMA) and sarcopenic obesity with both overall and severe complications was investigated using Student's *t* tests or

Mann–Whitney U test for continuous variables and χ^2 or Fisher exact tests for categorical variables. Demographic variables were checked for confounding. Variables related ($P<0.15$) to the studied skeletal muscle mass measurement and the studied complications were afterward entered in a multivariate logistic regression analysis.

The relation between sarcopenia, sarcopenic obesity, and overall survival were displayed with Kaplan–Meier graphs and analyzed by univariate and multivariate Cox regression analyses for 1- and 3-year survival.

Unless otherwise noted, all test are two-sided and a p value <0.05 was considered significant. All statistical analyses were performed using SPSS version 20 (IBM SPSS, Chicago, IL, USA).

Results

Ninety-one patients who underwent elective open colon resection with primary anastomosis qualified for the study. The median follow-up was 21 (2–74) months. Mean age was 71.3 ± 9.7 years, 42 (46.2 %) patients were female, and patients had a median length of hospital stay of 7 (4–74) days. The mean BMI was 27.0 ± 4.1 kg m^{-2}; 61 patients (67 %) had a BMI higher than 25 kg m^{-2}.

Postoperative complications

The overall postoperative complication rate was 60.4 % with 44.0 % moderate complications (CDC grade I–II) and 16.4 % severe complications (CDC grade III–V). The mortality rate was 2.2 % (CDC grade V). Ten patients (11.0 %) required at least 1 readmission and 11 patients (12.1 %) were returned to the operation theatre for 13 unscheduled operations. Two patients died during admission due to postoperative complications.

Differences in characteristics by complications and possible confounders are shown in Table 1. Overall complications showed significant relation with age and previous abdominal surgery.

Complications and skeletal muscle mass

In univariate analyses, lower average muscular HU for TAMA at all three measurement levels was significantly associated with overall complications (Table 2). With every decrease of 1 HU at L3, the risk on developing overall complications increased with 8.8 % (odds ratio (OR) 0.919; 95 % confidence interval (CI) 0.873–0.967), at L4 superior with 8.1 % (OR 0.925; 95 % CI 0.881–0.971), and at L4 inferior with 7.6 % (OR 0.929; 95 % CI 0.884–0.976). In final multivariate models for complications that were controlled for age, Charlson index, and previous abdominal surgery, lower HU for TAMA remained the only factor independently associated with risk of one or more complications (Table 3).

TPA or TAMA were not related to overall complications (Table 2). No statistical significant relation was found between TPA or HU for TAMA and severe complications.

Complications and sarcopenic obesity

Patients with sarcopenic obesity developed more severe complications, however, only when defined with TPA or TAMA at L3 (Table 4). In the multivariate model with gender, sarcopenic obesity remained independently associated with a risk of severe complications (Table 5).

No significant relation was found between sarcopenic obesity and overall complications (Table 4).

Survival and sarcopenia

Patients with sarcopenia, measured as TAMA at the level of L3, had a significantly shorter median overall survival than patients without sarcopenia (37.4 vs 63.0 months; $P=0.013$). The Kaplan–Meier survival curve TAMA at L3 (Figs. 1 and 2) shows that sarcopenia was associated with decreased 1- and 3-year cumulative survival rates. One-year cumulative survival rates for patients with sarcopenia were 85.7 % (SE 0.055) versus 100 % for those without sarcopenia ($P=0.014$). For 3-year survival, the rates were 80.1 % (SE 0.064) versus 97.0 % (SE 0.030), respectively. This translated into an 8.5 greater risk (HR 8.54; 95 % CI 1.07–68.32) for sarcopenic patients of dying during follow-up compared to patients without sarcopenia. When adjusting for gender in multivariate analyses, sarcopenia was no longer a significant predictor of survival.

Overall survival was not associated with sarcopenia measured as TAMA at L4 superior or inferior, or measured as TPA or HU at all measurement levels.

Survival and sarcopenic obesity

No association was found for sarcopenic obesity and 1- and 3-year overall survival (all P values ≥0.068).

Discussion

The quality of skeletal muscle mass was a risk factor for the development of overall complications, whereas patients with sarcopenic obesity had greater risk of developing severe postoperative complications. Sarcopenia in patients with colon cancer resulted in worse overall survival compared to those without sarcopenia. Our findings highlight the importance of assessing skeletal muscle mass and quality as in order to perform risk stratification prior to surgery.

Table 1 Clinicopathological characteristics by complications

	All	Complications			Severe complications		
		No (*n* = 36)	Yes (*n* = 55)	*P* value	No (*n* = 76)	Yes (*n* = 15)	*P* value
Age (mean ± SD)	71.3 ± 9.74	68.1 ± 12.0	73.4 ± 7.3	0.022*	71.1 ± 10.0	72.7 ± 8.6	0.546
Gender (*n* (%))				0.791			0.098*
Female	42 (46.2 %)	16 (44.4 %)	26 (47.3 %)		38 (50.0 %)	4 (26.7 %)	
Male	49 (53.8 %)	20 (55.6 %)	29 (52.7 %)		38 (50.0 %)	11 (73.3 %)	
BMI	27.0 ± 4.09	26.3 ± 4.1	27.4 ± 4.0	0.205	27.1 ± 4.2	26.5 ± 3.4	0.617
Smoking status				0.667			0.323
Never	69 (75.8 %)	25 (69.4 %)	44 (80.0 %)		55 (72.4 %)	14 (93.3 %)	
History of smoking	4 (4.4 %)	2 (5.6 %)	2 (3.6 %)		4 (5.3 %)	–	
Current smoker	18 (19.8 %)	9 (25.0 %)	9 (16.4 %)		17 (22.4 %)	1 (6.7 %)	
ASA class				0.522			0.562
I	9 (9.9 %)	5 (13.9 %)	4 (73 %)		9 (11.8 %)	–	
II	58 (63.7 %)	23 (63.9 %)	35 (63.6 %)		47 (61.8 %)	11 (73.3 %)	
III	24 (26.4 %)	8 (22.2 %)	16 (29.1 %)		20 (26.3 %)	4 (26.7 %)	
IV	0 (0.0 %)	–	–		–	–	
Charlson Index				0.089*			1.000
0–1	67 (73.6 %)	30 (83.3 %)	37 (67.3 %)		56 (73.7 %)	11 (73.3 %)	
≥2	24 (26.4 %)	6 (16.7 %)	18 (32.7 %)		20 (26.3 %)	4 (26.7 %)	
Previous abdominal surgery	34 (37.4 %)	9 (25.0 %)	25 (45.5 %)	0.049*	29 (38.2 %)	5 (33.3 %)	0.724
AJCC stage				0.380			0.507
I	8 (8.8 %)	1 (2.8 %)	7 (12.7 %)		7 (9.2 %)	1 (6.7 %)	
II	42 (46.2 %)	17 (47.2 %)	25 (45.5 %)		34 (44.7 %)	8 (53.3 %)	
III	35 (38.5 %)	16 (44.4 %)	19 (34.5 %)		31 (40.8 %)	4 (26.7 %)	
IV	6 (6.6 %)	2 (5.6 %)	4 (7.3 %)		4 (5.3 %)	2 (13.3 %)	
Location of tumor				0.547			0.178
Left-sided	59 (64.8 %)	22 (61.1 %)	37 (67.3 %)		47 (61.8 %)	12 (80.0 %)	
Right-sided	32 (35.2 %)	14 (38.9 %)	18 (32.7 %)		29 (38.2 %)	3 (20.0 %)	
Preoperative complications				0.470			0.847
Ileus	2 (2.2 %)	1 (2.8 %)	1 (1.8 %)		2 (2.6 %)	–	
Anemia	43 (47.3 %)	15 (41.7 %)	28 (50.9 %)		35 (46.1 %)	8 (53.3 %)	

BMI body mass index, *ASA* American Society of Anesthesiologists, *AJCC* American Joint Committee on Cancer.

* *P* value <0.15

The overall morbidity rate of 60.4 % in this study is relatively high compared to other studies [18–20]. This rate might be misleading in that we classified every deviation from the ideal postoperative course as a complication, including relatively minor complications with minimal impact on outcome. In addition, we included open resections only whereas most studies also include laparoscopic resections, which show a lower reported surgical site infection rate than the relatively high rate of 16.5 % which we observed with open resections [21]. Major complications are with a rate of 16.4 % in accordance with previous reports [20, 22]. The most feared major complication is anastomotic leakage, and with 4.3 %, this rate is similar to previous publications [18]. The mortality rate of 2.2 % for colon cancer is reasonably low, but we excluded emergency operations in which this rate is significantly increased [23].

With a mean BMI of 27.0, the population was relatively overweight and obese, but this might be related to the fact that obesity is a risk factor for developing CRC and it is in line with previous research [3, 5, 24]. Also, the variability of skeletal muscle mass we found in the present study was in accordance with previous reports [3, 5, 20].

There is no generally accepted definition of sarcopenia for CT-based measurements in the medical literature, and there are no standardized cutoff values determined. As we used skeletal muscle mass as a continuous variable and the sex-specific median as cutoff value for defining sarcopenic obesity [3, 5], tertiles as cutoff or optimum stratification techniques

Table 2 Skeletal muscle mass and complications

	Complications			Severe complications		
	No (n = 36)	Yes (n = 55)	P value	No (n = 76)	Yes (n = 15)	P value
L3						
TPA	5.3 ± 1.6	5.1 ± 1.4	0.469	5.1 (4.1–6.2)	4.5 (2.9–8.0)	0.320
TAMA	46.7 ± 8.6	44.9 ± 7.7	0.312	45.1 (39.9–51.5)	43.5 (38.9–48.7)	0.589
HU TAMA	37.1 ± 10.0	29.8 ± 8.8	<0.001*	33.0 (26.3–39.2)	29.9 (24.3–37.8)	0.454
L4 superior						
TPA	7.2 (5.9–8.8)	7.0 (5.6–8.1)	0.480	7.2 ± 1.8	6.7 ± 1.6	0.351
TAMA	48.0 (41.7–53.9)	46.5 (40.9–54.0)	0.519	47.1 (41.0–54.0)	49.2 (42.8–53.3)	0.826
HU TAMA	37.2 ± 10.7	29.9 ± 8.8	0.001*	32.1 (26.2–38.8)	29.0 (25.5–40.3)	0.756
L4 inferior						
TPA	7.9 (6.2–9.2)	7.9 (6.3–8.8)	0.881	7.9 (6.3–8.8)	7.5 (5.7–9.5)	0.665
TAMA	44.9 (41.0–50.1)	44.1 (39.0–50.0)	0.519	44.9 (38.8–49.9)	43.9 (40.3–50.2)	0.996
HU TAMA	36.0 ± 10.1	29.7 ± 8.6	0.002*	31.4 (25.3–38.4)	33.3 (23.4–42.9)	0.966

TPA total psoas area (cm^2/m^2), *TAMA* total abdominal muscle area (cm^2/m^2), *HU* Hounsfield unit

* P value <0.05

can also be used. Different techniques could, however, lead to different results. In addition, the amount of muscle mass and, thereby, the prevalence of sarcopenia are highly dependent on applied correction factors, such as fat mass and height [25]. We corrected only for height, i.e., absolute muscle mass, which could lead to an overestimation of sarcopenia in underweight individuals and an underestimation of sarcopenia in obese individuals [26].

Table 3 Multivariate analyses for one or more complications

	OR	95 % CI	P value
L3			
HU	0.912	0.863 – 0.964	0.001
Age	–	–	–
Previous surgery	–	–	–
Charlson	3.031	0.956 – 9.611	0.060
L4 superior			
HU	0.918	0.871 – 0.967	0.001
Age	–	–	–
Previous surgery	–	–	–
Charlson	3.037	0.965 – 9.553	0.057
L4 inferior			
HU	0.922	0.875 – 0.972	0.003
Age	–	–	–
Previous surgery	–	–	–
Charlson	2.986	0.967 – 9.219	0.057

HU Hounsfield unit

* P value <0.05

Muscle quality

During the ageing process, there is not only loss of muscle fibers but also increase in intramuscular adipose tissue that may lead to a decline in strength and muscle quality [27]. In this study, increased fat infiltration in muscle was reflected by the mean HU of TAMA, where lower mean HU of TAMA indicates poorer muscle quality.

We did find a relation between lower muscular HU and overall complications, but not between skeletal muscle mass and overall or severe complications. There only have been three previous studies investigating the effect of skeletal muscle mass on outcomes after CRC surgery [5, 28, 29]. Two of these studies found significantly increased risk on infectious complications related to sarcopenia or HU of TAMA. Three other studies investigated the role of skeletal muscle mass on outcome after major abdominal surgery, of which two concluded that sarcopenic patients have a higher risk on complications

Sarcopenic obesity

We are, to our knowledge, the first to assess the effect of sarcopenic obesity on complications after colon cancer surgery.

Sarcopenic obesity is a common combination, since the same factors that affect sarcopenia also support the development of obesity. The process is accelerated when malignant disease is present. Sarcopenic obesity was a significant predictor of severe complications compared to the rest of the cohort.

Table 4 Sarcopenic obesity and complications

	Complications				Severe complications			
	No ($n=36$)	Yes ($n=55$)	OR	95 % CI	No ($n=76$)	Yes ($n=15$)	OR	95 % CI
TPA								
L3								
Non-SO	29 (80.6 %)	34 (61.8 %)	1.0		56 (73.7 %)	5 (33.3 %)	1.0	
SO	7 (19.4 %)	21 (38.2 %)	0.1	0.9–6.9	20 (26.3 %)	10 (66.7 %)	6.4*	1.9–21.3
L4 superior								
Non-SO	29 (80.6 %)	34 (61.8 %)	1.0		58 (76.3 %)	5 (33.3 %)	1.0	
SO	7 (19.4 %)	21 (38.2 %)	2.6	0.9–6.9	18 (23.7 %)	10 (66.7 %)	6.4*	1.9–21.3
L4 inferior								
Non-SO	26 (72.2 %)	35 (63.6 %)	1.0		58 (76.3 %)	5 (33.3 %)	1.0	
SO	10 (27.8 %)	20 (36.4 %)	1.5	0.6–3.7	18 (23.7 %)	10 (66.7 %)	5.6*	1.7–18.4
TAMA								
L3								
Non-SO	27 (75.0 %)	38 (69.1 %)	1.0		58 (76.3 %)	7 (46.7 %)	1.0	
SO	9 (25.0 %)	17 (30.9 %)	1.3	0.5–3.5	18 (23.7 %)	8 (53.3 %)	3.7*	1.2–11.6
L4 superior								
Non-SO	28 (77.8 %)	39 (70.9 %)	1.0		56 (73.7 %)	11 (73.3 %)	1.0	
SO	8 (22.2 %)	16 (29.1 %)	1.4	0.5–3.8	20 (26.3 %)	4 (26.7 %)	1.0	0.3–3.6
L4 inferior								
Non-SO	28 (77.8 %)	36 (65.5 %)	1.0		54 (71.1 %)	10 (66.7 %)	1.0	
SO	8 (22.2 %)	19 (34.5 %)	1.8	0.7–4.8	22 (28.9 %)	5 (33.3 %)	1.2	0.4–4.0

Non-SO is reference group

TPA total psoas area (cm^2/m^2), *TAMA* total abdominal muscle area (cm^2/m^2), *SO* sarcopenic obesity

* P value <0.05

There have only been three studies regarding sarcopenic obesity and outcome after surgery [14, 17, 30]. All concluded that sarcopenic obesity is a risk factor for outcome after surgery, but most results are not directly applicable and translatable to our cohort due to major differences in population, diagnosis, and measurement methods.

Table 5 Multivariate analyses for survival

	OR	95 % CI	*P* value
L3			
TPA	6.573	1.938–22.289	0.003
Gender	0.351	0.096–1.290	0.115
L4 superior			
TPA	7.034	2.046–24.182	0.002
Gender	0.314	0.084–1.168	0.084
L4 inferior			
TPA	5.705	1.698–19.160	0.005
Gender	0.352	0.097–1.280	0.352
L3			
TAMA	3.655	1.140–11.717	0.029
Gender	0.367	0.104–1.296	0.119

TPA total psoas area (cm^2/m^2), *TAMA* total abdominal muscle area (cm^2/m^2),

* P value <0.05

Survival

In agreement with many authors, we found that patients with sarcopenia, when defined with TAMA at L3, had a significant shorter overall survival compared to patients without sarcopenia.

There are only two previous studies investigating survival in CRC surgery. Sabel et al. concluded that psoas density was not a predictor of worse overall survival after adjustment for age and Charlson score [29]. Reisinger et al. concluded that 30-day or in-hospital mortality rate in sarcopenic patients is significantly higher compared to non-sarcopenic patients after colorectal cancer surgery [28].

Six other studies regarding major abdominal surgery and sarcopenia investigated 1-year mortality [3, 12–14, 31, 32]. Five of these studies found decreased 1-year survival related to low core muscle area, of which one found this relation only for men [3, 12, 13, 31, 32]. However, only two of these studies corrected for height and none for weight. As previously

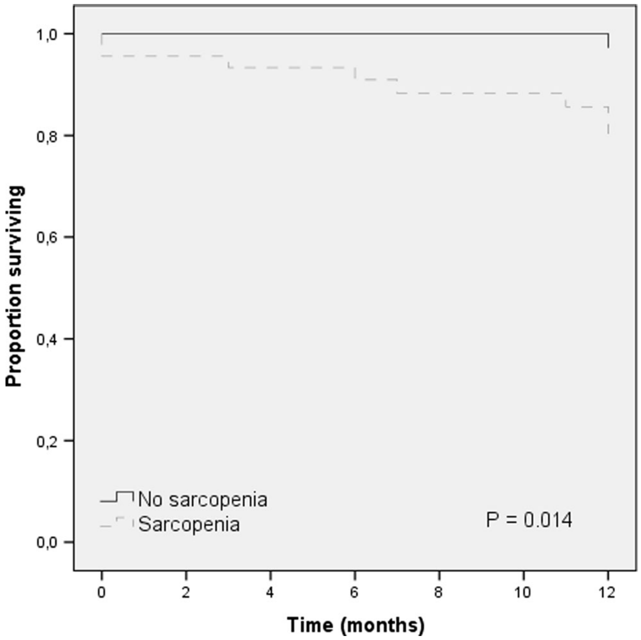
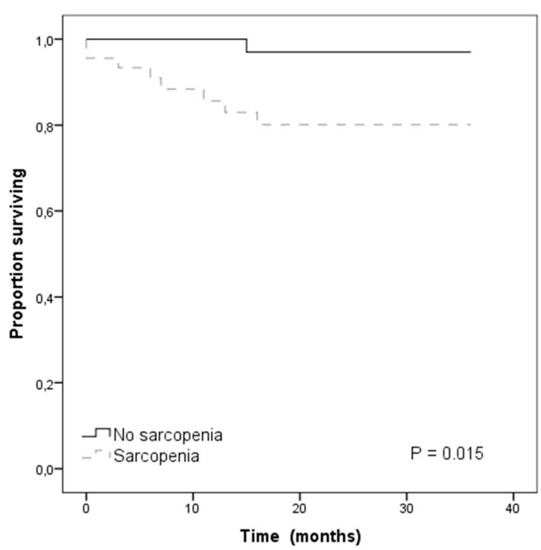


Fig. 1 Kaplan–Meier survival curve TAMA at L3 showing that sarcopenia was associated with decreased 1-year cumulative survival rate

described, the differences in defining sarcopenia may influence these results.

We did not find a difference in overall survival for sarcopenic obese patients. There are only three studies concerning survival in sarcopenic obese patients with cancer of which two concluded that sarcopenic obesity is a predictor of worse survival, but both are not surgery related [4, 14, 30].

Our findings underscore the importance of assessment of skeletal muscle mass with the use of CT scans to provide powerful prognostic information for postoperative outcome. The ability to stratify patients at risk for perioperative complications after colorectal resection for CRC has several benefits. Objective postoperative risk stratification can identify patients that may benefit from preoperative optimization and are in need of more intense monitoring in the perioperative phase. Preoperative optimization can be accomplished by exercise training and eventually improve postoperative recovery [33] in less than 4 to 6 weeks [34].



No. at risk

No sarcopenia	45	36	27	17	5
Sarcopenia	44	33	21	14	5

Fig. 2 Kaplan–Meier survival curve TAMA at L3 showing that sarcopenia was associated with decreased 3-year cumulative survival rate

Our study has several limitations. Possible limitations of this study are the small sample size and being retrospective; therefore, prospective studies are necessary. Ideally, cutoff values for sarcopenia should be defined within each specific population and BMI category. A much larger sample would be required to use tertiles or optimum stratification techniques.

Our findings are suggestive, although they should undoubtedly be interpreted with caution in consideration of the level of evidence yielded by a single-center retrospective study design. A large prospective study could confirm our results and lead to more robust results.

Conclusion

Skeletal muscle mass and muscle quality measurements can be used to predict postoperative complications after open colon cancer surgery.

Skeletal muscle quality is a predictor for overall complications, whereas sarcopenic obesity is a predictor for severe postoperative complications. Sarcopenia on itself is a predictor for worse overall survival.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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