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Title: The ability of malnutrition screening and assessment tools to identify computed tomography defined low muscle mass in colorectal cancer surgery

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Keywords: sarcopenia; nutrition assessment; malnutrition; colorectal cancer; muscle strength

CONFLICTS OF INTEREST, SOURCE OF FUNDING AND AUTHORSHIP

The authors have no competing interests to declare.

No funding was received for this study.

AD performed the data collection and drafted the manuscript. ID conceived the study, conducted the CT muscle mass measurements and statistical analysis, and assisted with drafting the manuscript. JY conceived the study and was involved in results analysis and drafting of the manuscript. NK assisted with CT muscle mass measurements, data analysis and with drafting the manuscript. VC and SM assisted with study design and drafting of the manuscript. RS assisted with CT scan analysis and interpretation and reviewed the manuscript. All authors have critically reviewed the manuscript and approved the final version submitted.

ABSTRACT

Background: Malnutrition and low muscle mass are independently associated with poor outcomes in colorectal cancer (CRC). However, tools to identify low muscle mass are limited in the clinical setting. We investigated the ability of existing malnutrition screening and assessment tools to identify low muscle mass assessed by computed tomography (CT). Secondary aims were to determine the feasibility of CT analysis and handgrip strength (HGS).

Methods and analysis: An exploratory study of patients who underwent curative surgery for CRC between February and September 2019. Nutritional tools used included body mass index (BMI), Malnutrition Screening Tool (MST) and Patient-Generated Subjective Global Assessment (PG-SGA). Muscle mass was determined by preoperative CT image at the third lumbar vertebral level (L3), and muscle strength was determined by HGS dynamometry. Fisher's exact and Mann-Whitney U tests were used to compare results of nutrition tools with CT muscle assessment.

Results: In total, 57 patients were included. MST classified 18 (32%) as at-risk of malnutrition and PG-SGA classified 10 (17%) as malnourished. Fifty-one (90%) CT scans were analysable and 21 (47%) had low muscle mass. Of those with low muscle mass, PG-SGA classified 22 (92%) as well-nourished and MST classified 17 (71%) as not being a nutritional risk. No tool was able to identify CT diagnosed low muscle mass. Inability to complete HGS was associated with malnutrition (p=0.001).

Conclusion: In this cohort, nutritional screening and assessment tools did not identify CT diagnosed low muscle mass. Feasible tools to identify low muscle mass in the clinical setting are required.

INTRODUCTION

Colorectal cancer (CRC) is the second most common cause of cancer death worldwide.[1] Treatment for CRC primarily involves surgical resection with chemotherapy reserved for those with advanced disease. Prognostication is typically based on tumour stage, however, other factors are being increasingly recognised. Malnutrition and low muscle mass have been established as independent prognostic indicators in patients undergoing cancer surgery and have been linked with lower tolerance of adjuvant treatment, higher rates of post-operative complications and lower survival.[2-4]

Within this population, malnutrition may be attributed to progression of malignant disease, patients' response to the tumour and its therapy, or may be directly related to malabsorption due to bowel obstruction.[5, 6] Low muscle mass may be a result of malnutrition, the progression of malignant disease impacting appetite and oral intake, or due to decreased mobility due to cancer induced fatigue.[7] Although the term sarcopenia is frequently used in cancer research, this often refers to low muscle mass alone as opposed to primary sarcopenia which is typically defined as a combination of low muscle mass and strength, with or without poor muscle function.[8]

Early screening and identification of both malnutrition and low muscle mass in the clinical setting is highly recommended to determine which patients will benefit from interventions to improve or prevent further decline in nutritional status and muscle mass.[9] There are validated tools for screening and diagnosis of malnutrition which can be performed easily in the clinical setting, however low muscle mass is more difficult to identify. Traditional methods of muscle mass assessment such as dual-energy X-ray absorptiometry (DXA) or bioelectrical impedance analysis (BIA) are not readily available or easily measured in the surgical setting. In recent years, computed tomography (CT) scans have been increasingly utilised for body composition analysis in the cancer research setting, as CT scans conducted as part of routine cancer staging are readily available, are up to date and do not require the patient to partake in any additional tests. Analysis of an axial image at level 3 of the lumbar spine (L3) using specialised software is now considered one of the "gold standard" methods of muscle mass assessment in patients with cancer.[10, 11] However, this research method has not yet translated into routine clinical practice due to high software costs, limited availability of CT analysis training to clinicians and the time needed for CT image download and analysis.[12]

In lieu of this, surrogate markers such as handgrip strength (HGS) and those used in nutrition screening and assessment, have been proposed to identify low muscle mass.[8, 13, 14] Therefore, it is important to determine if readily available validated tools for malnutrition screening and assessment can capture patients with low muscle mass, and whether additional CT and HGS assessment would provide a better assessment and be feasible to implement in the clinical setting.

The primary aim of this study was therefore to assess the ability of common nutrition assessment tools and techniques to detect low muscularity compared to "gold standard" CT determination. A secondary objective was to determine the feasibility of utilising CT analysis and HGS measurement in the clinical setting.

METHODS

Study Design

This exploratory study was conducted at a major tertiary centre for CRC treatment in ___ between February and September 2019. Patients admitted for CRC resection were screened for eligibility (Table 1). The study was approved by the local human research ethics committee (2018.77) and all patients were required to give explicit verbal consent to participate. Patients who declined were excluded whilst patients who preferred to be assessed at a later time were done so. For patients who were of non-English speaking background, an in-hospital interpreter was utilised. All eligible patients who met the inclusion criteria and provided consent, were included in the study. The study is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology guideline.[15] Study data was collected and managed using the REDCap electronic data capture tools.[16, 17]

Data Collection

Anthropometry, the Malnutrition Screening Tool (MST), the Patient-Generated Subjective Global Assessment (PG-SGA) and handgrip strength (HGS) were administered between post-operative days one and three by a single member of the research team (a final year medical student who was trained to complete the assessments by a senior clinical dietitian/researcher). Inter-rater reliability testing performed prior to commencing the study was >90%). Patients identified to be at risk or clinically malnourished were referred for dietetic assessment to confirm nutritional status by an experienced clinical dietitian. Therefore, data collection was cross-checked against clinical dietetics assessment for further confirmation of inter-relater reliability.

Demographic and Clinical Characteristics

Age, sex, diabetes status, smoking status, tumour location, neoadjuvant treatment received, and surgery type were collected from the patient's medical record. Tumour staging was as per the American Joint Committee on Cancer (AJCC) staging system.[18]

Anthropometry and Body Mass Index

Weight was measured using calibrated scales and recorded to the nearest 0.5kg. Patients were wearing hospital gowns and if unable to be weighed, weight was obtained from pre-admission clinic (PAC) data in the patient's medical record or patients were asked to recall their weight the week prior to surgery. Height was either obtained from the medical record or patient reported and recorded to the nearest cm. Patient reported weight and height history has been demonstrated to be reliable against actual history.[19] Body Mass Index (BMI, kg/m^2) was calculated using the following formula: BMI = weight (kg)/height squared (m^2). Patients were categorised according to the World Health Organisation (WHO) BMI classifications regardless of age.[20]

Malnutrition Screening Tool (MST)

The MST was used to determine nutritional risk and has been validated for use in oncology settings.[21] As it focuses on two key aspects of malnutrition, it is a rapid screening tool which is easy to implement and does not require specialised staff to complete. In comparison to the gold-standard, PG-SGA, it has been shown to have high specificity and acceptable inter-relater reliability to be a valid screening tool.[22] The MST consists of two questions regarding recent unintentional weight loss and appetite. An MST score ≥2 indicates risk of malnutrition. The MST was verbally administered.

Patient-Generated Subjective Global Assessment (PG-SGA)

Assessment of nutritional status was completed using the PG-SGA, which is validated for use in oncology populations. Although some training is required it is simple to administer, well-validated and cost-effective. It is the gold-standard for nutritional assessment due to its high sensitivity and specificity.[23] Nutritional assessment ratings are as follows: A – well nourished; B – mild to moderately malnourished; C – severely malnourished. The PG-SGA numerical score was also recorded.

Handgrip Strength Measurement

Muscle strength has been recommended as a supportive measure alongside muscle mass.[14] HGS is a measure of muscle strength and function and has been shown to be a surrogate indicator of muscle mass and malnutrition. It has also been validated against total body composition.[24] Muscle strength was measured using a digital Jamar Plus hand dynamometer as per the methodology of the American Society of Hand Therapists (ASHT), which is considered the gold standard.[25] The mean value of both left and right hands were recorded, and the highest mean value taken for analysis. Cut-offs for low muscle strength diagnosis were as per the European Working Group on Sarcopenia in Older People (EWGSOP) sarcopenia guidelines; <27kg for males and <16kg for females.[8]

CT Muscle Mass Analysis

CT-body composition has been validated against total body muscle mass with DXA and magnetic resonance imaging (MRI).[10, 11] Staging CT scans undertaken within 30 days pre-operatively were obtained for analysis, and a single axial image at the L3 level was utilised for analysis. Quantification of abdominal and vertebral muscles (psoas, erector spinae, quadratus lumborum, transversus abdominus, external and internal obliques, and rectus abdominus) was performed according to tissue-specific Hounsfield units (HU) ranges (-29 to 150HU) using Slice-O-Matic Software version 5.0 (Tomovision, Quebec, Canada). Analysis was conducted by a single observer who is trained in using the Alberta protocol (__). Inter-rater reliability assessment was conducted between the observer and a member of the research team who is also credentialled to perform CT body composition analysis (__), and the coefficient of variation was <2%.[26] A trained radiologist was also consulted for guidance on interpretation of CT images as required. Skeletal muscle index (SMI, cm^2/m^2) was calculated as the skeletal muscle area (SMA, cm^2) scaled to height (m^2). Cut-offs used for low muscle mass diagnosis were by Prado et al. 2008; <52.4 cm^2/kg^2 for males and <38.5cm^2/kg^2 for females.[27]

Feasibility of CT Muscle Mass Analysis and Handgrip Strength Measurement

Unanalysable scans and number of patients unable to undergo HGS were recorded as this influences overall results and has implications in the utility of these tools in the post-operative setting.

Statistical Analysis

Normally distributed data are presented as mean (SD) and not normally distributed data presented as median (IQR). Non-parametric fisher's exact test were utilised for categorical variables and Mann Whitney U test were utilised for continuous variables due to small sample size. Agreement between PG-SGA, MST, BMI and CT analyses was analysed using Cohen's kappa coefficient. Agreement was classified as slight (<0.20), fair (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80) or excellent (>0.80) as per published reference values.[28] The statistical package SPSS (Version 24, licensed to the University of ____, Chicago, Illinois, USA) was utilised for data analysis.

RESULTS

Demographic Characteristics and Assessment Outcomes

A total of 57 patients who had CRC surgery were included in the study, with a mean (SD) age of 64 (13) years. Baseline demographic characteristics as well as the results from anthropometric, nutritional and muscle mass assessment are shown in Table 2. The majority presented with left sided tumours (73.7%), whilst laparoscopic surgery was performed in the majority of cases (34; 59.6%). There were no significant differences in any of the demographic characteristics between males and females.

The majority of patients were overweight or obese (34; 60%), with only two (4%) patients being classified as underweight according to their BMI. Of those able to complete HGS assessment, most had normal measurements (25; 93%). Eighteen (32%) of patients were identified as at risk of malnutrition according to MST and 10 (18%) of patients were classified as malnourished according to PG-SGA. CT-determined low muscle mass was identified in 24 (47%) patients and was statistically more prevalent in males than females (60% vs 29%, p=0.045). Aside from CT-determined low muscle mass, the results from the other tools showed no significant differences between males and females.

Ability of Tools to Detect Low Muscularity Compared to CT Analysis

Figures 1a, 1b and 1c depict the ability of each screening/assessment tool to identify patients with CT-defined low muscle mass. Amongst patients with CT-defined low muscle mass 22 (92%) patients were classified as being well-nourished by the PG-SGA, and the agreement was slight (Kappa= -0.068, p=0.473). Seventeen (71%) patients with low muscle mass were classified as not at nutritional risk by MST, and the agreement was slight (Kappa=0.071, p=0.570). BMI results of patients with CT-defined low muscle mass revealed, 1 (4%) patient was underweight, 12 (50%) were of normal BMI, 4 (17%) were overweight and 7 (29%) were obese, with the agreement also being slight (Kappa=0.082, p=0.054).

Figure 1: Ability of Screening and Assessment Tools to Identify Patients with Low Muscle Mass According to CT

The percentage of patients with normal muscularity vs. CT-defined low muscularity within each tool is depicted in Figures 2a, 2b and 2c. Within the PG-SGA, two (33%) of the six malnourished patients and 22 (49%) of the forty-five well-nourished patients had CT-defined low muscle massSeven (54%) out of 13 patients classified as at risk of malnutrition by MST and 17 (45%) out of 38 patients classified as not a nutritional risk were identified as having CT-defined low muscle mass. Amongst the BMI categories, the only underweight participant also had low muscle mass. For each tool, there were no significant differences between the proportions of patients identified as having low muscle mass versus those with normal muscle mass (p=0.671, 0.749 and 0.06 for PG-SGA, MST and BMI respectively). However, the sample size, particularly for malnourished patients, was small.

Figure 2: Prevalence of Low Muscularity on CT According to PG-SGA, MST and BMI

Feasibility of CT Analysis and Handgrip Strength in Clinical Practice

Figure 3 shows the number of participants who participated in each assessment. Overall, 51 (90%) patients were able to have muscle mass measured using CT analysis. The remaining six patients had scans which were either of poor image quality or unavailable prior to surgery. Those unable to participate in CT analysis included 14% of moderately malnourished patients (PG-SGA score B) and 100% of severely malnourished patients (PG-SGA score C) (p=0.007).

Only 27 (47%) patients were able to complete HGS testing within the three days post-surgery. Those unable to complete HGS testing included all malnourished patients, 72% of patients with MST ≥2 and both underweight patients. Reasons for inability to perform HGS testing in the remaining 30 patients in the post-operative period included post-operative pain and nausea, inability to transfer to sitting for correct positioning and comorbidities affecting the upper limbs such as arthritis or previous neurological injury.

Figure 3: Completion of Study Assessments by Participants

DISCUSSION

There is increasing evidence to support the importance of identifying and treating both malnutrition and low muscle mass in patients with cancer.[9, 29] This exploratory study assessed the ability of MST, PG-SGA, BMI and HGS to detect low muscularity compared to the gold standard of CT analysis in a small cohort of patients with CRC. Given tools to assess muscle mass are limited in the clinical setting, we aimed to explore the potential utility of readily available to identify low muscle mass. The feasibility of utilising CT-analysis and HGS measurement in the clinical setting was also briefly explored, which has previously not been investigated in a colorectal cancer surgery cohort.

Our overall incidence of low muscle mass was 47% while 92% of these patients were classified as well-nourished according to PG-SGA. This is in the setting of 60% of our population being classified as overweight or obese. Our results indicate that CT diagnosed low muscle mass is likely to be missed by PG-SGA. Few studies have investigated the utility of existing nutritional screening and assessment tools to identify patients with low muscularity compared to an objective measure. A study of outpatients with CRC by Souza et al. conducted in 2019 comparing CT analysis with surrogate tools for assessment of muscle status found that the physical examination component of the PG-SGA (not the complete PG-SGA assessment) had the best agreement with CT, compared to mid-upper arm muscle area, calf circumference and skeletal muscle mass from bioelectrical impedance analysis (BIA).[30] An earlier study in patients with CRC by the same group investigated the prevalence of malnutrition diagnosed by PG-SGA, CT diagnosed low muscle mass (termed pre-sarcopenia in their study) and sarcopenia diagnosed using CT analysis with muscle strength and functional testing. Similar to our results there was a higher prevalence of CT detected low muscle mass in males vs. females. Souza et al, showed a significant association between malnutrition diagnosed by PG-SGA and sarcopenia diagnosed by CT analysis and strength/functional testing.[31] This is in contrast to our findings, however their study did not explore the associations between patients with low muscle mass and malnutrition which would have made their results more comparable. In comparison to our study and cohort, both Souza et al. studies had larger sample sizes, were conducted in patients with CRC undergoing a mixed range of treatments at varying timepoints and had a high percentage of stage III-IV cancers (72% and 78% respectively, compared to 35% in our study). It is unsurprising that the prevalence of malnutrition was almost double that of our cohort given the high percentage of advanced cancers. Furthermore, if HGS measurements were more feasible in our study it would have provided an opportunity to explore whether malnutrition screening and assessment are able to capture patients with primary sarcopenia..

We found the MST classified 71% of patients with low muscle mass as not being a nutritional risk. To the authors' knowledge, only one other study has assessed the utility of MST to identify patients with low muscle mass in patients with cancer. Bhuachalla et al. found that only 16% of outpatient oncology patients with CT determined low muscle mass were classified as at-risk of malnutrition by MST.[32] Interestingly, Almasaudi et al. found a statistically significant difference in CT defined low muscle mass prevalence according to another commonly utilised screening tool, the Malnutrition Universal Screening Tool (MUST), in surgical patients with CRC. The results demonstrated that 76% of patients with MUST $\geq$2 (high risk of malnutrition) had low muscularity according to CT compared with 45% of patients with MUST 0.[33] Given both the MUST and MST are commonly utilised malnutrition screening tools in hospital settings, future research should compare the utility of MUST versus MST for the potential identification of low muscularity as well as malnutrition in a larger sample size. It would be important to see whether BMI together with objective weight loss measurement allows for higher positive predictive value in identifying patients with low muscle mass. Alternatively, screening tools designed to detect primary sarcopenia, such as the SARC-F, should be explored for their ability to detect low muscle mass alone.[34]

Sarcopenia defined by CT analysed low muscle mass and diminished muscle strength/function, has been shown to be a predictor of poorer survival, higher risk of post-operative complications and higher need for in-patient rehabilitation.[35] However, assessment for low muscle mass and impaired muscle strength/function is not a routine part of in-patient assessment. Given this, we aimed to explore whether using pre-operative CT scans and HGS in a post-operative setting would be feasible. Based on the availability of preoperative CT scans, we found that CT muscle analysis is feasible in patients with CRC undergoing surgery. However, limited availability of skilled staff and expensive software are still obstacles to the use of CT analysis in the clinical setting. It is important to note that the small number of patients in our study who were unable to have CT analysis completed included a high proportion of those with a PG-SGA score C as well as an MST score ≥2. This may have led to an underestimation of low muscle mass prevalence in our cohort, and a further underestimated ability of the PG-SGA and MST to identify low muscularity in this cohort.

Handgrip strength is becoming increasingly recommended as a quick, supportive measure alongside muscle mass assessment for diagnosis of sarcopenia, as it is known that a decrease in muscle mass is often associated with a decrease in muscle strength.[14] In our study, many patients were unable to undergo hand dynamometry postoperatively and malnutrition was significantly associated with inability to complete HGS measurement. A similar study demonstrated that, unsurprisingly, well-nourished patients had higher HGS than malnourished patients.[36] The inability to complete HGS raises the question of the clinical utility of HGS in post-operative patients with CRC. Funding limitations and the constraints of a small student research project prevented us from performing HGS pre-operatively thus hindering interpretation relating to the ability of HGS to identify patients with low muscle mass. Pre-operative HGS measurement would likely be more feasible and would allow for implementation of a functional component such as the gait speed test. There is evidence to support adding a functional component when assessing low muscle mass, results in better prediction of post-operative complications.[37]

The utility of BMI to identify those with low muscle mass or malnutrition has been researched and found to be unreliable.[38] The C-SCANS study of 3,264 patients with stage I-III CRC demonstrated that patients with high levels of adiposity and low muscle mass had a high risk of mortality.[39] In this study, one-third of obese patients who had CT analysis completed had low muscle mass. The study by Souza et al. found that low BMI was significantly associated with muscle mass.[31] Thoresen et al. conducted a study in patients with stage IV CRC using the same low muscle mass cut-offs as our study and found that no obese patients had low muscle mass.[40] However, again the advanced tumour stage of participants in both these studies would likely impact results and limit comparison with our study. The challenges in interpretation of body composition assessment in patients with CRC have been previously described including lack of consistency in definitions and methodology.[41] The thresholds used to diagnose low muscle mass in this study were based on the landmark study by Prado et al.[27] Whilst these thresholds have been utilised by the majority of studies assessing low muscle mass in oncology and surgical populations, there are no universally accepted thresholds for CT muscle mass analysis.[41] Obesity has been found to be a confounder when quantifying skeletal muscle mass with suggestions that low muscle mass cut-offs based on BMI category are much more representative of the true sarcopenic status.[39] Hopkins et al. 2019 carried out optimal stratification of SMI according to BMI.[42] Ideally this would be carried out to set cut-offs that are tailored to each individual population, however, this is not feasible for many studies including this study.

There are several strengths to our study. It was prospectively designed and allowed for implementation of screening and assessment tools in 'real-time' thereby facilitating investigation of the feasibility of conducting HGS and CT body composition analysis in clinical practice. Our study was clinically relevant as we studied the most common tools used for nutrition assessment in the oncological setting. We also limited our cohort to patients undergoing curative CRC surgery, which minimised confounding from patients with advanced cancer that may have cancer cachexia and higher levels of chronic inflammation. The limitations to our study included the small sample size and short recruitment period. A larger sample size would have allowed for statistical analyses of sensitivity and specificity, Furthermore, the number of CT scans which were unable to be evaluated as well as the number of patients who were malnourished and unable to complete HGS post-operatively influenced the strength of our analyses. Increased numbers of CT scans would have improved the study power and changing the timing of HGS assessment to facilitate increased participation would have potentially allowed us to add a functional component to our analysis of low muscle mass.

CONCLUSION

In this exploratory study, existing nutritional screening and assessment tools did not perform well in capturing low muscle mass in surgical patients with CRC. Analysis of muscle mass using pre-operative CT scans is feasible provided there is access to the skills and software required, however HGS post-surgery was not feasible in a substantial proportion of patients. There is a gap in identifying patients with low muscle mass and the results highlight the need for further research regarding the application and timing of use of clinically feasible tools for diagnosis of low muscle mass in the clinical setting.

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported. The design and reporting of this study comply with the STROBE checklist for reporting of exploratory studies. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned have been explained.

FIGURE LEGENDS

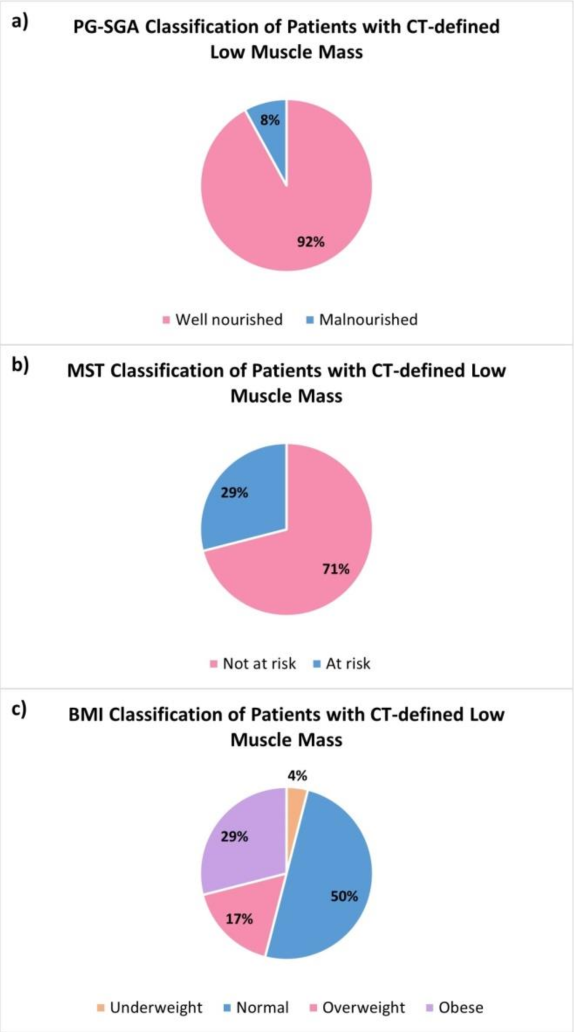

Figure 1.

BMI Body Mass Index

CT Computed Tomography

MST Malnutrition Screening Tool

PG-SGA Patient-Generated Subjective Global Assessment

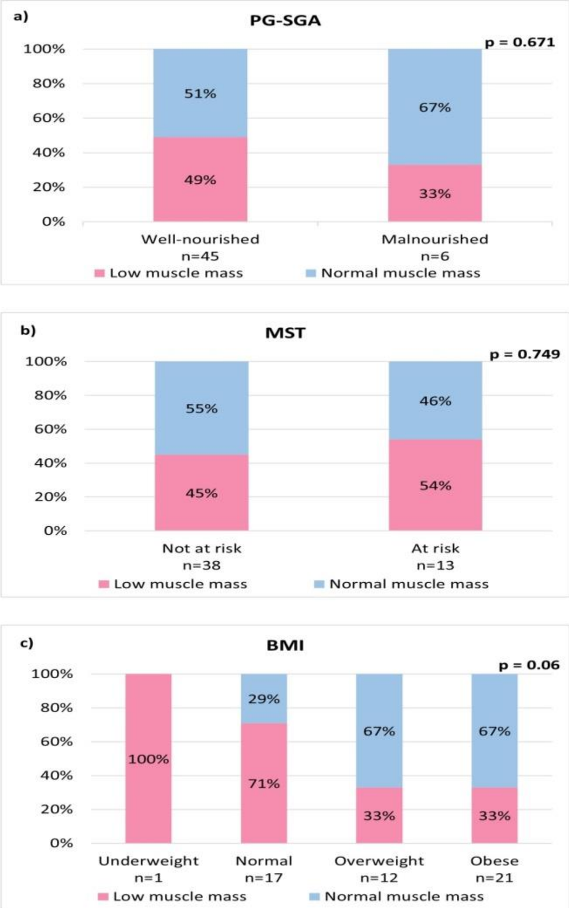

Figure 2.

BMI Body Mass Index

CT Computed Tomography

MST Malnutrition Screening Tool

PG-SGA Patient-Generated Subjective Global Assessment

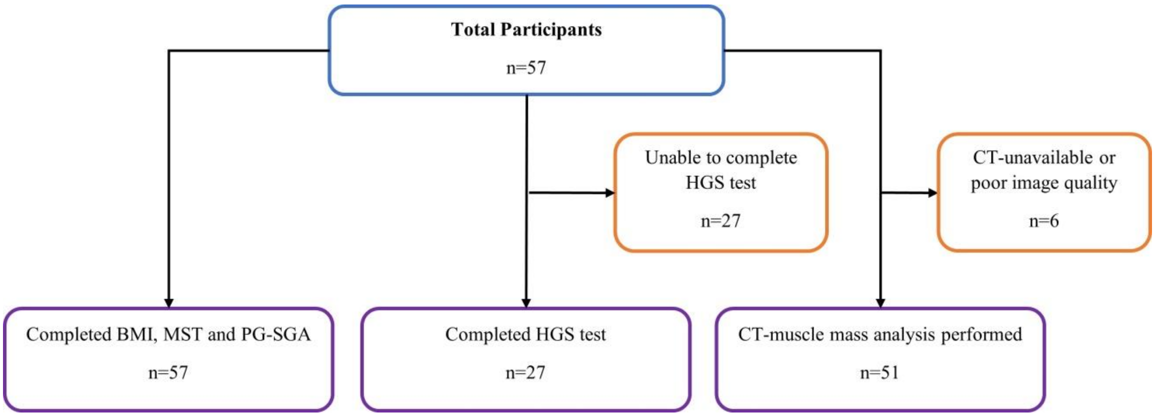

Figure 3.

One (14%) patient with PG-SGA score B and all 3 (100%) patients with PG-SGA score C were unable to have CT analysis complete (p=0.007). All patients with a PG-SGA score B or C were unable to complete HGS (n=10, p=0.001).

BMI Body Mass Index

CT Computed Tomography

HGS Handgrip Strength

MST Malnutrition Screening Tool

PG-SGA Patient-Generated Subjective Global Assessment

SMI Skeletal Muscle Index

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Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
1. ≥ 18 years old 2. Primary diagnosis of CRC 3. Had curative surgery for CRC this admission 4. Were within 3 days of admission to the surgical ward 5. Agreed to take part in this study	1. < 18 years old 2. Had palliative surgery 3. Unable to consent to screening and assessment due to cognitive impairment or psychiatric illness 4. Too unwell to complete assessment

Table 2: Demographic Characteristics and Assessment Outcomes

	Total (n-57)	**Males (n=34)**	**Females (n=23)**	**P value Males vs Females**
Age (y)#	64 (13)	64 (11)	66 (15)	0.520
Diabetes				0.760
Yes	15 (26.3%)	8 (24%)	7 (30%)	
No	42 (73.7%)	26 (76%)	16 (70%)	
Smoking (n=56)				0.449
Yes	8 (14.0%)	6 (17%)	2 (9%)	
No	48 (84.2%)	27 (83%)	21 (91%)	
Tumour location				0.760
Right	19 (33.3%)	9 (26.5%)	10 (43.5%)	
Left	38 (66.7%)	25 (73.5%)	13 (56.5%)	
AJCC Stage				0.935
0	2 (3.5%)	1 (2.9%)	1 (4.4%)	
1	14 (24.6%)	9 (26.5%)	5 (21.7%)	
2	21 (36.8%)	13 (38.2%)	8 (34.8%)	
3	20 (35.1%)	11 (32.4%)	9 (39.1%)	
4	0 (0%)	0 (0%)	0 (0%)	
Neoadjuvant treatment				0.689
Yes	7 (12.3%)	5 (15%)	2 (2%)	
No	50 (87.7%)	29 (85%)	21 (91%)	
Surgery type				0.786
Open	23 (40.4%)	13 (38%)	10 (43%)	
Laparoscopic	34 (59.6%)	21 (62%)	13 (57%)	
BMI (kg/m^2)#	28.9 (7.6)	29.0 (7.2)	28.2 (8.5)	0.505
BMI range (kg/m^2)				0.738
<18.5	2 (3.5%)	1 (3%)	1 (4%)	
18.5 – 24.9	21 (36.8%)	12 (35%)	9 (39%)	
25.0 – 29.9	12 (21.1%)	6 (18%)	6 (26%)	
>30	22 (38.6%)	15 (44%)	7 (30%)	
HGS (n=27)				0.538
Normal	25 (92.6%)	16 (89%)	9 (100%)	

Low	2 (7.4%)	2 (11%)	0 (0%)	
MST <2 ≥2	 39 (68.4%) 18 (31.6%)	 25 (74%) 9 (26%)	 14 (61%) 9 (39%)	0.388
PG-SGA numerical score#	7.2 (5.9)	6.1 (5.3)	8.9 (6.5)	0.72
PG-SGA category A B C	 47 (82.5%) 7 (12.3%) 3 (5.3%)	 29 (85%) 2 (6%) 3 (9%)	 18 (78%) 5 (22%) 0 (0%)	0.09
Skeletal Muscle Index# (SMI, cm^2/kg^2, n=51)	N/A gender specific variable	51.0 (8.8)	44.4 (9.6)	N/A gender specific variable
Low muscle mass (n=51) Yes No	 24 (47.1%) 27 (52.9%)	 18 (60%) 12 (40%)	 6 (29%) 15 (71%)	**0.045***

BMI, body mass index; HGS, handgrip strength; MST, malnutrition screening tool; PG-SGA, patient-generated subjective global assessment; SMI, skeletal muscle index
n=57 unless otherwise specified
*p-value < 0.05
#Values expressed as mean (standard deviation)
Remaining values expressed as number (percentage)