

Low skeletal muscle mass predicts poor prognosis of elderly patients after emergency laparotomy: A single Asian institution experience

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ABSTRACT

Introduction: Sarcopenia, defined as low skeletal muscle mass and poor muscle function, has been associated with worse postoperative recovery. This study aims to evaluate the significance of low muscle mass in the elderly who require emergency surgeries and the postoperative outcomes.

Method: Data from the emergency laparotomy database were retrieved from Khoo Teck Puat Hospital, Singapore, between 2016 and 2019. A retrospective analysis was performed on patients aged 65 years and above. Data collected included skeletal muscle index (SMI) on computed tomography scan, length of stay, complications and mortality. Low muscle mass was determined based on 25th percentile values and correlation with previous population studies.

Results: A total of 289 patients were included for analysis. Low muscle mass was defined as L3 SMI of $<22.09\text{cm}^2/\text{m}^2$ for females and $<33.4\text{cm}^2/\text{m}^2$ for males, respectively. Seventeen percent of our patients were considered to have significantly low muscle mass. In this group, the length of stay (20.8 versus 16.2 $P=0.041$), rate of Clavien-Dindo IV complications (18.4% vs 7.5% $P=0.035$) and 1-year mortality (28.6% vs 14.6%, $P=0.03$) were higher. Further multivariate analysis showed that patients with low muscle mass had increased mortality within a year (odds ratio 2.16, 95% confidence interval 1.02–4.55, $P=0.04$). Kaplan-Meier analysis also shows that the 1-year overall survival was significantly lower in patients with low muscle mass.

Conclusion: Patients with low muscle mass have significantly higher post-surgical complication rates and increased mortality.

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Keywords: Emergency laparotomy, geriatrics, mortality, postoperative outcome, sarcopenia

INTRODUCTION

Emergency laparotomy (ELAP) for elderly patients is associated with higher mortality and increased postoperative complications compared with those undergoing elective surgery.¹⁻³ Elderly patients, who are more likely to have comorbidities, have lower functional reserves to cope with the increased physiological demand due to their acute illness and eventual surgical stress. Studies have shown that elderly patients tend to fare poorer postoperatively—including higher mortality rate,³ functional decline and loss of independence, with an increased likelihood of discharge to nursing homes and step-down units.⁴ Due to the global trend of an ageing population, we are increasingly performing ELAP for elderly patients. This will

inherently lead to poorer surgical outcomes and the increased utilisation of more resources.^{5,6} Surgeons must now gain a better understanding of the fundamental pathophysiology of the elderly that distinctly affects their perioperative care.

There has been growing interest in frailty and sarcopenia, and their relationship with surgical outcomes.^{7,8} Frailty is described as a geriatric syndrome primarily determined by physical function and overlaps with sarcopenia, the loss of muscle mass.^{9,10} Sarcopenia is widely regarded as a marker of poor health and suggestive of chronic illness, which makes patients more vulnerable to poor outcomes.^{11,12} The definition and diagnosis of sarcopenia are still evolving as new findings challenge current understanding.¹³

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CLINICAL IMPACT

What is New

- Elderly patients with low muscle mass have an increased risk of complications and mortality following emergency surgeries.
- Low muscle mass can be determined using available computed tomography (CT) images often available in the emergency setting to calculate CT-derived L3 skeletal mass index values. This provides a quick and simple way to identify at-risk populations and guides clinical decision-making without additional procedures or costs.

Clinical Implications

- The study highlights the importance of identifying elderly with low muscle mass and poor surgical outcomes.
- CT-derived L3 skeletal muscle index could facilitate accurate postoperative prognostication and clinical decision-making.

Recently, the Asian Working Group on Sarcopenia (AWGS) and the International Working Group on Sarcopenia have defined sarcopenia as low muscle mass and poor muscle function in older people.^{10,13} A growing body of literature has focused on this definition of sarcopenia and its effect on postoperative outcomes. Studies have shown its association with higher mortality and morbidity in emergency¹⁴⁻¹⁶ and elective operations for gastric cancer,¹⁷ pancreatic cancer,¹⁸ liver tumours¹⁹ and colorectal cancer.²⁰

Based on recent consensus, low skeletal muscle mass remains crucial in establishing sarcopenia diagnosis.^{21,22} Furthermore, AWGS 2019 recommends screening for sarcopenia by measuring calf circumference as it has moderate-to-high sensitivity and specificity in predicting sarcopenia or low skeletal muscle mass.²¹ In addition, existing strength and performance assessments, which involve specialised clinical tests such as measurement of gait speed and hand grip strength assessment, can be time-consuming and labour-intensive, requiring specially trained professionals to assess.²³ However, the precarious conditions of critically ill patients and the relatively limited time before surgery make these examinations impractical in the emergency setting.

On the other hand, computed tomography (CT) scans, which are almost always performed preoperatively

in emergencies for diagnostic reasons, are readily available. They can be used to quantify muscle mass and aid in screening sarcopenia owing to their ability to separate fat from other soft tissues. CT is also considered to be the gold standard for non-invasive assessment of muscle quantity/mass.²² Recent studies have shown that CT-derived low muscle mass measurements may indicate sarcopenia.²⁴ The cross-section skeletal muscle index (SMI) at the L3 level can predict overall skeletal muscle mass.^{25,26} Therefore, it provides the opportunity to quantify muscle mass promptly with no additional cost.

In this study, we looked at SMI values measured via muscle area at the L3 level on CT scans to assess if lower muscle mass was a predictor of poor outcomes for elderly patients who underwent ELAP. Although many studies have looked at sarcopenia and postoperative outcome, there is no consensus on a cut-off value for SMI that correlates to the reported outcomes, as it varies with different population groups. Given the difference in body size, lifestyle, and background of the Asian population compared to Caucasians,¹³ the cut-off in the Asian population is likely to differ. Our study is also pioneering in Singapore to correlate CT-derived SMI scores with postoperative outcomes.

METHOD

Study population

Patients were selected from the Emergency Laparotomy Pathway Database of Khoo Teck Puat Hospital, Singapore. The database was developed with criteria modelled after the National Emergency Laparotomy Audit in the UK.²⁷ All general surgery patients undergoing laparotomies had their details, surgical procedure and the outcome recorded in our database. Patients over 65 years of age were reviewed by a geriatric specialist postoperatively. Procedures involving subspecialists such as hepatopancreatobiliary, vascular and gynaecological surgeries were excluded. For this study, a retrospective analysis was done on patients aged 65 years and above between 2016 and 2019. Clinical variables for our study included age, sex, race/ethnicity, American Society of Anesthesiology (ASA) score, Charlson Comorbidity Index, type of operative procedures and the indications for surgery. This study was approved by the National Health Group Domain Specific Review Board.

Outcomes assessments

Our primary outcomes were that of 30-day and 1-year mortality. Secondary outcomes include the length of stay in the acute hospital, Clavien-Dindo grade III and above complications, and discharge destination.

Image analysis: Screening for sarcopenia

A retrospective analysis of CT images was done for the patients identified. The skeletal and psoas muscle area was analysed using our hospital's radiology system (Centricity version 6.0, GE Healthcare, Chicago, US). The cross-sectional area of skeletal muscle was measured manually, outlining the skeletal muscles using a freehand region of interest (ROI) tool. Measurements were done by a medical student and a junior radiologist, both trained by a senior radiologist following a predefined method of ROI measurement. A consultant radiologist then rechecks the dataset and key images to confirm the measurements. The readers and consultant radiologists were blinded to the clinical outcomes. Skeletal muscle area (SMA) in cm^2 was derived by radiodensity measurement in Hounsfield units (HU) and defined by a HU range of -29 to $+150$. Measurements were obtained for all the skeletal and psoas muscles in a single 3mm slice at the mid-L3 level (Fig. 1). These muscle area values were then normalised by the patient's height to calculate the skeletal muscle index ($\text{SMI} = \text{total SMA divided by height squared}$) for each patient.

We initially used the cut-off for SMI based on the study population's lowest quartile, or the 25th percentile. This methodology is commonly described in various papers reporting the link between low skeletal mass and postoperative outcome.²⁸⁻³⁰ These values were determined to be 33.4 and $26.3\text{cm}^2/\text{m}^2$ in males and females, respectively. However, based on a local epidemiological population study by the Yishun Study group,³¹ they have determined that the SMI cut-off for the female group was lower at $<22.09\text{cm}^2/\text{m}^2$. Our study data did not exhibit a normal distribution, so the

25th percentile data may not have accurately defined low muscle mass. Hence, we use the SMI values of $<22.09\text{cm}^2/\text{m}^2$ for females as a radiographic threshold to better represent low muscle mass. Cut-off for males remains at $<33.4\text{cm}^2/\text{m}^2$.

Statistical analysis

Data were summarised with descriptive statistics using SPSS Statistics software version 28.0 (IBM Corp, Armonk, US). Differences between the 2 groups (low muscle against normal muscle mass) were assessed using Student's t-test for continuous data and Pearson's chi-square test or Fisher's Exact test for categorical data where appropriate. Fisher's Exact test calculated *P* values for small sample sizes (when more than 20% of cells have expected cell counts >5). Mann-Whitney U test was used to compare the median length of stay across both groups.

Multivariate analysis was used to examine the association between low muscle mass and mortality by estimating the odds ratio (OR) of association and their 95% confidence interval (CI). The test accounted for confounding by adjusting for the patient's age, Charlson Comorbidity Index and malignant disease. These factors were chosen as they are biomarkers related to the geriatric population and have a known influence on survival. Kaplan-Meier survival curves were used to illustrate the relationship between the 2 groups and survival. Follow-up was censored one year after surgery, and a patient was deemed a censored case when they were alive at the end of 1 year post-surgery. *P* values for the survival curves were determined using the log-rank test from the Kaplan-Meier survival curves. Results with $P < 0.05$ are considered statistically significant.

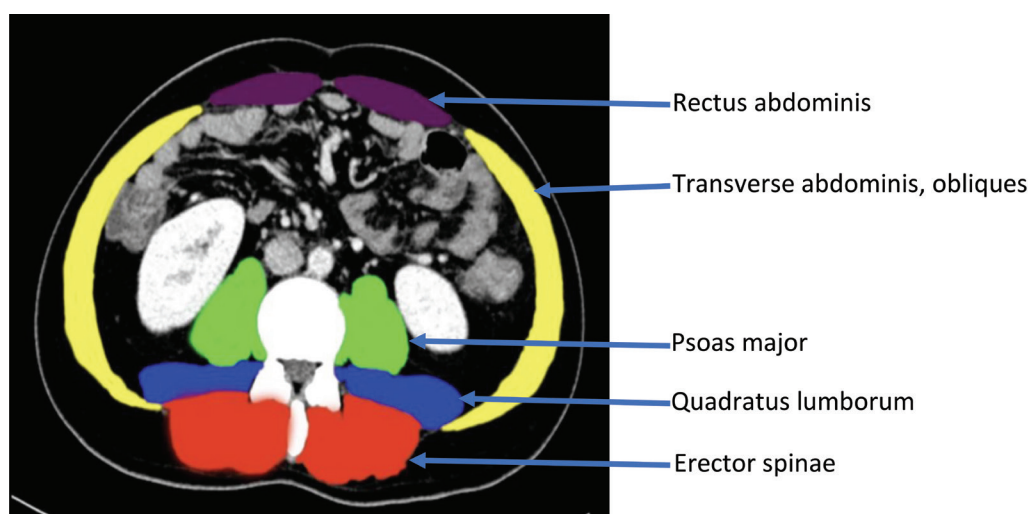


Fig. 1. Sample image of L3 skeletal muscle index measurement on computed tomography imaging.

RESULTS

Between 2016 and 2019, there were 302 emergency laparotomies performed in Khoo Teck Puat Hospital on patients aged 65 years old and above. Thirteen cases were excluded as they did not have preoperative CT scans. A total of 289 cases were analysed and had their L3 SMI calculated. The most common pathology resulting in surgery was due to bowel obstruction (63%), followed by perforation (24%), bowel ischaemia (9%) and others (4%), which include haemorrhage, severe abdominal infection and anastomotic leakage. Thirty percent of these operative cases were malignant in nature.

Based on our SMI cut-off (female SMI <22.09, male <33.4), 17% of our patients were considered to have low muscle mass at presentation. As shown in Table 1, both groups were comparable for most demographic variables except that patients with low muscle mass are older (mean age 78 years vs 75 years), and there were more male patients (75.5%). No statistical difference was observed in the incidence of malignant cases between both groups (34.7% in the low muscle mass group and 28.3% in the normal muscle mass group, $P=0.47$).

When examining the clinical outcomes for both groups (Table 2), patients with low muscle mass had a higher rate of Clavien-Dindo IV complications (18.4% vs 7.5%, $P=0.035$), a longer overall length of stay (20.8 vs 16.2 days, $P=0.041$) and a lower rate of discharge to own home (46.9% vs 63.3%, $P=0.048$). In terms of mortality, patients with low muscle mass had a higher 30-day and 1-year mortality rate, but only differences seen at 1-year mortality were deemed statistically significant (28.6% vs 14.6%, $P=0.03$). Further multivariate analysis (Table 3) showed that patients with low muscle mass were twice as likely to die within 1 year of surgery (OR=2.16, 95% CI 1.023–4.550, $P=0.043$). Cancer patients also had a greater likelihood of 1-year mortality among those that underwent emergency laparotomy (OR 2.756, 95% CI 1.441–5.270, $P=0.002$). The Kaplan-Meier analysis (Fig. 2) shows that the 1-year overall survival differs significantly between the low and normal muscle mass groups ($P=0.014$). The low muscle mass group had a steeper decline rate, particularly within the first half of the year.

DISCUSSION

The rapid ageing of populations around the world presents an unprecedented set of challenges, with shifting disease burdens and increased health expenditure.³² The world now sees a paradigm shift in geriatric surgical care, with increasing attention focused on the quality of life and survival outcomes postopera-

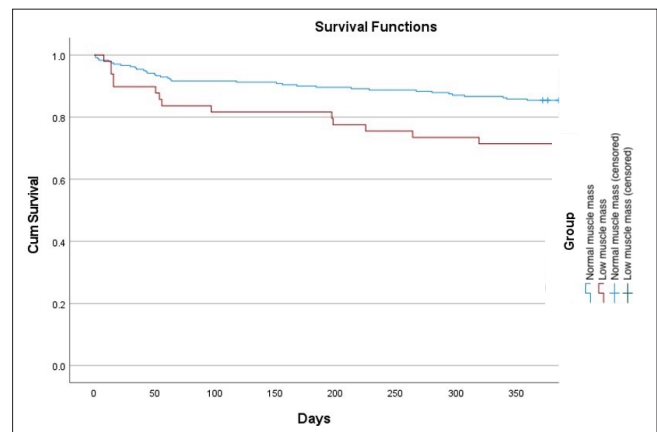


Fig. 2. Kaplan-Meier analysis of 1-year overall survival between low and normal muscle mass groups.

tively.³³ Host-related factors, including premorbidities and body muscle composition, often have a significant association with survival postoperatively. In many studies, reduced skeletal muscle mass, or sarcopenia, has led to worse overall outcomes.^{15,16} Therefore, preoperative diagnosis of sarcopenia may be imperative in clinical decisions for considering an alternative approach to divert an acute surgical emergency to a semi-emergent one. This would buy time for these patients, to be optimised medically in the emergency setting prior to a major surgery.

During an emergency, the additional evaluation of preoperative CT-derived L3 SMI value, based on a pre-existing readily available CT, can add to the current armamentarium of risk stratification tools to predict higher morbidity and mortality in patients whose values fall below the cut-off. Thus, L3 SMI values can be used to predict outcomes, aid in preoperative counselling, and manage patient and family expectations. In addition, using CT-derived L3 SMI values in surgical risk prediction in an emergency set-up is attractive for several reasons. Many studies have consistently demonstrated the ease of using routine staging CT scans to measure body composition.^{21,22,24,26,30} The issue of radiation exposure is irrelevant, as most patients already have the required imaging for diagnostic or preoperative planning purposes. Secondly, while sarcopenia has also been associated with poor grip strength, muscle mass analysis, and gait speed, these assessment tools are often impractical to execute in the emergency setting. It may also be challenging for acutely ill and frail elderly patients to comply with such assessment tests. On the contrary, cross-sectional views of trunk musculature on CT scans can provide a quick, practical and objective method for estimating lean muscle mass in an emergency setting.

Table 1. Demographic and baseline characteristics of the study population

	Low muscle mass (female: SMI <22.09, male: SMI <33.4)	Normal muscle mass	<i>P</i>
Total cases, N	49	240	-
Age, mean ± SD, years	78 ± 6	75 ± 7	0.000
Sex			
Male	37 (75.5)	130 (54.2)	0.009
Female	12 (24.5)	110 (45.8)	
Ethnicity, n (%)			
Chinese	37 (75.5)	179 (74.6)	0.892
Malay	9 (18.4)	43 (17.9)	0.940
Indian	2 (4.1)	14 (5.8)	1.000
Others	1 (2.0)	4 (1.7)	1.000
Charlson Comorbidity Index, mean ± SD	4.9 ± 2.3	4.5 ± 1.9	0.187
Charlson Comorbidity Index, median (range)	4 (2–13)	4 (1–11)	-
American Society of Anesthesiologists (ASA) score, n (%)			
1	3 (6.1)	6 (2.5)	0.182
2	12 (24.5)	81 (33.8)	0.273
3	26 (53.1)	119 (49.6)	0.774
4	8 (16.3)	32 (13.3)	0.744
5	0	2 (0.8)	-
3–5	34 (69.4)	153 (63.7)	0.556
Pathology, n (%)			
Benign	32 (65.3)	172 (71.7)	0.472
Malignant	17 (34.7)	68 (28.3)	-
Indication for surgery, n (%)			
Intestinal obstruction	22 (44.9)	117 (48.8)	0.738
Gastric/bowel perforation	15 (30.6)	56 (23.3)	0.370
Bowel ischaemia	4 (8.2)	23 (9.6)	1.000
Adhesiolysis	8 (16.3)	36 (15.0)	0.986
Others*	0	8 (3.3)	0.359

SMI: skeletal muscle index; SD: standard deviation

* Include anastomotic leak, haemorrhage and abdominal infection

The assessment of sarcopenia has been performed in various contexts and populations using different tools. One component of assessment is to quantify skeletal muscle mass through a reduced CT-derived SMI. Unfortunately, the current literature for defining sarcopenia using CT-derived L3 SMI is heterogenous, with various statistical methods and cut-off values

utilised in different populations and contexts. Not surprisingly, the varying cut-off values in other population groups can be attributed to diverse demographics or even to differing physiques between Asians and their Western counterparts.¹³

While lower L3 SMI values are unequivocally associated with poorer survival,³⁴ the challenge remains

Table 2. Comparison of clinical outcomes between low and normal muscle mass groups

Clinical outcomes	Low muscle mass (n=49)	Normal muscle mass (n=240)	P
Postoperative complications, n (%)			
Clavien-Dindo III	1 (2.0)	13 (5.4)	0.477
Clavien-Dindo IV	9 (18.4)	18 (7.5)	0.035
Clavien-Dindo V	4 (8.2)	9 (3.8)	0.245
Clavien-Dindo III–V	14 (28.6)	40 (16.7)	0.081
Hospital length of stay			
Overall length of stay, mean $\pm$ SD, days	20.8 $\pm$ 14.8	16.2 $\pm$ 14.0	0.041
Overall length of stay, median (IQR), days	16.0 (9.5–27.5)	12.0 (8.0–18.0)	0.016
Critical care days, mean $\pm$ SD	7.2 $\pm$ 6.8 (n=31)	6.4 $\pm$ 7.6 (n=125)	0.608
Critical care days, median (IQR)	2.0 (0–6.0)	1.0 (0–4.0)	0.110
Discharge facility			
Home	23 (46.9)	152 (63.3)	0.048
Other acute hospitals	0	1 (0.4)	-
Community hospitals	19 (38.8)	74 (30.8)	0.359
Nursing homes	2 (4.1)	4 (1.7)	0.270
Overall mortality			
30-day mortality	5 (10.2)	9 (3.8)	0.068
90-day mortality	8 (16.3)	20 (8.3)	0.145
1-year mortality	14 (28.6)	35 (14.6)	0.030

IQR: interquartile range; SD: standard deviation

Table 3. Multivariate analysis of factors associated with 1-year mortality

	Odds ratio	95% confidence interval		P value
		Lower	Upper	
Age $\geq$ 75 years	1.710	0.873	3.347	0.118
Charlson Comorbidity Index $\geq$ 5	1.713	0.888	3.304	0.108
Malignancy	2.756	1.441	5.270	0.002
Low muscle mass	2.158	1.023	4.550	0.043

to establish an appropriate cut-off value that best predicts negative outcomes. In our study, by establishing the 25th percentile of L3 SMI values for our Singapore population undergoing emergency laparotomy, we identified the values for low muscle mass as $<33.4\text{cm}^2/\text{m}^2$ and $<26.3\text{cm}^2/\text{m}^2$ in males and females, respectively, to prognosticate poorer outcomes. Previous studies have used the 25th percentile of the study population

as an indicator of sarcopenia with a normal distribution of enrolled cases.^{28–30} However, since the SMI data in this study did not show a normal distribution, using the 25th percentile was not robust enough to measure a significant difference in outcomes. As such, to better refine our Singapore diagnostic criteria for low muscle mass, we correlated our data with a similar population-based study conducted by Pang et al.³¹ The latter seeks

to describe the prevalence of elderly with low skeletal muscle mass among community-dwelling adults according to the Asian Working Group for Sarcopenia criteria, 2019 (AWGS2019),²¹ and European Working Group on Sarcopenia in Older People criteria, 2018 (EWGSOP2) guidelines.²² Pang et al. identified the appendicular lean mass (ALM) sarcopenia cut-off measured using dual-energy X-ray absorptiometry for this population. This was determined to be 5.28kg/m² and 3.69kg/m² in males and females, respectively.³¹ Using a linear regression model previously formulated to determine the relationship between ALM and SMI, the SMI cut-off for sarcopenia in this local population was extrapolated to be <37.4cm²/m² and <22.09cm²/m² for males and females, respectively.³¹ We selected the lower threshold for SMI values of <33.4cm²/m² and <22.09cm²/m² for both males and females, respectively, and subsequently showed that they could predict statistically significant negative outcomes. Significantly, we were able to establish the CT-derived L3 SMI values that could predict negative effects in our Asian population in Singapore.

Nevertheless, the retrospective nature of our study in a single institution limits the generalisability of our results. In addition, muscle strength and physical performance evaluations often described within the definition of sarcopenia were not measured in this study, as such examinations may not be feasible in acutely ill patients and there is limited time before surgery. There is also a lack of consensus surrounding sarcopenic thresholds; for example, the most frequently used cut-off points come from Martin et al.³⁵ and Prado et al.³⁶ Both studies used optimal stratification to define their cut-off points in a Canadian population of obese and mixed body mass index cohort of gastrointestinal and respiratory tract tumours.^{35,36} Optimal stratification is one known and validated statistical tool used by other groups to identify cohort-specific cut-offs.³⁵ However, when applying Martin's or Prado's cut-offs, the prevalence of sarcopenia in published cohorts ranges from 41–47% and 15–60%, respectively.^{35–37} In our Singapore data of patients above 65 years old who required emergency laparotomy, using these published cut-offs did not find any statistically significant adverse outcomes as such. Applying population-specific cut-off points by optimal stratification may be helpful only if they have not been previously defined in a similar population. There is not a universally accepted or easily generalisable cut-off value for low muscle mass, as we can naturally expect Asian cohorts to have a lower cut-off than their Caucasian counterparts.^{13,21}

The pitfall in using a reference cut-off value lies in its generalisability due to inherent differences in population demographics. Using a cut-off value will be appropriate and meaningful only when validated within the native population.

CONCLUSION

In conclusion, the literature on sarcopenia and adverse outcomes rapidly evolves and continues to gain traction. Our data suggest that patients with low muscle mass requiring emergency surgeries have a higher risk of postoperative complications, an increase in the overall length of hospital stay, and a greater risk of 1-year mortality than those with higher muscle mass. The availability of CT-derived SMI scores preoperatively in the emergency setting may help with preoperative decision-making and predict postoperative outcomes. Emergency surgery in geriatric surgical patients remains an exciting field, and using CT-derived SMI value may revolutionise perioperative care and patient selection, as well as guide decisions for surgery.

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