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# The association between psoas muscle area index and morbidity/mortality in laparoscopic gastric cancer surgery

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**Abstract**

As advanced gastric cancer often leads to obstruction or cancer-related cachexia, gastric cancer seems to have a closer association with sarcopenia than other types of cancer. Our study aim was to investigate the relationship between the psoas muscle area (PSMA) and morbidity and mortality in patients undergoing gastric cancer surgery. The data of patients who underwent laparoscopic gastric resection between November 2014 and April 2020 were analyzed retrospectively. The intervertebral disc space was verified at L3-4 in the sagittal plane. The PSMA on the right and left sides were measured separately and then added to obtain the total PSMA. This value was then divided by the patient's height ($m^2$) to calculate the psoas muscle area index (PSMAI) ($mm^2/m^2$). The mean PSMAI of men (741.1 $mm^2/m^2$) was significantly higher than that of women (502.1 $mm^2/m^2$) ($p<0.001$). While there was a positive correlation between the PSMAI and BMI (r:0.352, p:0.019 in women; r:0.447, $p<0.001$ in men), the correlation between PSMAI and age was negative (r: -0.369, p:0.014 in women; r:-0.349, $p<0.001$ in men). PSMAI was statistically lower in patients with attendant morbidity (p:0.035). There was no significant relationship between PSMAI and the first 30-day mortality rate (p:0.096); however, the association between PSMAI and both the 90-day mortality rate (p:0.023) and the total mortality rate (p:0.046) were significant. In our opinion, assessing gastric cancer patients for sarcopenia and supporting them with the necessary nutrition and exercise program prior to surgery can help predict and lower postoperative morbidity and mortality rates.

**Keywords:** Gastric cancer, laparoscopic surgery, morbidity, mortality, sarcopenia, psoas muscles

## Introduction

Gastric cancer is the fifth most common type of cancer in worldwide and is the third leading cause of cancer-related deaths [1]. Despite significant advances in medical treatment, curative surgery is still the gold standard; however, since gastric cancer surgery is a major abdominal operation, the perioperative process needs careful handling. For all major abdominal surgeries, the patients' preoperative physical condition, their nutritional status and the presence of any comorbidities carry great importance. In particular, advanced gastric cancer can impair preoperative nutrition, through cancer-related cachexia and by causing obstruction. In addition, as the volume of the stomach is reduced after gastric resection, post-op food intake will decrease considerably [2]. For these reasons, gastric cancer seems more closely associated with sarcopenia than other types of cancer [3].

Sarcopenia is a condition characterized by a decline in muscle mass, muscle strength and capacity for physical activity [4]. It was first described by Rosenberg as a phenomenon related to age [5]. Although it was originally considered to be confined to the aging process, a second type of sarcopenia is now recognized. Sarcopenia may occur secondary to a systemic disease, particularly a disease such as malignancy that accelerates the inflammatory process in the

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body and through restricting food consumption, causes insufficient intake of protein and calories [6].

In order to diagnose sarcopenia, muscle mass, muscle quality and physical activity levels must be measured. In routine practice, different reference points are used to measure muscle mass, such as appendicular skeletal muscle mass or the cross-sectional area of particular muscle groups, and several parameters such as height, body mass index or body surface area have been proposed for adjusting the results. Whichever method is chosen, magnetic resonance imaging or computed tomography is considered the gold standard for these measurements [7-10].

Many previous studies have shown that sarcopenia has an adverse effect on the perioperative period and is associated with poor prognosis in many types of cancer. Studies carried out to assess the relationship between sarcopenia and gastric cancer, in particular, have commonly used the total skeletal muscle area index at the L3 vertebra level [3,11,12]. However, a previous study investigating the relationship between sarcopenia and liver cirrhosis reached reliable results using the psoas muscle area index (PSMAI) [13]. In our study of patients undergoing surgery for gastric cancer, we aimed to investigate the correlation between PSMAI and morbidity and mortality.

## Materials and Methods

### Patients

This study was designed as a case series analysis and approved by the Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee (2021/1736). The data of 195 patients who underwent laparoscopic gastric resection for gastric cancer at the General Surgery Clinic between November 2014 and April 2020 were retrospectively analyzed. The study comprised patients who had had a computed tomography examination during the four-week period before surgery and whose images were still available. Patients whose surgery was palliative or emergency and those whose resection was planned as open surgery were excluded from the study.

### Clinical Data

Patient demographics such as age, gender, height, weight, body mass index, comorbid diseases, and history of previous abdominal surgeries were recorded in the database. In addition, details related to the tumor and operation such as tumor type, grade, location and stage; operation type, technique, duration, lymph node dissection status and additional organ resection were recorded. Intraoperative complications, time to oral intake, hospitalization time, and chemotherapy initiation time were verified to evaluate the perioperative process. Postoperative complications were grouped according to Clavien-Dindo classification [14], and postoperative morbidity and mortality data were obtained from the relevant medical records.

### PSMAI measurement

PSMAI measurements were determined by a radiologist, with six years of experience, using thin-section abdominal CT images taken within the 4 weeks prior to gastrectomy. Reformatted 3D images were obtained. L3-4 intervertebral disc space within the sagittal plane was established. Axial correction was made in the coronal and sagittal planes, and a mm² measurement was taken in the axial plane using the region of interest (ROI) area tool. Right and left PSMAs were measured separately and the total PSMA was obtained by combining the two values. PSMAI (mm²/m²) was calculated by dividing this total value by the patient's height (m²). (Figure 1,2)

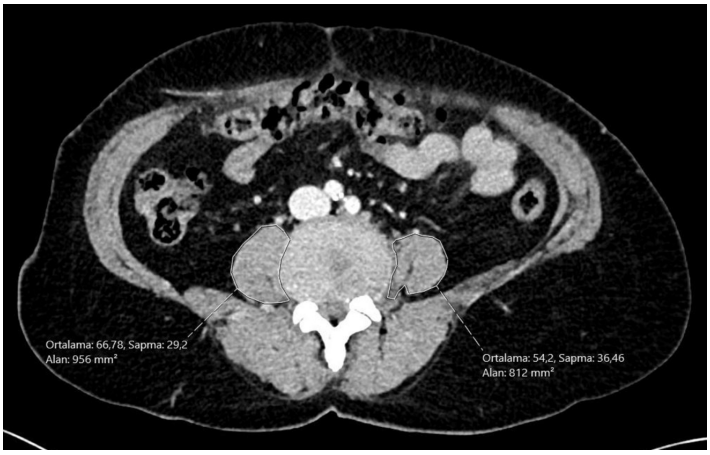


**Figure 1.** An example of how PSMAI is measured in axial CT images

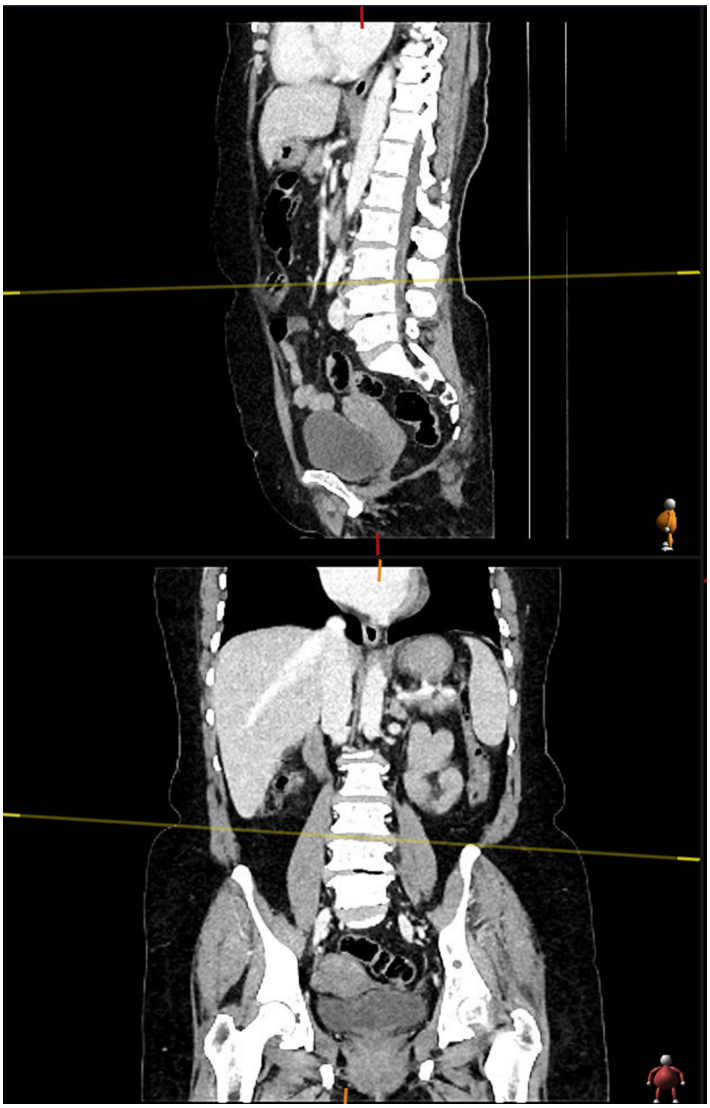

**Figure 2.** An example of level determination for PSMAI measurement in sagittal and coronal sections

**Statistical Analysis**

We used the IBM SPSS Statistics for Windows, version 25.0 for data analysis. The Shapiro-Wilk test was performed to analyze the normality of the distribution of continuous variables. Categorical data were summarized with numbers and percentages. Numerical variables were summarized as mean – standard deviation or median minimum and maximum. Correlation analysis was performed using Spearman's rho to determine the correlations between PSMAI and other continuous variables. We used the Mann–Whitney U-test or the Kruskal-Wallis test for comparisons of the continuous variables between the groups, as appropriate. Receiver operating characteristics (ROC) curves were performed to determine the optimal cut-off value of PSMAI when a significant difference was found with the Mann–Whitney U-test or the Kruskal-Wallis test. Univariate analysis was performed to find potential risk factors and then multivariate analysis to identify independent factors. A two-tailed P-value of less than 0.05 was considered significant.

**Results**

The records of 195 patients were reviewed, but due to limited data in 49 cases, only 146 patients were included in the study. Of these, 44 were women and 102 were men. The overall mean age was 58.1±13.1, and BMI was 24.46±5.02 kg/m². While 136 patients had isolated gastric tumors, there was extragastric involvement in 10 patients. Laparoscopic resection was performed in 136 patients, while conversion to open surgery was required in 10 cases. Additional organ resection was carried out in 19 patients. The general characteristics of the patients according to their morbidity and mortality status are shared in Table 1.

The mean PSMAI of men (741.1 mm²/m²) was significantly higher than that of women (502.1 mm²/m²) (p<0.001). While there was a positive correlation between the PSMAI and BMI (r:0.352, p:0.019 in women; r:0.447, p<0.001 in men), the correlation between PSMAI and age was negative (r:-0.369, p:0.014 in women; r:-0.349, p<0.001 in men).

No significant association was found between intraoperative complication rates and PSMAI (p:0.528). Postoperative complications were classified according to the Clavien-Dindo scale with morbidity defined as class 3 and above. A total of 33 (22.6%) patients had morbidities. PSMAI was statistically lower in patients with morbidity (mean PSMAI=599.8±152.6 in patients with morbidity vs. 689.3±227.2 in patients without morbidity; p:0.035). Considering the subgroups by gender, low PSMAI significantly increased morbidity in men (mean PSMAI=644.2±125.9 in men with morbidity vs. 774.2±209.2 in men without morbidity; p<0.001). No similar relationship was found in women, probably because of the low number of the patients (mean PSMAI=434.9±133.7 in women with morbidity vs. 514.8±151.2 in women without morbidity; p:0.200).

Analysis of postoperative mortality was carried out according to three different time periods: the first 30 days after surgery; the first 90 days; and total mortalities up to the present date. The mortality rates were as follows: 5 (3.4%) in the first 30 days, 9 (6.2%) in the first 90 days, and 33 (22.6%) in total. There was no significant relationship between PSMAI and the first 30-day mortality rate (mean PSMAI=511.2±258.8 in patients with 30-day mortality vs. 674.6±212.7 in patients without 30-day mortality; p:0.096), but its relationship with both the 90-day mortality rate (mean PSMAI =511±201.9 in patients with 90-day mortality vs. 679.4±212.9 in patients without 90-day mortality; p:0.023) and the total mortality rate (mean PSMAI = 610.2±223.2 in patients with total mortality vs. 686.2±211 in patients without total mortality; p:0.046) were significant. The PSMAI cut-off value for mortality in men was calculated as 680.1 mm²/m² [sensitivity, 61.5%; specificity, 61.8%; AUC (95% CI): 0.680 (0.575-0.785); p=0.006]. (Figure 3) A statistically significant cut-off value for women was not determined due to the low number of patients. In addition, when subgroup analysis was performed in men according to the PSMAI cut-off value found for mortality, a statistically higher morbidity rate was seen in those with PSMAI below 680.1 mm²/m² (morbidity rate =35.6% in PSMAI<680.1 vs 17.5% in PSMAI>680.1; p:0.038).

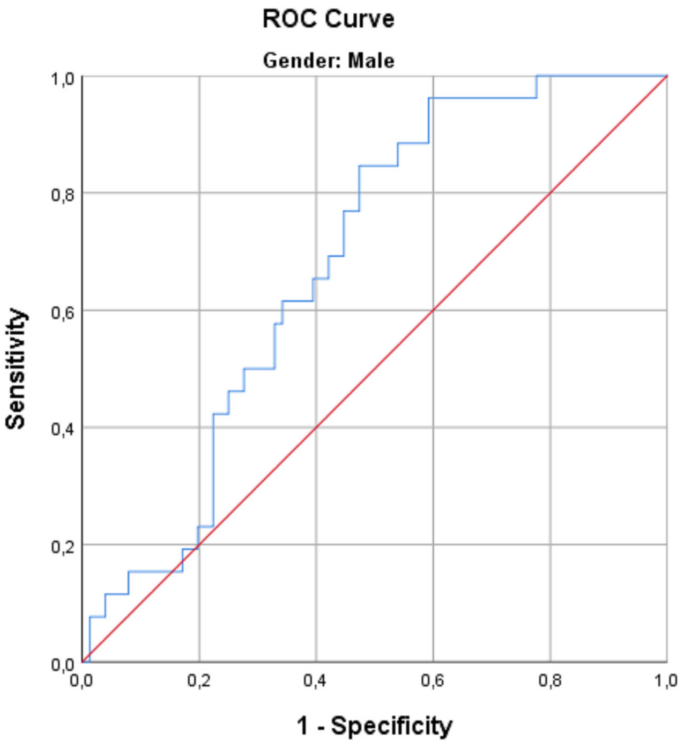


**Figure 3.** PSMAI cut-off value for mortality in men: 680.1 mm²/m²

Although there was a statistically significant difference between the pathological type of tumor and PSMAI, further statistical analysis could not be performed due to the small number of patients in certain tumor type groups. Regarding tumor characteristics, no significant association was found between PSMAI and tumor grade, differentiation, invasion depth, location or lymphovascular invasion. Tumor characteristics are described in Table 2.

Age, gender, BMI, PSMAI, presence of metastases, lymphovascular invasion, perineural invasion, CEA level, Ca 19-9 level, operation time, blood loss, number of lymph nodes removed and the type of surgery performed on the patient (distal or total gastrectomy) were taken as risk factors in univariate and multivariate analyses carried out for morbidity and mortality. In the univariate test for morbidity, age, PSMAI, operation time, and blood loss were significant, whereas in the multivariate test, male gender, PSMAI and blood loss were found to be associated with increased morbidity as independent factors. Likewise, in multivariate tests performed

for total mortality, PSMAI, presence of metastases and blood loss were established as factors that increased mortality (Table 3). The only factor found to affect 30-day mortality was increased operation time (OR 1.030, 95% CI 1.003-1.058; p=0.027). In the multivariate test performed at 90-day mortality, both low PSMAI (OR 0.983, 95% CI 0.968-0.998; p=0.023) and increased operation time (OR 1.014, 95% CI 1.002-1.027; p=0.024) were independently associated with increased 90-day mortality (Table 4).

**Table 1.** General characteristics of patients according to morbidity and mortality status

| | All patients (n:146) | Without morbidity (n:113) | With morbidity (n:33) | p-Value | Without mortality (n:113) | Withmortality (n:33) | p-Value |
|---|---|---|---|---|---|---|---|
| Age (years), mean±SD | 58.1±13.1 | 56.6±13.3 | 63.1±11.2 | 0.011 | 56.9±13 | 62±12.8 | 0.048 |
| **Gender, n(%)** | | | | **0.204** | | | **0.649** |
| Male | 102 (69.9) | 76 (67.3) | 26 (78.8) | | 80 (70.8) | 22 (66.7) | |
| Female | 44 (30.1) | 37 (32.7) | 7 (21.2) | | 33 (29.2) | 11 (33.3) | |
| **ASA Classification, n(%)** | | | | **0.132** | | | **0.478** |
| 1 | 21 (14.4) | 16 (14.2) | 5 (15.2) | | 18 (15.9) | 3 (9.1) | |
| 2 | 94 (64.4) | 77 (68.1) | 17 (51.5) | | 70 (61.9) | 24 (72.7) | |
| 3 | 31 (21.2) | 20 (17.7) | 11 (33.3) | | 25 (22.1) | 6 (18.2) | |
| BMI (kg/m²), mean ± SD | 24.46±5.02 | 24.43±5.17 | 24.56±4.54 | 0.894 | 24.62±5.18 | 23.91±4.43 | 0.479 |
| PSMAI (mm²/m²), mean±SD | 669±215.4 | 689.3±227.2 | 599.8±152.6 | 0.035 | 686.2±211 | 610.2±223.2 | 0.046 |
| **Tumor Location, n (%)** | | | | **0.256** | | | **0.260** |
| Distal | 77 (52.7) | 62 (54.9) | 15 (45.5) | | 65 (57.5) | 12 (36.4) | |
| Central | 8 (5.5) | 8 (7.1) | 0 | | 5 (4.4) | 3 (9.1) | |
| Proximal | 50 (34.2) | 35 (31) | 15 (45.5) | | 36 (31.9) | 14 (42.4) | |
| Diffuse | 6 (4.1) | 5 (4.4) | 1 (3) | | 4 (3.5) | 2 (6.1) | |
| Remnant | 5 (3.4) | 3 (2.7) | 2 (6.1) | | 3 (2.7) | 2 (6.1) | |
| CEA (ng/ml), median (Q1-Q3) | 1.88 (0.85-3.6) | 1.8 (0.79-3.69) | 1.93 (0.97-2.94) | 0.992 | 1.8 (0.78-3.66) | 1.95 (1.19-3.28) | 0.353 |
| Ca 19-9 (IU/ml), median (Q1-Q3) | 9.34 (3.9-28.54) | 9.37 (3.9-30.45) | 8 (3.51-27.9) | 0.814 | 8.14 (3.95-22.5) | 19.8 (3.4-46.2) | 0.205 |
| **LN Dissection, n (%)** | | | | **0.510** | | | **0.218** |
| No | 8 (5.5) | 7 (6.2) | 1 (3) | | 8 (7.1) | 0 | |
| D1 | 39 (26.7) | 32 (28.3) | 7 (21.2) | | 28 (24.8) | 11 (33.3) | |
| D2 | 99 (67.8) | 74 (65.5) | 25 (75.8) | | 77 (68.1) | 22 (66.7) | |
| Additional Organ Resection, n (%) | 19 (13) | 10 (8.8) | 9 (27.3) | 0.015 | 11 (9.7) | 8 (24.2) | 0.040 |
| Operation Time, median (Q1-Q3) | 330 (250-420) | 300 (245-420) | 360 (290-480) | 0.042 | 350 (270-420) | 280 (220-435) | 0.095 |
| Blood loss, median (Q1-Q3) | 100 (50-200) | 100 (50-200) | 200 (85-400) | 0.017 | 100 (50-200) | 100 (50-300) | 0.880 |
| LN Removed, mean ± SD | 31.3±16.7 | 32.4±16.8 | 27.8±16 | 0.166 | 30.7±16.6 | 33.1±17.2 | 0.475 |
| Positive LN, median (Q1-Q3) | 3 (0-12) | 4 (0-12.8) | 2 (0-8.5) | 0.264 | 2 (0-8.5) | 10 (5-16.5) | <0.001 |
| Presence of Metastases, n (%) | 10 (6.8) | 9 (8.9) | 1 (3.1) | 0.450 | 4 (4) | 6 (18.2) | 0.015 |
| Lymphovascular Invasion, n (%) | 101 (69.2) | 80 (78.4) | 21 (63.6) | 0.089 | 70 (68.6) | 31 (93.9) | 0.004 |
| Perineural Invasion, n (%) | 83 (56.8) | 65 (64.4) | 18 (54.5) | 0.314 | 56 (54.9) | 27 (84.4) | 0.003 |
| Time to oral intake (day), median (Q1-Q3) | 2 (1-3) | 2 (1-2.5) | 2 (1-4) | 0.028 | 2 (1-3) | 2 (1-3) | 0.101 |
| Length of hospital stay (day), median (Q1-Q3) | 7 (5-10.5) | 6 (5-9) | 10.5 (6.3-23) | <0.001 | 7 (5-10) | 7.5 (6-13.8) | 0.150 |
| Intraoperative complication, n(%) | 9 (6.2) | 7 (6.2) | 2 (6.1) | 1.000 | 7 (6.2) | 2 (6.1) | 1.000 |

**ASA:** American Society of Anesthesiologists Physical Status Classification, **BMI:** Body Mass Index, **PSMAI:** Psoas Muscle Area Index, **LN:** Lymph Node, **Morbidity:** Clavien Dindo class 3 and above complication

**Table 2.** Postoperative complications according to Clavien-Dindo classification and Mortality

| | Women | | Men | | Total | |
|---|---|---|---|---|---|---|
| | n (44) | % | n (102) | % | n (146) | % |
| **Clavien Dindo** | | | | | | |
| **No complication** | 31 | 70.4% | 60 | 58.8% | 91 | 62.3% |
| **Grade 1** | 2 | 4.5% | 4 | 3.9% | 6 | 4.1% |
| **Grade 2** | 4 | 9.0% | 12 | 11.7% | 16 | 10.9% |
| **Grade 3[a]** | 1 | 2.2% | 7 | 6.8% | 8 | 5.4% |
| **Grade 3[b]** | 3 | 6.8% | 12 | 11.7% | 15 | 10.2% |
| **Grade 4** | 0 | 0% | 1 | 0.9% | 1 | 0.6% |
| **Grade 5** | 3 | 6.8% | 6 | 5.8% | 9 | 6.1% |
| **Grade <3** | 37 | 84.0% | 76 | 74.5% | 113 | 77.3% |
| **Grade ≥3** | 7 | 15.1% | 26 | 25.4% | 33 | 22.6% |
| **30 day mortality** | 2 | 4.5% | 3 | 2.9% | 5 | 3.4% |
| **90 day mortality** | 3 | 6.8% | 6 | 5.8% | 9 | 6.2% |
| **Mortality** | 11 | 25% | 22 | 21.5% | 33 | 22.6% |

**Table 3.** Univariate and multivariate analyses for morbidity and total mortality

| | Morbidity | | | | Total Mortality | | | |
|---|---|---|---|---|---|---|---|---|
| | Univariate analyses | | Multivariate analyses | | Univariate analyses | | Multivariate analyses | |
| **Variables** | **Odds ratio (95%CI)** | **p value** | **Odds ratio (95%CI)** | **p value** | **Odds ratio (95%CI)** | **p value** | **Odds ratio (95%CI)** | **p value** |
| **Age (Years)** | 1.044 (1.009-1.081) | 0.013 | 0.980 (0.932-1.031) | 0.438 | 1.033 (1.000-1.068) | 0.050 | 1.015 (0.969-1.064) | 0.519 |
| **Gender (Male)** | 1.808 (0.719-4.549) | 0.208 | 37.302 (4.437-313.632) | 0.001 | 0.825 (0.360-1.891) | 0.649 | 1.596 (0.279-9.132) | 0.599 |
| **BMI (kg/m²)** | 1.005 (0.931-1.086) | 0.893 | 1.121 (0.973-1.291) | 0.113 | 0.971 (0.895-1.053) | 0.477 | 1.054 (0.923-1.203) | 0.439 |
| **PSMAI (mm²/m²)** | 0.998 (0.996-1.000) | 0.038 | 0.991 (0.987-0.996) | 0.001 | 0.998 (0.996-1.000) | 0.077 | 0.996 (0.992-1.000) | 0.036 |
| **Presence of metastases** | 0.330 (0.040-2.708) | 0.302 | 1.350 (0.079-23.180) | 0.836 | 5.333 (1.403-20.272) | 0.014 | 16.893 (2.203-129.522) | 0.007 |
| **Lymphovascular invasion** | 0.481 (0.205-1.128) | 0.092 | 0.704 (0.160-3.090) | 0.641 | 7.086 (1.597-31.434) | 0.010 | 8.654 (0.892-83.952) | 0.063 |
| **Perineural invasion** | 0.665 (0.300-1.475) | 0.315 | 0.814 (0.207-3.196) | 0.768 | 4.436 (1.582-12.435) | 0.005 | 1.328 (0.311-5.675) | 0.702 |
| **CEA (ng/ml)** | 0.994 (0.970-1.018) | 0.625 | 0.982 (0.944-1.021) | 0.349 | 0.980 (0.942-1.021) | 0.337 | 0.934 (0.864-1.010) | 0.087 |
| **Ca 19-9 (IU/ml)** | 1.000 (0.997-1.004) | 0.777 | 1.001 (0.997-1.005) | 0.559 | 1.001 (0.998-1.004) | 0.617 | 1.001 (0.997-1.006) | 0.556 |
| **Operation time (min)** | 1.004 (1.001-1.008) | 0.013 | 1.004 (0.998-1.009) | 0.181 | 0.999 (0.995-1.002) | 0.451 | 0.995 (0.989-1.001) | 0.105 |
| **Blood loss (cc)** | 1.003 (1.001-1.005) | 0.001 | 1.004 (1.000-1.007) | 0.037 | 1.001 (0.999-1.003) | 0.159 | 1.005 (1.002-1.009) | 0.005 |
| **Number of LN removed** | 0.983 (0.958-1.007) | 0.166 | 0.971 (0.935-1.008) | 0.122 | 1.009 (0.985-1.032) | 0.473 | 1.002 (0.970-1.036) | 0.898 |
| **Total Gastrectomy** | 1.459 (0.669-3.179) | 0.342 | 0.722 (0.233-2.242) | 0.573 | 2.370 (1.063-5.281) | 0.035 | 0.842 (0.244-2.903) | 0.785 |

**Morbidity:** Clavien Dindo class 3 and above complication, **BMI:** Body Mass Index, **PSMAI:** Psoas Muscle Area Index, **LN:** Lymph Node

**Table 4.** Univariate and multivariate analyses for 30-day and 90-day mortality

| | 30-day Mortality | | | | 90-day Mortality | | | |
|---|---|---|---|---|---|---|---|---|
| | Univariate analyses | | Multivariate analyses | | Univariate analyses | | Multivariate analyses | |
| **Variables** | **Odds ratio (95%CI)** | **p value** | **Odds ratio (95%CI)** | **p value** | **Odds ratio (95% CI)** | **p value** | **Odds ratio (95% CI)** | **p value** |
| **Age (Years)** | 1.046 (0.964-1.136) | 0.278 | 0.966 (0.812-1.149) | 0.694 | 1.059 (0.992-1.131) | 0.084 | 1.012 (0.918-1.115) | 0.813 |
| **Gender (Male)** | 0.636 (0.103-3.948) | 0.627 | 955.820 (0.018-51944845) | 0.217 | 0.854 (0.204-3.581) | 0.829 | 27.568 (0.414-1836.1) | 0.122 |
| **BMI (kg/m²)** | 0.932 (0.756-1.148) | 0.507 | 1.158 (0.559-2.399) | 0.693 | 0.958 (0.826-1.111) | 0.567 | 1.137 (0.895-1.443) | 0.294 |
| **PSMAI** | 0.995 (0.990-1.001) | 0.099 | 0.965 (0.920-1.013) | 0.147 | 0.995 (0.991-0.999) | 0.025 | 0.983 (0.969-0.998) | 0.026 |
| **Presence of metastases** | 3.306 (0.334-32.762) | 0.307 | 5259 (0.001-20369745191) | 0.268 | 1.597 (0.179-14.225) | 0.675 | 30.453 (0.206-4509.3) | 0.180 |
| **Lymphovascular invasion** | 1.361 (0.147-12.613) | 0.786 | 189.947 (0.063-573095) | 0.199 | 2.839 (0.342-23.566) | 0.334 | 37.898 (0.725-1980.9) | 0.072 |
| **Perineural invasion** | 0.919 (0.148-5.694) | 0.927 | 0.003 (0.000-9.789) | 0.159 | 1.247 (0.298-5.220) | 0.763 | 0.060 (0.002-1.486) | 0.086 |
| **CEA (ng/ml)** | 0.981 (0.887-1.086) | 0.714 | 0.909 (0.646-1.279) | 0.585 | 0.967 (0.854-1.095) | 0.600 | 0.885 (0.659-1.190) | 0.419 |
| **Ca 19-9 (IU/ml)** | 1.004 (1.000-1.008) | 0.067 | 1.003 (0.994-1.013) | 0.474 | 1.003 (0.999-1.007) | 0.128 | 1.002 (0.996-1.008) | 0.589 |
| **Operation time (min)** | 1.007 (1.000-1.014) | 0.037 | 1.031 (1.001-1.061) | 0.042 | 1.005 (0.999-1.010) | 0.101 | 1.013 (1.001-1.026) | 0.039 |
| **Blood loss (cc)** | 1.001 (0.996-1.005) | 0.803 | 0.997 (0.986-1.009) | 0.615 | 1.001 (0.997-1.004) | 0.757 | 0.997 (0.991-1.003) | 0.363 |
| **Number of LN removed** | 0.981 (0.926-1.040) | 0.520 | 0.876 (0.728-1.053) | 0.158 | 0.998 (0.958-1.040) | 0.938 | 0.958 (0.880-1.042) | 0.313 |
| **Total Gastrectomy** | 4.677 (0.510-42.898) | 0.172 | 0.810 (0.009-72.907) | 0.927 | 4.234 (0.849-21.119) | 0.078 | 2.052 (0.228-18.447) | 0.521 |

**BMI:** Body Mass Index, **PSMAI:** Psoas Muscle Area Index, **LN:** Lymph Node

## Discussion

Sarcopenia is a condition involving progressive loss of skeletal muscle mass and strength. In its 2010 report, the European Working Group on Sarcopenia in Older People (EWGSOP) [15], focused mainly on loss of muscle mass. However, in the revised version published in 2019 [16], importance was also placed on muscle strength, although muscle mass was still considered a critical feature. Prospectively designed research on muscle strength and physical activity is needed. However, this study focused on muscle mass. In addition, EWGSOP distinguished between two forms of sarcopenia, primary and secondary, the term 'secondary sarcopenia' being used in cases where sarcopenia accompanied malignancy, inflammatory disease, or malnutrition [15]. We believe that our patient group also fits this definition.

In Eastern Asia, stomach cancers are usually detected in the early stages, while in the West they are not generally diagnosed until they are more advanced. At this point, many patients present with advanced stage cancer, severe weight loss, and impaired pre-operative nutritional status. Consequently, sarcopenia and cachexia emerge as serious problems in patients with stomach cancers. Many studies have shown that the long-term prognosis after cancer surgery is adversely affected by sarcopenia [17-20]. This may be related to some of the aforementioned issues. Firstly, since sarcopenia is directly connected to poor nutritional status [21], it is a determining factor for the adverse effects of malnutrition in the perioperative period. Secondly, because of its direct relation to muscle mass and strength, sarcopenia adversely affects important steps in the postoperative recovery process, such as early mobilization and return to physical activity.

In general, studies investigating the relationship between sarcopenia and major abdominal surgeries have used the total skeletal muscle area at the L3 vertebra as a base measurement. This is more difficult to measure than the isolated psoas muscle area. Several previous studies on sarcopenia found the measurement of the psoas muscle area alone to be sufficient [13,22,23], and we decided to use this method in our own study.

Our study showed an association between PSMAI and age, gender, and BMI. There was a negative correlation between age and PSMAI in both genders, although the PSMAI of men was significantly higher than that of women. This age correlation is unsurprising as the first descriptions of sarcopenia considered it to be an age-related condition. However, over time, several other factors leading to sarcopenia have been identified.

With regard to tumor characteristics, at the beginning of the study we expected the location of the tumor to have a direct effect on

PSMAI; however, our results revealed no significant relationship. Tumor locations were predominantly of diffuse and distal type with no homogeneous distribution; therefore, an ideal evaluation could not be made. Furthermore, the number of patients was insufficient to establish a clear association between PSMAI and tumor biology, as some patient groups were not large enough to allow for comparison. Although we were unable to obtain significant results for this criteria a previous study have suggested that cases with more aggressive tumors are more likely to develop sarcopenia due to rapid muscle destruction [24]. We believe that further studies involving more comprehensive patient series will be useful to clarify this issue.

The main focus of our study was to determine the independent factors affecting morbidity and mortality. Therefore, univariate and multivariate analyses were performed. According to univariate analysis, factors affecting morbidity were age, PSMAI, operation time and blood loss. As previously mentioned, a correlation between age and PSMAI had already been established. An increase in morbidity was also expected, because of prolonged operation time and increased intraoperative bleeding. Multivariate analysis showed factors independently affecting morbidity to be male gender, PSMAI and blood loss. There was no obvious reason for a higher morbidity level in men and, as mentioned earlier, the low number of women in the study was not ideal for comparison and may account for this result. However, the amount of bleeding was directly related to morbidity. Factors affecting early mortality (90 days) were also examined, and in multivariate analysis, PSMAI and operation time were found to be independent risk factors. Consequently, independent risk factors affecting both postoperative morbidity and mortality can be summarized as PSMAI, intraoperative blood loss and operation time.

In order to discern any significant relationship between blood loss, operation time and total or distal gastrectomy, patients were divided into two groups. Patients with distally located tumors were categorized as the distal gastrectomy group, while those with tumors located in the cardia, corpus, or diffusely were allocated to the total gastrectomy group. In both univariate and multivariate analyses, the selected type of surgery and location of the tumor were observed to have no direct effect on either morbidity or mortality. Likewise, excessive blood loss and long operation time were case-based and not dependent on the technique used. Regarding factors affecting long-term mortality, PSMAI and the presence of metastasis were both found to be independent risk factors in multivariate analysis. The significant relationship between metastasis and postoperative mortality was an expected outcome.

In conclusion, this study revealed PSMAI to be an independent risk factor for postoperative morbidity, early mortality, and long-term mortality after laparoscopic gastric cancer surgery. One strength of this study is the finding that assessment of the psoas muscle area with preoperative abdominal CT can accurately establish sarcopenia, without need for detailed or difficult measurements. Therefore, it is our opinion that sarcopenia should be included in criteria used to predict the perioperative course and postoperative period, similar to ASA score, BMI or weight loss. This can easily be done as routine computed tomography is already performed at the time of diagnosis or in the preoperative period for staging purposes in patients with gastric cancer or other malignancies. Also, the psoas muscle area measurement used in this study is a straightforward and practical method and, at the same time, objective.

Furthermore, a previous study pointed out that supporting patients with a physical activity and nutritional program preoperatively can significantly reduce sarcopenia [25]. This suggests that, unlike other prognostic factors, sarcopenia is a correctable condition.

Our study has certain limitations. Since the study was designed retrospectively, many eligible patients had to be excluded as their data could not be accessed. In addition, research into levels of muscle quality or physical activity, which are as important as muscle mass when assessing sarcopenia, was beyond our scope. Finally, since data from a single center was used, the number of patients was too low for further, more detailed analysis. These issues could be resolved with prospectively designed multi-center studies involving higher numbers of patients.

## Conclusion

In conclusion, measuring PSMAI with routine computed tomography in the preoperative period is an easy and useful method for detecting sarcopenia in most patients. In our opinion, evaluating preoperative abdominal tomography for sarcopenia and providing the necessary nutritional and exercise support to patients with sarcopenia can be an effective way to predict and reduce postoperative morbidity and mortality.

**Conflict of interests**
*The authors declare that there is no conflict of interest in the study.*

**Financial Disclosure**
*The authors declare that they have received no financial support for the study.*

**Ethical approval**
*This study was designed as a case series analysis and approved by the Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee (2021/1736).*

**Informed consent statement**
*As it is a retrospective study and data was reviewed retrospectively from chart review so patient's consents are not needed.*

**Data Availability Statement**
*All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.*

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