American Journal of Emergency Medicine 47 (2021) 180–186

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Predictive value of sarcopenic findings in the psoas muscle on CT imaging among patients with sepsis

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ARTICLE INFO

Article history:
Received 10 December 2020
Received in revised form 1 April 2021
Accepted 6 April 2021
Available online xxxx

Keywords:
Sarcopenia
Frail
Frailty
Psoas muscles
Critical illness
Prediction model

ABSTRACT

Purpose: This study aimed to determine the association between sarcopenic findings of the psoas muscle and mortality in patients with sepsis; further, it aimed to assess its clinical utility, in addition to the sequential organ failure assessment (SOFA) score, in predicting mortality.
Method: This retrospective single-center cohort study included adult patients with sepsis, who were admitted to the intensive care unit, between January 2012 and December 2018. The cross-sectional area of the psoas muscle at the L3 level was measured using computed tomography (CT) images, following which the subjects were categorized as "Above middle," "Middle," and "Sarcopenic." The association between sarcopenic findings and 90-day mortality was investigated by logistic regression analysis. A "modified SOFA score," by adding sarcopenic findings to the SOFA score, was developed and evaluated for its predictive performance.
Results: Here, 255 patients with sepsis, who were admitted to the intensive care unit (median age, 76 [64–84] years; SOFA score, 9 [5–14]), were included. The adjusted odds ratio for the "Middle" and "Sarcopenic" groups for 90-day mortality was 2.40 (95% confidence interval [CI]: 0.93–6.15) and 3.67 (95% CI: 1.39–9.68), respectively. The c-statistics of the SOFA and modified SOFA score was 0.731 [95% CI: 0.650–0.799] and 0.749 [95% CI: 0.673–0.813]. On decision curve analysis, a little additional net benefit was observed on using the modified SOFA score.
Conclusion: The results suggested an association of the sarcopenic findings of the psoas muscle on CT imaging with 90-day mortality; however, the modified SOFA had few additional clinical values to that of SOFA in predicting 90-day mortality.

1. Introduction

Sepsis, a critical condition defined as an organ dysfunction caused by an infection, generally requires advanced treatment such as emergency surgery and critical care in the intensive care unit (ICU) [1,2]. The main population affected by sepsis is older adults in a super-aging society; the clinical decision of invasive treatment and critical care in such individuals should be carefully considered, because critical care needs a lot of medical resources and critically ill elderly patients have generally higher mortality and longer lengths of stay in the ICU than younger patients [3-6]. Further, some elderly patients prefer end-of-life care, focused on symptomatic treatment and pain reduction, as opposed to aggressive treatment in the ICU [7]. Considering the individual's preferences and limited medical resources, it is essential to tailor the administration of aggressive treatment and care in critically ill patients, based on accurate prediction and each patient's condition and value.

In general, for the assessment of critically ill patients, physiological scoring systems such as the sequential organ failure assessment (SOFA) score are utilized to evaluate the severity and predict the probability of the outcome. However, these scales only focus on physiological status and do not include frailty in older adult patients; frailty assessments, in addition to the physiological status, may contribute to a more precise prediction of the outcome. Sarcopenia, defined as the loss of skeletal muscle and strength, has been reported to be associated with mortality [8-11]. Previous literature has suggested an association of sarcopenic findings, on computed tomography (CT) imaging, with mortality in patients with severe surgical conditions such as trauma, sepsis, post major surgery, and liver transplantation [10-18]. Based on these results, we hypothesized that sarcopenic findings on CT imaging, in addition to the SOFA score, might be useful for accurately predicting mortality and, thus, facilitate the decision of administering or withdrawing aggressive treatment, tailored to the frailty of the patients

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https://doi.org/10.1016/j.ajem.2021.04.011
0735-6757/

with sepsis. Therefore, we aimed to determine the association of sarcopenic findings of the psoas muscle, on CT imaging, with mortality in patients with sepsis. Further, we assessed the clinical utility of sarcopenic findings, in addition to the SOFA score, in predicting mortality in such patients.

2. Methods

This retrospective cohort study was approved by the ethical committees of our institution. The requirement for informed consent was waived by the ethical committees based on the Ethical Guidelines for Medical and Health Research Involving Human Subjects published by the Ministry of Health, Labor and Welfare, Japan [19].

2.1. Data source and settings

We retrospectively obtained the clinical data by electronic chart review. Kyoto city is an urban area with a population of approximately 1.5 million, and approximately 80,000 cases are transferred by ambulance in the city every year [20]. Our hospital is one of the four tertiary critical care centers in Kyoto city certified by the Ministry of Health, Labor, and Welfare and is located in the center of the city. The ICU in the hospital is certified by the Japanese Society of Intensive Care Medicine. The hospital has 672 beds and provides primary emergency as well as tertiary critical care for cases, including trauma, cardiac arrest, and sepsis. In 2017, 7679 cases arrived in our emergency department by ambulance, and 20,312 cases were walk-in visits; of which 540 elective and emergency cases were admitted to the ICU.

2.2. Study population

In this study, adult patients with sepsis (aged ≥20 years) who were admitted to the ICU in an emergent manner between January 2012 and December 2018 were enrolled. Patients with sepsis were defined as patients with an infection causing organ dysfunction. Infection was diagnosed by the physician-in-charge of the patient, based on objective findings such as CT imaging or culture inspection. Organ dysfunction was defined as an acute change of ≥2 points in the SOFA score based on Sepsis-3 criteria [1,2,21]. Similar to previous literature [1,2,21], the baseline SOFA score was assumed to be zero in patients without preexisting organ dysfunction. ICU admission was defined as the admission of the patients with sepsis to ICU within 24 h of their visit to the emergency department. In our hospital, the decision of ICU admission is based on the criteria used for admission in tertiary critical care centers in Japan; in general, patients suffering from sepsis, severe trauma, post-cardiac arrest, respiratory failure, and acute coronary syndrome, requiring medical resource are admitted [22]. On reviewing electronic medical charts and the medical history of ICU admitted patients, we selected patients who met the inclusion criteria. Further, we excluded patients (such as those at the terminal stage of chronic disease) who withdrew from intensive care before their admission to the ICU; such patients, instead of intensive care, wanted supportive care.

2.3. Data collection and management

The following clinical information, for all patients was collected by investigators, who were certified intensive care physicians and were trained for collecting data, on a predefined sheet using electronic data capturing system (RedCap: Research Electronic Data Capture) [23]: age (20–64, 65–74, and ≥ 75 years), sex, the activity of daily living (independent or assistance required), comorbidity defined as the Charlson comorbidity index (low: 0 points, middle: 1, 2 points, and high: 3, 4 points, very high: ≥5) [24], vital signs on hospital arrival, including systolic blood pressure, heart rate, impaired level of consciousness (alert, minor, moderate, or severe), body temperature, lactate level, SOFA score [21], emergency treatment (intubation in the emergency department, emergency surgery, or percutaneous drainage performed within 24 h), infection site (respiratory, abdominal, urological, or others), detected microorganisms, CT imaging, and outcome. The impaired level of consciousness was categorized based on the Glasgow Coma Scale (GCS): alert (GCS = 15), minor (GCS = 13–14), moderate (GCS = 9–12), and severe (GCS <9). The CT imaging data was anonymized when collected from the database (the details of reviewing the CT images are described in the next section). The other definitions in detail are described in the supplementary file (S-Method). The collected data were double-checked by the researchers, and any inappropriate value, if found, was corrected.

2.4. Outcome measures

The primary outcome was 90-day mortality after admission. We collected the primary outcome by chart review. If the patients were transferred to other medical facilities or not followed up, we made an attempt to contact the facilities or the patients' families to confirm the outcome. The secondary outcome was 1-year mortality.

2.5. Measurement on CT imaging

Sarcopenic findings in the psoas muscle were assessed by psoas index (PI), defined as the cross-sectional area of psoas muscle at lumber 3 (L3) level divided by the area of the L3 vertebra ([the area of the right psoas muscle + the area of the left psoas muscle]/ the area of the L3 vertebrae), using CT imaging (Figure1). The cross-sectional area of the psoas muscle at L3 or L4 level and PI have been reported as surrogate markers of sarcopenia and found to be associated with mortality [10-14,16-18,25]. PI was measured based on the prespecified measurement protocol: CT imaging of included patients scanned within 24 h of hospital arrival was selected. Using coronal or sagittal scout images, the slice at the middle of the L3 vertebra was identified. Using axial images, the outer circumferential of both the psoas muscles and the L3 vertebrae were identified and traced (Fig. 1), and the cross-sectional area was measured. In case of abnormality in the psoas muscle, such as psoas abscess, the affected site was not measured; if one was involved, the other was doubled, and if both were involved, the measurement was not taken. In case of abnormal anatomy of the L3 vertebra such as in burst fracture, L2 or L4 was measured, if considered appropriate. The images were independently reviewed by two researchers blinded to the clinical details; if there were any doubt regarding the measurement, researchers planned to resolve it consensually. PI was then calculated, as defined above. If CT imaging was unavailable, it was treated as missing. Since there was no widely accepted cut-off value of PI, it was grouped into quantiles. Osirix MD DICOM viewer® (Pixmeo SARL, Geneva, Switzerland) was used for measurements.

2.6. Predictors and prediction model

In this study, the predictor of interest was "low PI" on CT imaging. First, we evaluated an association between sarcopenic findings and mortality, adjusted for the potential confounders, to check whether sarcopenic findings could be a potential predictor for mortality. Then, we assessed the clinical predictive value of sarcopenic findings. Since among patients with sepsis, the SOFA score has been widely accepted to evaluate the severity and predict mortality [21], we developed a "modified SOFA score" as mentioned below. Furthermore, we compared the SOFA score and modified SOFA score to assess the clinical utility of the sarcopenic findings in predicting mortality [26].

2.7. Missing data and sample size

For the predictors with missing data, multiple imputations were conducted using the random forest model (missForest) [27,28]. Multiple imputations is a nonparametric algorithm to accommodate nonlinearities

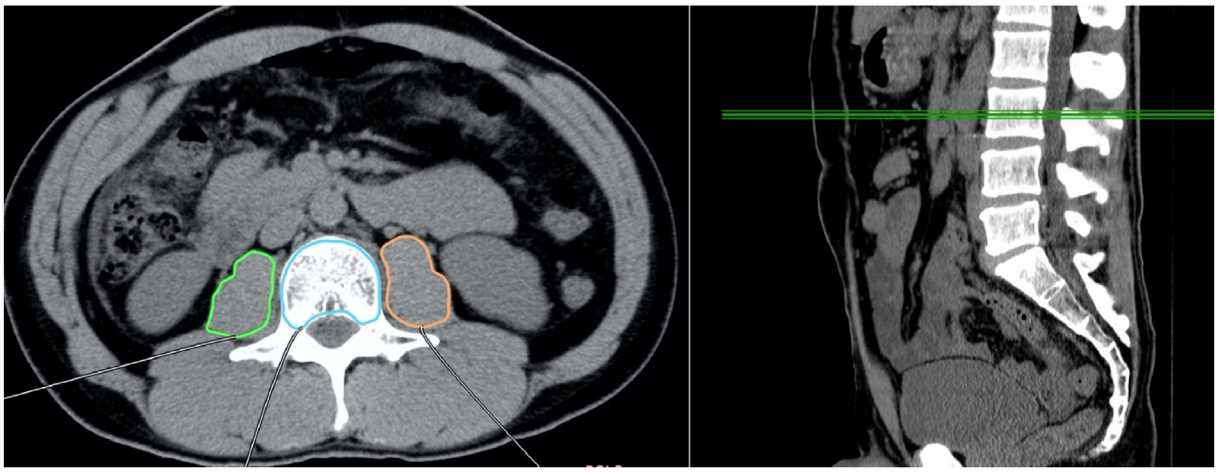

Fig. 1. Measurement of cross-sectional area of psoas muscle and L3 vertebra. Right: The middle of L3 vertebra in sagittal image. Left: The measurement of cross-sectional of psoas muscle and L3 vertebra. Psoas muscle index = [(the right + left area of psoas muscle)/ the area of L3vertebra].

and interactions; it generates single-point estimates using the random forest model [27,28]. The model uses bootstrap aggregation of multiple regression trees, to reduce the risk of overfitting, and combines estimates from many trees. Its use is advantageous, as it can handle both continuous and categorical responses, requires very little tuning, and provides an internally cross-validated error estimate [27,28].

There are no generally accepted approaches to estimate the sample size requirements for observational retrospective analysis. Based on empirical investigations, more than 10 events per variable in the logistic model led to the risk of overfitting [29]; in accordance, we planned the statistical analyses.

2.8. Statistical analyses

The patient characteristics and distribution of the variables were presented as the median and interquartile range (IQR) for continuous variables, and number and proportion (%) for categorical variables. For the association between sarcopenic findings and mortality crude and adjusted odds ratio (OR) with 95% confidence interval (CI), of the sarcopenic group for the 90-day mortality, were calculated using logistic regression models. The following covariates were set as potential confounders: sex, age category, infection site, SOFA score, and Charlson comorbidity index. Further, to assess the dose-response relationship between the sarcopenic findings and outcome, the groups were coded 1, 2, or 3 as an integer number and a trend test was performed using the logistic model as described elsewhere [30]. Moreover, PI was considered a continuous variable and assessed for potential non-linear relationship by plotting the restricted cubic spline curve (knot = 3) of the OR of PI for the outcome, adjusted for age, sex, infection site, SOFA, and Charlson comorbidity index.

For developing the modified-SOFA score, SOFA and PI category were set as covariates in the logistic model and the beta-coefficient for 90-day mortality was calculated. For a simplified understanding of the model in clinical settings, the relative predictive value of sarcopenic findings for each 1 point of the SOFA score, based on the beta-coefficient, was estimated, and thus a "modified SOFA score" was developed. Subsequently, to assess discriminatory ability, c-statistics [area under the curve of receiver operating curve (AUC of ROC)] of the SOFA and modified SOFA score were compared. Further, the calibration plot (x-axis: prediction, y-axis: actual mortality) was assessed by bootstrapping procedure ($n = 200$) for internal validation [29]. Then, the net benefit of these scores was assessed by decision curve analysis for clinical utility [31,32]. The details of the decision curve analysis and net benefit are described elsewhere [31,32]. In summary, net benefit indicated the benefit of true-positive, adjusted for the harm of false-negative, by using the prediction model or test [31,32]. It was calculated as ([True-positives/N] – [(False-positives/N) ×p/(1-p)]), where N was the total number of patients and p was threshold probability to treat the patients as positive [31,32]. Further, p/(1-p) in the calculation meant weighting false-positive cases relative to one true-positive case. In the decision curve, the net benefit for each threshold probability was described; it could be compared to a different prediction model, empirical all treatment strategy, or no treatment strategy [31,32]. In our analysis, if the 90-day survival predicted probability was higher than the threshold, the survival prediction was considered positive, and if the probability was lower than the threshold, it was considered negative. Using this assumption, true-positive, false-positive, true-negative, and false-negative were interpreted as follows; true-positive: predicted survival and survived, false-positive: predicted survival but death, true-negative: predicted death and death, and false-negative: predicted death but survived.

All statistical results were considered significant for two-sided *P* values of <0.05. Statistical analyses were performed using JMP Pro® 14 software (SAS Institute Inc., Cary, NC) and R software (version 1.1.456; R Studio Inc.) with the "rms", "rmda," and "missForest" package [33,34].

3. Results

3.1. Patient characteristics

Of 3725 patients admitted to the ICU during the study period, 255 adult patients with sepsis who were emergently admitted to the ICU were included (Fig. 2). The characteristics of the patients are shown in Tables 1 and 2. In summary, the median (IQR) of the age was 76 (64–84) years, and that of the SOFA score was 9 (5–14). The infection sites were respiratory (43, 16.9%), abdomen (145, 56.9%), urological (24, 9.4%), and others (43, 16.9%); the details of infection are described in the supplementary file, S-Table 1. The median (IQR) of PI was 0.79 [0.61–1.00], the distribution of which was similar to that observed previously (mean [standard deviation]: 0.85 [0.25]) [12].The measurement by the main reviewer was substantially consistent with that by the other reviewer (Pearson's correlation coefficient [95% CI]: 0.79 [0.74–0.83]). For 16 patients, the abdominal CT imaging was unavailable (7 patients: only chest CT, 6 patients: CT not performed, and 1 patient: unmeasurable format); thus, PI for missing values was imputed using multiple imputations. The included patients were equally categorized into three groups based on the PI tertiles: "Above middle"

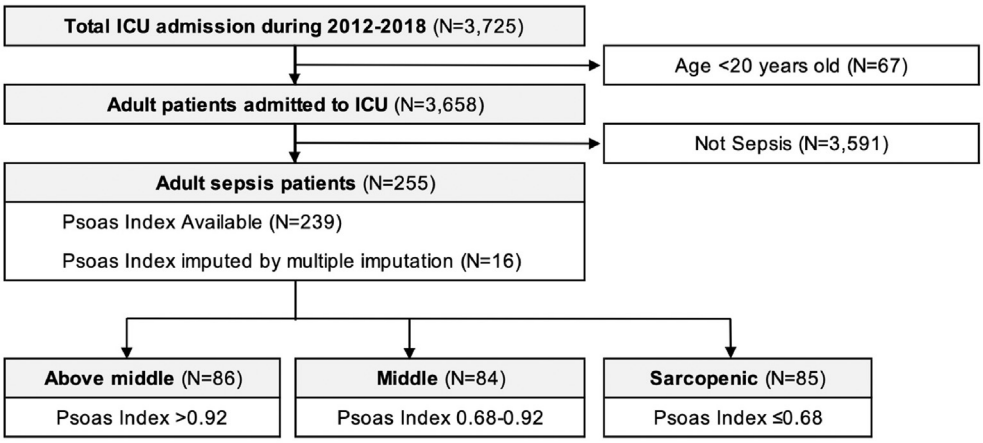

Fig. 2. Study flowchart. SOFA: Sequential organ failure assessment score. ICU: Intensive care unit.

(PI >0.92, $N = 86$), "Middle" (PI: 0.68–0.92, $N = 84$), and "Sarcopenic" (PI<0.68, $N = 85$). The characteristics before imputation and other information are described in the supplementary file, S-Tables 2 and 3.

3.2. Outcome

As primary outcome, the overall 90-day mortality was 21.6% (55/255) and for each group, it was: "Above middle," 14.0% (12/86); "Middle," 21.4% (18/84); and "Sarcopenic," 29.4% (25/85) (Table 2). Among the patients who died within 90 days, 49 patients (89.1%, 49/55) died before hospital discharge; the median duration and IQR were 12 (1–19.5) days. For secondary outcome, 1-year mortality, 17.5% of the patients (44/255) were lost to follow-up. Total 1-year mortality was 27.8% (70/255) and for each group, it was: "Above middle," 20.0% (17/86); "Middle," 27.4% (23/84); and "Sarcopenic," 36.1% (30/85).

3.3. Association between sarcopenic findings of the psoas muscle and outcome

With the "Above middle" group as reference, adjusted OR with 95% CI for the 90-day mortality for the "Middle" and the "Sarcopenic" group was 2.40 (0.93–6.15) and 3.67 (1.39–9.68), respectively (Table 3). The adjusted OR of other covariates are described in the supplementary file, S-Table 4. Further, the trend test suggested a dose-response relationship between the sarcopenic findings and mortality ($p = 0.015$). Moreover, the cubic spline curve of the adjusted OR of PI for the outcome was consistent with the results of the primary analysis (Supplementary file, S-Fig. 1).

3.4. Predictive ability of the SOFA and modified SOFA score for the 90-day mortality

The distribution of SOFA score and 90-day mortality is described in Fig. 3. In the multivariate logistic model using SOFA score and PI groups, the beta-coefficients (standard error) were as follows: SOFA, 0.193 (0.037) per 1 point; and PI, when compared to "Above Middle": "Middle," 0.084 (0.236) and "Sarcopenic," 0.539 (0.227) (Table 4). Based on the results, we assumed that "Sarcopenic" was approximately 3-fold more predictive than SOFA 1-point. The "Middle" group was less predictive than SOFA 1-point; thus, it was omitted. Finally, a modified SOFA score was developed—if "sarcopenic," then 3 points were added to the original SOFA score.

The c-statistics of the SOFA score and modified SOFA were 0.731 (95% CI: 0.650–0.799), and 0.749 (95% CI: 0.673–0.813), respectively. The difference was −0.018 (95% CI: −0.042–0.005). Calibration plots indicating predicted and actual mortality for each score is shown in the supplementary file (S-Fig. 2). The net benefit of the SOFA and modified SOFA score, using the decision curve analysis (Fig. 4), indicated that the net benefit of the modified SOFA was the same as SOFA for any treatment threshold.

Table 1
The patient characteristics

Variables	Total patients (N = 255)	Above middle (N = 86) Psoas Index >0.92	Middle (N = 84) Psoas Index 0.68–0.92	Sarcopenic (N = 85) Psoas Index ≤ 0.68
Men, n, (%)	153 (60%)	62 (72.1%)	53 (63.1%)	38 (44.7%)
Age	76 [64–84]	68 [53–79]	78.5 [65.3–85.0]	79 [72.5–86]
<65	64 (25.1%)	36 (41.9%)	20 (23.8%)	8 (9.4%)
65–74	52 (20.4%)	21 (24.4%)	14 (16.7%)	17 (20%)
75–84	82 (32.2%)	22 (25.6%)	28 (33.3%)	32 (37.7%)
≥85	57 (22.4%)	7 (8.1%)	22 (26.2%)	28 (32.9%)
ADL before admission				
Assistance required	71 (27.8%)	21 (24.4%)	23 (27.4%)	27 (31.8%)
Comorbidity	1 [0–2]	1 [0–2]	1 [0–3]	2 [1–3]
Minor (0)	79 (31%)	28 (32.6%)	31 (36.9%)	20 (23.5%)
Moderate (1–2)	118 (46.3%)	45 (52.3%)	32 (38.1%)	41 (48.2%)
Severe (3–4)	43 (16.9%)	11 (12.8%)	16 (19.1%)	16 (18.8%)
Very severe (≥5)	15 (5.9%)	2 (2.3%)	5 (6%)	8 (9.4%)

PI: Psoas index, ADL: Activity of daily living, Comorbidity: Charlson comorbidity index.
Categorical variables: number, (%).
Continuous variables: median, IQR.

Table 2
In-hospital information

Variables	Total patients (N = 255)	Above middle (N = 86) Psoas Index >0.92	Middle (N = 84) Psoas Index 0.68–0.92	Sarcopenic (N = 85) Psoas Index ≤ 0.68
sBP(mmHg)	119 [97–145]	125 [94–150]	118 [98–140]	119 [93–145]
Heart rate(bpm)	98 [81–120]	100 [81–123]	95 [80–118]	100 [81–119]
Level of consciousness				
Alert	113 (44.3%)	38 (44.2%)	38 (45.2%)	37 (43.5%)
Minor	77 (30.2%)	25 (29.1%)	25 (29.8%)	27 (31.8%)
Moderate	27 (10.6%)	8 (9.3%)	8 (9.5%)	11 (12.9%)
Severe	38 (14.9%)	15 (17.4%)	13 (15.5%)	10 (11.8%)
BT(°C)	36.9 [36.2–38.0]	36.9 [36.1–38.2]	37.1 [36.2–38.0]	36.7 [36.2–37.6]
Lactate (mmol/l)	2.8 [1.7–5.2]	3.4 [2.0–5.7]	2.7 [1.9–4.7]	2.7 [1.6–4.4]
SOFA	9 [5–14]	9.5 [5–14.25]	9.5 [5–13]	9 [5–14]
Tracheal intubation in ER	63 (24.7%)	29 (33.7%)	19 (22.6%)	15 (17.7%)
Emergency treatment				
Surgery	147 (57.7%)	40 (46.5%)	54 (64.3%)	53 (62.4%)
Percutaneous drainage	4 (1.6%)	1 (1.2%)	1 (1.2%)	2 (2.4%)
Endoscopic intervention	9 (3.5%)	2 (2.3%)	5 (6%)	2 (2.4%)
Psoas Index	0.79 [0.6–1]	1.11 [1.00–1.32]	0.80 [0.73–0.85]	0.54 [0.44–0.62]
RRT	69 (27.1%)	26 (30.2%)	23 (27.4%)	20 (23.5%)
ICU duration (day)	3 [1–7]	4 [1−10]	2 [1–6]	3 [1–6.5]
The condition at hospital discharge				
ADL: Independent	96 (37.8%)	40 (46.5%)	36 (43.4%)	20 (23.5%)
ADL: Assistance required	107 (42.1%)	35 (40.7%)	30 (36.1%)	42 (49.4%)
Death	51 (20.1%)	11 (12.8%)	17 (20.5%)	23 (27.1%)

Categorical variables: number, (%), Continuous variables: median, IQR.
sBP: Systolic blood pressure, BT: body temperature, SOFA: Sequential organ failure assessment, ER: Emergency room, RRT: Renal replacement therapy, PI: Psoas muscle index defined as [(the right + left area of psoas muscle)/ the area of L3vertebra], ADL: Activity of daily living, Level of consciousness: Alert (GCS15), minor (GCS13–14), moderate (GCS9–12), and severe (GCS < 9).

Table 3
Association of psoas muscle findings with 90-day mortality

Variables	Mortality	Crude OR	95%CI	AOR	95%CI
Above middle (PI >0.92)	14.0% (12/86)	Ref	–	Ref	–
Middle (PI:0.68–0.92)	21.4% (18/84)	1.68	0.75–3.75	2.40	0.93–6.15
Sarcopenic (PI≤0.68)	29.4% (25/85)	2.57	1.19–5.54	3.67	1.39–9.68

OR: Odds ratio, AOR: adjusted odds ratio, CI: confidence interval, PI: Psoas muscle index.
Adjusted by age, sex, infection site, SOFA, and the Charlson comorbidity index.
Psoas muscle index: [(the right + left area of psoas muscle)/ the area of L3vertebra].

Table 4
Prediction model using SOFA and Psoas Index

Variable	β coefficient	SE
Intercept	−3.430	0.473
PI group		
Above middle	Ref	–
Middle	0.084	0.236
Sarcopenic	0.539	0.227
SOFA score/1 pt	0.193	0.037

SE: Standard error, PI: Psoas muscle index.

The results suggested an association of the sarcopenic findings with 90-day mortality; however, the modified SOFA had an additional clinical value to that of SOFA in predicting 90-day mortality.

4. Discussion

4.1. Key observations

The results of this retrospective cohort study indicated an association between sarcopenic findings of the psoas muscle on CT imaging and 90-day mortality among adult patients with sepsis. However, based on the results of ROC and decision curve analysis, the sarcopenic findings on CT, in conjunction with SOFA, had few additional clinical values to that of SOFA in predicting 90-day mortality.

4.2. Previous literature and strength

There are some strengths of our study when compared to the previous literature. First, we showed a dose-response relationship between the sarcopenic findings and 90-day mortality. Although most previous studies have assessed the sarcopenic findings among critically ill patients, it was treated as a binary variable (that is, sarcopenic or not) [10-16]. On the other hand, here it was a continuous variable with three categories; as a result, our study could show that less cross-sectional area of psoas muscle was associated with higher mortality. Second, despite negative results, this study assessed not only the association of sarcopenic findings with the outcome but also its predictive

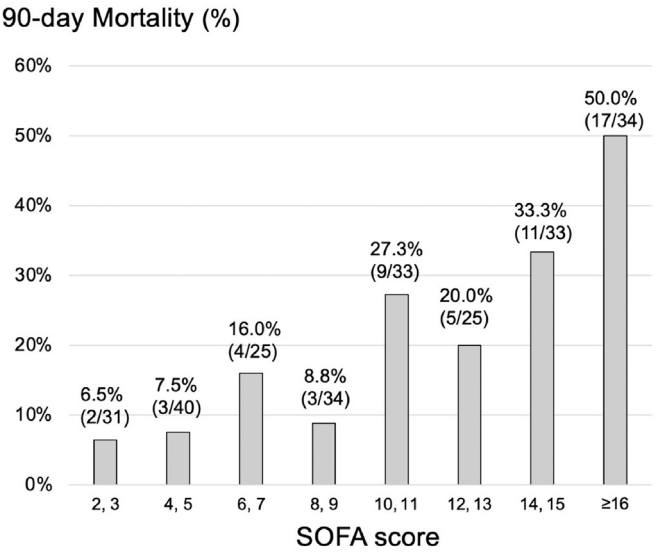

Fig. 3. The 90-day mortality according to SOFA score. SOFA score: Sequential organ failure assessment score.

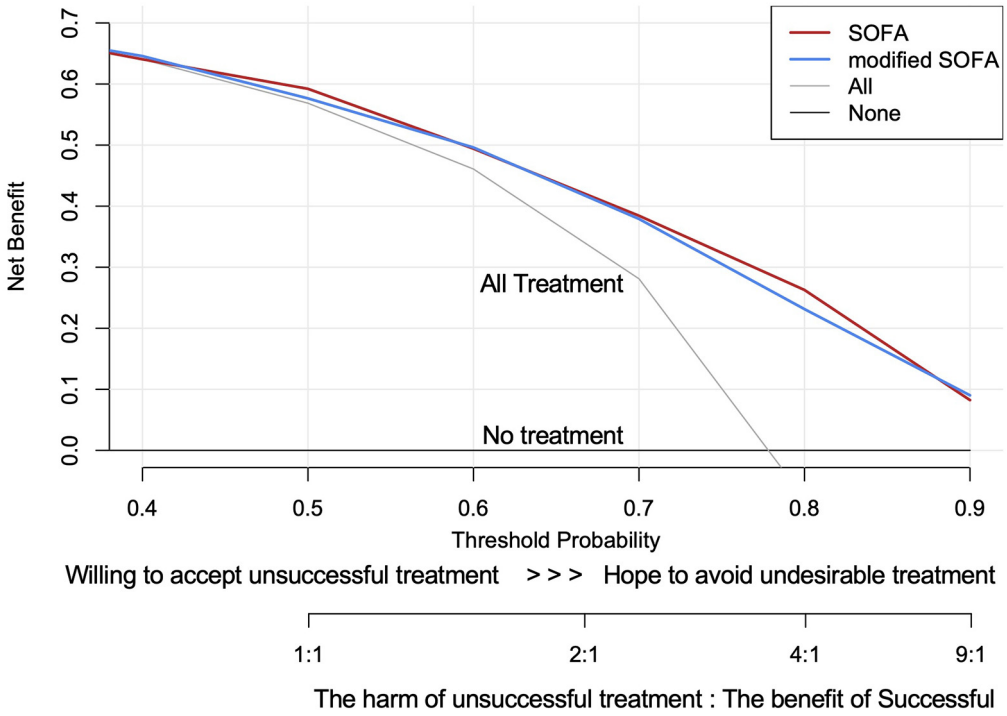

Fig. 4. The net-benefit of SOFA and modified SOFA. X-axis: Threshold probability p in the range between 0.4 and 1.0. Y-axis: Net-benefit. Cost-benefit ratio: p:(1-p) means clinical importance of unsuccessful treatment cases relative to the one successful treatment case. The net-benefit of the SOFA and modified SOFA is almost as same as in any threshold probability.

ability. According to previous studies, the sarcopenic findings might be one of the risk factors for unfavorable outcomes in critically ill patients [10-16]. Sarcopenic findings cannot be modified immediately in emergency settings. Thus, sarcopenic findings might have a clinical role as a predictor of the outcome rather than a modifiable factor. However, there are only a few studies that have compared the predictive performance of sarcopenic findings with an established risk assessment tool such as the SOFA score. Third, in this study, a decision curve analysis was done to evaluate the clinical utility and net benefit of the sarcopenic findings. In earlier studies, some parameters, such as AUC of ROC (c-statistics), sensitivity, or specificity, were used to compare the predictive performance. However, these parameters were not sufficient to understand the amount of benefit received by the patients using the prediction model [32]. Whereas the net benefit may represent the actual benefit, as true positive, received by the patients, the decision curve analysis, based on the net benefit, can evaluate prediction models [31,32]. Thus, through this study, we have added novel findings and additional value to the previous studies.

4.3. Interpretation and clinical implications

Initially, we thought that most of the sarcopenic patients would die soon after hospital discharge due to frailty, even if they could survive until discharge. Thus, we hypothesized that the sarcopenic findings would have an additional predictive value for the 90-day mortality. However, we observed that most of the patients, regardless of the sarcopenic findings, died before discharge (89.1%, median duration to die: 12 days). They may have died due to multiple organ failure; therefore, the physiological severity demonstrated by the SOFA score could be enough to predict the 90-day mortality.

However, the sarcopenic findings might be useful in predicting long-term mortality, the activity of daily living, or the quality of life. In this study, more than half of the "Sarcopenic" patients had been living independently before ICU admission; however, at the hospital discharge, the percentage of patients capable of living independently was only 23.5% (20/85), which was lower than that in the "Above middle" (46.5%, 40/86) and "Middle" groups (43.4%, 36/84) (Table 2). Further, 1-year mortality in the "Sarcopenic" patients was also higher than in the "Above middle" and "Middle" groups. Owing to the retrospective nature of this study, health-related quality of life, details of activities of daily living, and information on 1-year mortality in some of the patients were not available. Therefore, prospective studies focusing on these functional outcomes are warranted in the future.

5. Limitation

There were several limitations. First, the withdrawal of aggressive treatment before ICU admission was not recorded. Moreover, the criteria for ICU admission had not been strictly defined. Thus, these issues might have led to selection bias. Second, since the clinical information was retrospectively collected, the exact timing and validity of the variables were unclear. In addition, some variables were missing. Although the validity of the measurement of the area of the psoas muscle and the vertebra was ensured, the subjective bias might not have been eliminated entirely, thus causing measurement bias. Third, there could be some unmeasured confounding factors such as differences in treatment preferences of the patient's physician-in-charge or changes in treatment during the study period. Fourth, the study had a limited sample size, therefore, may lack the power to detect the difference in predictive value. Fifth, the predictive ability of the modified SOFA score was assessed in the same cohort in which the score was developed; therefore, there could be a risk of overfitting and optimization. Finally, this study was performed at a single center; thus, there would be concerns regarding its generalizability to other settings. Therefore, to eliminate these biases, and for more robust results, further research is necessary.

6. Conclusions

The results of this study indicated an association of the sarcopenic findings of the psoas muscle on CT imaging with 90-day mortality in adult patients with sepsis. However, the sarcopenic findings on CT, when added to the SOFA score, had few additional clinical values to that of SOFA in predicting 90-day mortality.

Sources of support

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

Conception and design of the work: YO, TK, and TI
Data acquisition: YO, AO, and RI
Analysis: YO and TK
Interpretation: YO, TK, TI, and SO
Writing the draft: YO, TK, TI, and SO
All authors revised the draft, approved the final draft, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2021.04.011.

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