Predicting Acute Pancreatitis Severity: A Comparative Analysis of Computed Tomography Severity Index, Including Fat and Muscle Parameters

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Abstract

Aim: The aim of this study was to investigate whether computed tomography-measured intra-abdominal fat and muscle parameters could improve the accuracy of acute pancreatitis severity assessment using the computed tomography severity index.

Methods: This retrospective study included clinical and imaging parameters of 87 patients with acute pancreatitis. Patients were assessed by the computed tomography severity index. Asan J-Morphometry (Seoul, Korea), an ImageJ-based software (NIH, USA), was used to quantify abdominal muscle and fat areas. Total fat area, superficial fat area, visceral fat area, total muscle area and total muscle-fat area were calculated. The severity of acute pancreatitis was determined according to the revised Atlanta classification. Interreader agreement assessments, univariate and multivariate analyses were performed.

Results: No significant differences were found in intra-abdominal fat and muscle parameters between groups with or without systemic or local complications ($p > 0.05$). When the patients were categorized as mild and severe disease based on computed tomography severity index score, no significant differences were found in fat and muscle parameters ($p > 0.05$). Surgery, systemic complications, and a high total computed tomography severity index score significantly increased the risk of local complications, with odds ratios of 0.001, 141.9, and 2.42, respectively. The intraclass correlation coefficients (ICC) were ≥ 0.90 between the readers.

Conclusions: In this study, our study suggested that computed tomography -measured fat and muscle parameters did not significantly improve the accuracy of computed tomography severity index in predicting severity of acute pancreatitis.

Keywords: *Acute pancreatitis, Atlanta classification, computed tomography, computed tomography severity index, disease severity, fat, muscle*

1. Introduction

Acute pancreatitis (AP) is a prevalent gastrointestinal condition with potentially life-threatening complications, affecting up to 20% of patients.[1-3] Though widely used, the Balthazar score alone struggles to predict organ failure or mortality. For more accurate diagnoses, computed-tomography (CT) severity index combines Balthazar grading with pancreatic necrosis with scores above 5 linked to higher mortality and longer hospital stays.[4-7] Early and accurate assessment of severity is crucial to identify those at risk and prevent adverse outcomes, as morbidity and mortality remain high for severe cases.[3] Previous research suggests promising roles for visceral fat surface area and peritoneal cavity circumference in early prediction of severity and mortality.[8,9] This study investigates the potential of CT-derived measurements of intraabdominal fat and muscle indices, alongside the established Balthazar score, to improve the accuracy of AP severity assessment.

Our objective is to refine the assessment of AP severity by exploring the combined predictive power of CT-measured intraabdominal fat and muscle parameters with the Balthazar score. This novel approach has the potential to enhance patient management strategies and optimize risk stratification in this critical condition.

2. Materials and methods

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by Adana City

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Training and Research Hospital Clinical Research Ethics Committee, (approval date:17.11.2022, project number:2246). Patients with AP referred/admitted to the department of general surgery from January 2018 to January 2021 were searched and among these cases, those who had a computed tomography scan at the time of diagnosis of AP were included in the study.

All CT scans were performed on a 128-slice Philips Ingenuity scanner (Eindhoven, Netherlands) at portal venous phase. All images were anonymized and independently reviewed by two physician specialists: a radiologist and a general surgeon specializing in gastrointestinal surgery. Both reviewers were blinded to patients' clinical data.

All CT scans were analyzed using Asan J-Morphometry software (Seoul, Korea), dedicated for abdominal muscle and fat area measurements based on ImageJ (NIH, USA).

2.1. Muscle and Fat Measurements

Following Schweitzer et al.[10], measurements were done on a single axial slice at the level of the inferior endplate of the third lumbar vertebra (L3). According to the different Hounsfield units, densities of different tissue types, the software automatically calculates the skeletal muscle area (–29 to +150), abdominal fat area (–50 to –150), and subcutaneous fat area (–190 to –30). The software automatically segmented and allowed manual adjustments for visceral fat area (within total abdominal muscle area), total muscle area (including abdominal wall, psoas, and paraspinal muscles)

Calculated parameters included: total fat area (TFA), Superficial fat area (SFA) = TFA - visceral fat area (VFA), Total muscle area (MA), Total muscle-fat area (MFA)

Balthazar score was assessed as follows: normal pancreas: 0**,** pancreas enlargement: 1**,** pancreatic/peripancreatic inflammation: 2, single ill-defined fluid collection: 3**,** two or more poorly defined fluid collections: 4.

Pancreatic necrosis score was categorized as follows: none: 0, **≤** 30%: 2, 30-50%: 4, 50%: 6

The computed tomography severity index was defined as the sum of Balthazar and necrosis scores (maximum 10).

Clinical severity was assessed by the Atlanta classification. Additionally, demographic data (age, gender) and clinical information were collected, including: etiological factors contributing to pancreatitis, mortality rates, occurrence of local and systemic complications, time to initiate feeding, duration of hospital stay, incidence of surgical or interventional procedures.

2.2. Statistical analysis

IBM SPSS software was used to analyze data. Categorical data were summarized with frequencies and percentages, while continuous data were summarized with various statistics like mean, standard deviation, and median. Statistical tests (chi-square, Fisher's exact, Mann-Whitney U) were used to compare variables based on their distribution and sample size. Significance was defined as $p < 0.05$.

Univariate models and Receiver Operating Characteristic (ROC) curve analysis were used to assess individual associations and the performance of selected variables and CT severity index in predicting outcomes. ROC analysis identified the best cutoff value for these variables, and sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated.

The reader agreement was assessed with intraclass correlation coefficient (ICC) ($r \geq 0.90$ excellent, 0.70-0.90 good, 0.50-0.70 fair, 0.30-0.50 weak, <0.30 poor).

3. Results

Initially eighty-eight patients diagnosed with AP admitted to our department were considered. One patient with cachexia due to rectal carcinoma was excluded. Therefore, our analysis included 87 participants. The mean age of the patients was 51.6±18.9 years, and of those 48 (55.2%) were male. The most frequent contributors to pancreatitis were gallstones (60.9%), followed by hyperlipidemia (20.8%).

According to the Atlanta classification, disease severity was classified as moderate in 36 patients (41.4%), mild in 32 patients (36.8%), and severe in 19 patients (21. 8%).We categorized mild cases as non-severe and combined moderate and severe cases as severe for statistical analysis.

Local complications were detected in 28 cases (32.2%)and systemic complications were developed in 36 cases (41.4%). Mortality rate was 2.3% (n=2). Additionally, 16.1% of the patients (n=14) underwent surgical or interventional procedures. Total CT severity index score was 2,86±1,8 (ranging from 0 to 9). The detailed demographic and clinical data are presented in Table 1.

Inter-reader agreement was excellent for all CT parameters, with ICCs ranging from 0.95 to 0.99. When a cutoff of 4 or higher was considered for the total CT severity index score, the diagnostic performance was as follows: sensitivity 81.25% (95% CI: 63.6-92.8), specificity 49.09% (95% CI: 35.4-62.9), positive predictive value (PPV) 51% (95% CI: 42.7-59.2), negative predictive value (NPV) 90% (95% CI: 74.8-96.5), and area under the curve (AUC) 0.721 (95% CI: 0.615-0.812) ($p < 0.001$).

When cases were grouped into mild and severe disease based on the total CT severity index score, no statistically significant differences were observed among the groups in terms of TFA, SFA, MA, and MFA (with p-values of 0.307, 0.15, 0.49, and 0.13, respectively). In patients with severe Atlanta findings, a higher rate of surgical interventions was observed ($p < 0.001$).

Table 1

The clinical parameters of the study population

	Number (n)	percentage (%)
Atlanta		
• Mild	32	36.8
• moderate	36	41.4
• Severe	19	21.8
Surgical intervention		
• Yes	14	16.1
• No	73	83.9
Distribution of the Interventions	14	16.1
• abscess drainage	2	14.2
• debridement	2	14.2
• cystogastrostomy	1	7.1
• cholecystectomy	2	14.2
• percutaneous drainage	7	50.3
Mortality	2	2.3
Local complications	28	32.2
• Wall of necrosis	4	4.6
• Abscess, fluid, pseudocyst	21	24.1
• Wound related complications	3	3.5
Systemic complications	36	41.4
• sepsis	32	36.8
• ARDS	10	11.5
• acute renal failure	4	4.6
• cholangitis	1	1.1

Table 2

Univariate analysis. Comparison of variables between patients with Severe and Non-severe acute pancreatitis

	Atlanta non-severe (n=32)	Atlanta severe (n=55)	p[b]
	mean±SD	mean±SD	
Age	53.1±19.8	50.7±18.6	0.517
Total CT severity index score	2.13±1.5	3.29±1.8	<0.001**
Time to feeding	2.19±1.8	6.07±6.6	<0.001**
Hospitalization	5.31±3.6	14.9±13.2	<0.001**
TFA	401.6±209.6	566.6±825.3	0.686
SFA	206.4±117.5	194.8±110.9	0.745
VFA	162.3±101.5	191.1±112.7	0.221
MA	113.6±34.1	123.2±43.9	0.365
MFA	34.3±16.8	33.3±13.5	0.905

** p<0.05, **p<0.001, a: chi-square - Fisher exact test, b: Mann Whitney U test, TFA: Total fat area, SFA:superficial fat area,VFA: visceral fat area, MA: total muscle area, MFA: total muscle-fat area*

Univariate analyses were performed, including parameters such as patients' gender, surgery, sepsis, systemic complications, age total CT severity index score, time to feeding, hospitalization, CT-measured fat and muscle parameters. According to the univariate analysis, results based on the presence of local complications, it was determined that surgery, sepsis, systemic complications, age, total CT severity index score, time to feeding, and hospitalization time parameters were significant ($p < 0.05$). Univariate analyses are presented in Table 2 and Table 3.

The parameters found to be significant in the univariate analysis were included in the multivariate analysis. Surgery, systemic complications, and a high total CT severity index score significantly increased the risk of local complications, with odds ratios of 0.001, 141.9, and 2.42, respectively.

Table 3

Univariate analysis. Comparison of variables between patients with Severe and Non-severe acute pancreatitis

	Atlanta non-severe (n=32) n(%)	Atlanta severe (n=55) n(%)	p[a]
Sex			
• Male	15 (46.9)	33 (60)	0.235
• Female	17 (53.1)	22 (40)	
Surgery			
• Yes	2 (6.3)	12 (21.8)	0.043*
• No	30 (93,8)	43 (78.2)	
Mortality	-	2 (3.6)	0.275
Local complication	1 (3.1)	27 (50)	<0.001**
• wall of necrosis	-	4 (7.3)	0.118
• abscess-fluid-pseudocyst	1 (3.1)	20 (36.4)	<0.001**
• wound related complications	-	3 (5.5)	0.179
Systemic complication	2 (6.3)	34 (61.8)	<0.001**
• Sepsis	1 (3.1)	31 (56.4)	<0.001**
• ARDS	-	10 (18.2)	0.010*
• Acute renal failure	-	4 (7.3)	0.118
• cholangitis	1 (3.1)	-	0.187

** p<0.05, **p<0.001, a: chi-square - Fisher exact test, b: Mann Whitney U test, ARDS: acute respiratory distress syndrome*

No significant differences were found in intra-abdominal fat and muscle parameters between groups with or without systemic or local complications ($p > 0.05$). When the patients were categorized as mild and severe disease based on computed tomography severity index score, no significant differences were found in fat and muscle parameters ($p > 0.05$).

4. Discussion

Although there are several studies evaluating the impact of body composition including fat and muscle distributions on outcomes of AP, the findings are still controversial. Our study demonstrated that fat and muscle parameters measured by CT did not differ among the groups with severe or mild disease based on either Atlanta classification or CT severity index. Furthermore, adding CT-measured parameters did not appear to improve the predictive power of the CT severity index score in AP. As expected, our study also found that surgical and interventional procedures were more prevalent in cases with more severe Atlanta findings. The presence of surgery, systemic complications, or a high CT severity index score appeared as risk factors for local complications. Consistent with our expectations, gallstones were identified as the most significant etiological factor. Interestingly, a high level of agreement was observed between measurements performed by radiologists and gastroenterology surgeons.

Gupta et al.[11] proposed a new fat modified scoring system for pancreatitis using automated software. It categorizes patients based on fat levels and traditional methods in predicting severity. Notably, in that study total to visceral fat ratio based version showed the best accuracy. They suggested that their fat modified scoring system especially the total to visceral fat ratio version, could be a valuable tool for improved pancreatitis diagnosis. In our study we did not show a significant difference in superficial, visceral or total fat area between severe and non-severe AP patients. Acute pancreatitis is a complex and highly inflammatory systemic condition. The factors including genetics, age, gender, diet, physical activity, hormonal imbalances, and certain medical conditions may affect the abdominal fat and muscle area may vary. These factors could potentially influence our study results. Individual differences and specific conditions also might play a role in disease severity and fat-muscle distribution. Pre-admission co-morbidities also varied between studies.

In a recent study by Lin et al.[12], the mortality group had a lower third lumbar skeletal muscle index compared to the survival group among AP patients and the skeletal muscle index showed a negative correlation with CT severity index scores. They proposed that diagnosing muscle depletion using third lumbar skeletal muscle index was a valuable radiological parameter for predicting in-hospital severity and short-term prognosis in patients with AP. In our study population mortality rates were too small and we were unable to compare the survival and mortality groups. Since fat and muscle parameters did not vary between severe and non-severe groups in our study, we could not determine a cut-off value. Therefore, it was not possible to add CT-measured fat and muscle parameters to the Balthazar score and analyze them.

Wang S. et al.[13] measured body composition parameters on a single slice at L2-3 of the unenhanced CT scans. They assessed the intermuscular adipose tissue, visceral adipose tissue, skeletal muscle area and skeletal muscle density. The intermuscular adipose tissue and visceral adipose tissue were higher in the severe AP group than in the moderately severe group, but were not associated with outcomes. The proposed that low skeletal muscle density was associated with poor outcomes in patients with severe and moderately severe AP. In our study, as in the study of Wang et al, no difference was

detected in the skeletal muscle area between cases with severe and non-severe acute pancreatitis. Additionally, Fu et al.[14] showed that rates of local complications, splenic vein thrombosis, and organ failure were increased in AP patients with lower psoas muscle area. Psoas muscle area showed good ability to predict splenic vein thrombosis in women. In contrast to this study, our study found no significant difference in CT-measured muscle parameters between patients with and without local complications. In our study, total CT-severity index score significantly increased the risk of local complications, with an odds ratio of 2.42, unlike other CT-measured fat and muscle parameters

Dawra et al.[15] notably found a strong correlation between CT and Dual-energy X-ray absorptiometry (DXA)derived abdominal fat measurements in AP patients, suggesting both techniques are valuable for assessing fat levels and their potential links to AP severity. Additionally, they found associations between both CT and DXA fat measurements and AP severity, highlighting the potential of non-invasive DXA as an alternative to CT for abdominal fat assessment in AP. However, it's worth noting that their study population was significantly younger than ours (38.2 years vs. 51.6years), and age can influence the fat-to-muscle ratio, potentially explaining some of the discrepancies between the studies.

The literature suggests obesity as an important prognostic factor, with body mass index exceeding 30 kg/m^2 increasing mortality and severe disease progression.[16-18] However, Higaki et al.[19] demonstrated that abdominal visceral obesity (assessed by umbilical-level visceral fat area) did not significantly impact mortality prediction compared to age and a prognostic factor score in severe AP patients in the Japanese population. Similarly, to their study, we found no correlation between CT-measured fat and muscle parameters and patient prognosis. Notably, survival times did not significantly differ between severe AP patients with and without visceral fat area exceeding 167 cm^2. [19]

4.1. Limitation

Our study has a few limitations including relatively small sample size and retrospective design.

The strength of our study is the double-blinded nature of the CT measurements. Analyzing the inter-reader correlation provided valuable information about measurement consistency.

5. Conclusion

No significant differences were found in CT measurements between groups with or without systemic or local complications, or between groups categorized as mild and severe based on total CT severity index scores. This study's findings suggest that CT-measured abdominal fat and muscle parameters do not significantly enhance the accuracy of the CT severity index in predicting local and/or systemic complications in AP patients.

Statement of ethics

This retrospective cohort study was approved by the Adana City Training and Research Hospital Clinical Research Ethics Committee, (The project number is 2246, approval date:17.11.2022).

Conflict of interest statement

The authors declare that they have no financial conflict of interest with regard to the content of this report.

Availability of data and materials

The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Author contributions

GO: Conceptualization, Project administration, Data curation, Formal Analysis, Writing – original draft, BCP: Data curation, Formal Analysis, Writing –review & editing, AS &AS: Data curation, Formal Analysis, Writing –review & editing

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