UDC 616.74-007.23:616.37-002.4-089;616.073.43
DOI http://doi.org/10.30978/GS-2026-1-16

ISSN 2786-5584 print
ISSN 2786-5592 online

Acute skeletal muscle loss in surgically treated patients with severe infected necrotizing pancreatitis: a longitudinal ultrasound study

V. Teterina

Bogomolets National Medical University, Kyiv

✉ Viktoriia Teterina: dr.teterina@nmu.ua

V. Teterina, http://orcid.org/0000-0001-8250-7646

Objective – to evaluate perioperative changes in ultrasound-derived parameters of peripheral muscle mass, using the cross-sectional area of the rectus femoris muscle as a representative measure, in patients undergoing surgery for severe acute pancreatitis complicated by infected necrosis. Additionally, changes in handgrip strength were assessed, and the association between ultrasound findings and computed tomography–derived muscle mass indices was analyzed.

Materials and methods. This prospective observational study was conducted at two clinical centers and included 28 patients aged 19–59 years who underwent surgery for infected necrotizing pancreatitis. The median length of hospital stay was 49 (39–59) days. Serial measurements of the cross-sectional area (CSA) of the rectus femoris muscle were obtained using a portable ultrasound device equipped with a wireless high-frequency linear transducer, and handgrip strength was assessed with a dynamometer at three clinically defined time points (T1–T3). Serial measurements were obtained at clinically defined time points reflecting the perioperative course of severe acute pancreatitis: the first examination was performed on day 8 (6–10) of hospitalization, and the second on day 29 (26–31). In a subgroup of 17 patients with available paired computed tomography (CT) scans, skeletal muscle area (SMA) at the L3 vertebral level was assessed, and the association between changes in ultrasound parameters and CT-derived measurements was analyzed using Spearman's rank correlation coefficient. Linear mixed-effects models were applied to evaluate the longitudinal dynamics of skeletal muscle parameters.

Results. A statistically significant progressive decrease in CSA of the rectus femoris muscle ($p < 0.001$) was observed during hospitalization. The total relative reduction in CSA between T1 and T3 was 20.5 %. Modeling the length of hospital stay as a continuous variable confirmed an independent association between CSA decline and time ($\beta = -0.025$ cm^2/day; $p < 0.001$). The reduction in handgrip strength was even more pronounced ($p < 0.001$), with a total relative decrease of 36.7 % between T1 and T3. In the subgroup of patients with paired CT scans, ultrasound-derived changes in CSA demonstrated a moderate positive correlation with changes in skeletal muscle area (SMA) at the L3 vertebral level ($\rho = 0.65$; $p = 0.005$), supporting the concordance between the two assessment methods.

Conclusions. Patients who underwent surgery for infected necrotizing pancreatitis demonstrated progressive deterioration in both morphological and functional skeletal muscle parameters during hospitalization. A more pronounced decline in muscle strength compared with ultrasound-derived measures of muscle mass may reflect asynchronous functional and morphological changes in skeletal muscle in the context of severe acute pancreatitis complicated by infected necrosis. These findings support the clinical utility of a combined morphological and functional assessment of muscle status for the timely identification of acute secondary sarcopenia and optimizing nutritional and rehabilitation interventions in this patient population.

Keywords
skeletal muscle wasting, acute sarcopenia, muscle ultrasound, severe acute pancreatitis, infected pancreatic necrosis, critical illness, catabolism.

ARTICLE • Received 2026-01-05 • Received in revised form 2026-02-13 • Published 2026-03-31

Acute pancreatitis is a common condition with a variable clinical course; in some patients, it is complicated by persistent organ failure and infected pancreatic or peripancreatic necrosis [4], necessitating intensive care and prolonged hospitalization. Severe disease is associated with a pronounced systemic inflammatory response, hypercatabolism, immobilization, and impaired nutritional status, creating conditions for rapid skeletal muscle loss. In critically ill patients, acute muscle wasting may develop as early as the first week of illness and can reach substantial levels [8, 19].

Sarcopenia, as confirmed by computed tomography (CT), is increasingly recognized as a predictor of adverse clinical outcomes in patients with acute pancreatitis [3, 7]. Despite growing interest in assessing skeletal muscle parameters in critically ill patients, data on muscle mass dynamics during the clinical course of infected necrotizing pancreatitis remain limited, particularly prospective studies evaluating muscle parameters serially in patients undergoing surgery for this condition.

Ultrasound (US) is considered an accessible, reliable, and effective tool for the serial assessment of skeletal muscle morphology in critically ill patients [16, 17]; however, its clinical application and the correlation of ultrasound-derived findings with functional muscle parameters in this surgical cohort have not been sufficiently investigated. Consequently, there is increasing interest in combining imaging and functional approaches to assess skeletal muscle status, allowing for more comprehensive characterization of sarcopenia and longitudinal monitoring of structural and functional changes without additional radiation exposure or substantial increases in resource utilization.

Objective – to evaluate perioperative changes in ultrasound-derived parameters of peripheral muscle mass, using the cross-sectional area of the rectus femoris muscle as a representative measure, in patients undergoing surgery for severe acute pancreatitis complicated by infected necrosis. Additionally, changes in handgrip strength were assessed, and the association between ultrasound findings and computed tomography–derived muscle mass indices was analyzed.

Materials and methods

Study Design

The study employed a prospective observational design. Patients were consecutively recruited from the surgical departments of two hospitals serving as clinical teaching sites of Bogomolets National Medical University between November 2024 and December 2025. All patients were screened throughout the study period; however, only those fulfilling the predefined criteria for the present observational analysis were included. The present analysis was restricted to patients managed under standard care; individuals receiving protocolized nutritional interventions during the same recruitment period were not included.

The primary endpoint was the change in rectus femoris cross-sectional area across time points T1–T3, including assessment of the overall effect of time and pairwise comparisons between observation points. Secondary endpoints included changes in handgrip strength and the association between ultrasound-derived rectus femoris cross-sectional area and computed tomography–derived skeletal muscle area at the L3 vertebral level.

The study included 28 patients aged 19–59 years diagnosed with severe acute pancreatitis according to the Revised Atlanta Classification, defined by the presence of persistent organ failure lasting more than 48 hours, often accompanied by local complications [1]. Additional inclusion criteria comprised the presence of pancreatic or peripancreatic necrosis with subsequent infection, surgical intervention during hospitalization as part of a step-up approach [23], and the availability of serial ultrasound measurements of rectus femoris cross-sectional area at predefined clinically relevant time points.

The age range of 19–59 years was selected to minimize the influence of age-related sarcopenia and to reduce sample heterogeneity when assessing secondary muscle mass loss associated with severe acute pancreatitis.

The study excluded patients aged <18 or ≥ 60 years, those with acute pancreatitis not meeting the criteria for severe disease according to the Revised Atlanta Classification, patients without confirmed infected necrosis or managed non-operatively, and those with missing or technically unfeasible serial ultrasound measurements of the rectus femoris muscle.

The sample size was determined by the number of eligible patients identified during the enrollment period, taking into account the relative rarity of severe acute pancreatitis complicated by infected necrosis requiring surgical treatment, as well as the feasibility of performing serial measurements. Eligibility criteria were defined in accordance with the objectives of the present observational analysis.

Clinical management

Management followed a step-up approach in accordance with contemporary principles for the treatment of infected necrotizing pancreatitis. Initial

Table 1. **Baseline characteristics of the study population (n = 28)**

Variable	Total group (n = 28)
Demographic characteristics	
Age, years	44.5 [36–52]
Male Female	18 (64.3 %) 10 (35.7 %)
Body mass index at admission, kg/m^2	30.5 [23.1–32.2]
Clinical characteristics	
Etiology of pancreatitis	
Alcoholic	17 (60.7 %)
Alimentary	9 (32.1 %)
Biliary	2 (7.1 %)
Admission to intensive care unit	28 (100 %)
Disease severity	
APACHE II score at admission	14.5 [13–17.5]
Respiratory failure	22 (78.6 %)
Renal failure	8 (28.6 %)
Cardiovascular failure	12 (42.9 %)
Multiple organ failure (≥ 2)	13 (46.4 %)
Laboratory markers	
C-reactive protein at admission, mg/L	172.5 [156.5–194]
Hospital course	
Length of hospital stay, days	49 [39–59]
In-hospital mortality	9 (32.1 %)
Nutritional parameters	
Body weight at admission, kg	86.2 [66.2–103.1]
Change in body weight, kg	–13.0 [–19.0 ... –8.4]
Nutritional support	
Enteral nutrition	20 (71.4 %)
Parenteral nutrition	8 (28.6 %)
Availability of data	
Complete CSA measurements (T1–T3)	26 (92.9 %)
Complete handgrip strength measurements (T1–T3)	26 (92.9 %)
Paired CT scans for validation	17 (60.7 %)
Timing of ultrasound examinations	
Days from admission to US T1	8 [6–10]
Days from admission to US T2	29 [26–31]

Note. Categorical variables are presented as the number of cases and percentage, while quantitative indicators are presented as median [IQR].

treatment consisted of conservative management, including intensive supportive care and close clinical and radiological monitoring. Patients received organ support when required, infection control with appropriate antimicrobial therapy, and source control of infected necrosis.

Nutritional support was provided according to clinical tolerance, with a preference for enteral nutrition when feasible. Management followed a step-up approach. Initial treatment consisted of conservative management, including intensive supportive care and close clinical and radiological monitoring. The decision to proceed with surgical intervention was made during the disease course in the presence of infected pancreatic or peripancreatic necrosis. Whenever feasible, surgical intervention was deferred until the development of walled-off necrosis, typically 3–4 weeks after disease onset. The timing of surgery was determined based on the patient's clinical condition and computed tomography (CT) findings [11]. Minimally invasive interventions, including percutaneous drainage, were applied when clinically indicated as part of the step-up strategy; however, all patients ultimately required open surgical necrosectomy due to disease progression or insufficient response to initial interventions. Baseline patient characteristics, indicators of disease severity and progression, and details of nutritional support are summarized in Table 1.

Ultrasound muscle assessment

All ultrasound measurements were performed by a single investigator using a standardized protocol, with subsequent random spot-checks conducted by a senior specialist blinded to the results of other instrumental examinations. Ultrasound examinations were carried out using a Sonostar Uprobe-L6C wireless linear transducer. A dedicated musculoskeletal preset with an operating frequency of 7.5–10 MHz was used for skeletal muscle assessment, depending on image quality. Scan depth was adjusted to the minimum level required for complete visualization of the rectus femoris cross-sectional area (typically 100 mm). Additional imaging parameters included an overall gain of 60 dB, a dynamic range of 50 dB, and spatial compounding enabled. The mechanical index (MI) and thermal index for soft tissue (TIS) were 0.9 and 0.2, respectively. Ultrasound acquisition settings were kept constant across serial measurements for each patient.

Participants were examined in the supine position with lower limb muscles relaxed. To maintain methodological consistency and enable reliable comparison of serial measurements, all assessments were performed on the right thigh. A transverse

image of the rectus femoris muscle was acquired at a standardized anatomical landmark located in the mid-thigh region, defined as the midpoint between the anterior superior iliac spine and the superior border of the patella.

Ultrasound assessment was performed in B-mode using a transverse scanning plane with minimal transducer pressure applied to the skin. At each time point, three consecutive measurements of rectus femoris cross-sectional area were obtained, and the mean value was used for statistical analysis. The validity and reproducibility of ultrasound-based assessment of rectus femoris cross-sectional area have been demonstrated in previous studies [6, 21]. The primary ultrasound outcome measure was rectus femoris cross-sectional area (cm^2).

Handgrip strength assessment

Handgrip strength was measured using a calibrated digital dynamometer (CAMRY EH-101; CAMRY Electronic Co., Ltd., China) with a maximum capacity of 90 kg. Measurements were recorded in kilograms from the dominant hand. Device settings were standardized and remained unchanged across serial assessments for each patient. Grip strength testing was performed with the patient seated, the shoulder in a neutral position, the elbow flexed at approximately 90°, and the forearm and wrist in a neutral position [20]. At each time point, three consecutive trials were conducted with brief rest intervals, and the highest value was used for statistical analysis.

Computed tomography

In a subgroup of 17 patients with available paired contrast-enhanced CT examinations, obtained for clinical indications related to the management of necrotizing pancreatitis and performed at corresponding time points (T1 and T2), skeletal muscle mass was assessed on a single axial image at the mid-vertebral level of the third lumbar vertebra (L3) [17].

Image analysis was conducted using the web-based version of CoreSlicer software (version 1.0), applying semi-automated tissue segmentation followed by manual correction. Skeletal muscle area (SMA) was quantified in cm^2 using a predefined attenuation range of −29 to +150 Hounsfield units (HU) [18]. Segmentation was performed by a single investigator and subsequently reviewed by a senior specialist who conducted an independent assessment and was blinded to the ultrasound measurement results.

For body composition analysis, images from the native (non-contrast) CT phase were used to ensure standardized tissue attenuation assessment. CT examinations and corresponding ultrasound measurements obtained at time points T1 and T2 were treated as paired observations, provided that the interval between the two procedures did not exceed 48 hours.

Measurement time points

The first measurement time point (T1) included an ultrasound examination performed after clinical stabilization of the patient's condition during the early course of hospitalization. A corresponding CT examination was obtained within the same clinical period. The median time from hospital admission to T1 was 8 days (IQR 6–10).

The second measurement time point (T2) corresponded to the later stage of hospitalization, when repeat ultrasound and follow-up CT examinations were performed as part of ongoing clinical assessment and surgical decision-making. The median time from hospital admission to T2 was 29 days (IQR 26–31).

The third measurement time point (T3) consisted of an ultrasound examination performed after surgical intervention during the late stage of hospitalization. In patients who were discharged, T3 corresponded to the period of clinical stabilization prior to discharge; in patients who died during hospitalization, it represented the late phase of the disease course. Thus, T3 reflected the final observation time point during the hospital stay. Computed tomography was not performed at this time point.

Analysis of the association between ultrasound and CT-derived parameters was therefore restricted to time points T1 and T2, for which paired measurements were available.

Statistical analysis

Continuous variables were summarized as mean and standard deviation or median (interquartile range), depending on data distribution, while categorical variables were presented as absolute and relative frequencies. All statistical tests were two-sided, and p-values < 0.05 were considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics software (version 31.0).

Longitudinal changes in rectus femoris cross-sectional area were analyzed using linear mixed-effects models. Model parameters were estimated by restricted maximum likelihood (REML). Time was included as a categorical fixed effect with predefined measurement points (T1–T3), while a random intercept for each patient was incorporated to account for interindividual variability. The correlation between repeated measurements was modeled using a Toeplitz covariance structure, selected based on information criteria (Akaike information

criterion (AIC) and Bayesian information criterion (BIC)) and model convergence stability.

The overall effect of time was evaluated using a Type III fixed-effects test. When a significant overall time effect was detected, pairwise comparisons between measurement points were performed with Bonferroni adjustment. Estimated marginal means with corresponding 95 % confidence intervals were reported to facilitate the interpretation of longitudinal effects. To assess the robustness of the results, time was additionally modeled as a continuous variable, defined as the number of days from the start of hospitalization to the corresponding measurement. The linear effect of time was evaluated by estimating the coefficient β, which represents the change in CSA per unit time, along with its 95 % confidence interval and p-value.

Longitudinal changes in handgrip strength were analyzed using linear mixed-effects models with time included as a categorical fixed effect (T1–T3). A random intercept for each patient was incorporated to account for interindividual variability, and the correlation between repeated measurements was modeled using a Toeplitz covariance structure. The overall effect of time was evaluated using a Type III fixed-effects test. When a statistically significant time effect was observed, pairwise comparisons between measurement points were performed with Bonferroni adjustment. Results were reported as estimated marginal means with corresponding 95 % confidence intervals.

In the subgroup of patients with available paired CT and ultrasound measurements, the association between ultrasound-derived changes in rectus femoris cross-sectional area and CT-derived changes in skeletal muscle area at the L3 vertebral level was evaluated using correlation analysis. Spearman's rank correlation coefficient (ρ) was used to quantify the strength of the association.

Model convergence was evaluated based on the presence or absence of algorithm warnings and the stability of parameter estimates. Model assumptions were assessed through residual diagnostics, including inspection of histograms, Q–Q plots, and residuals plotted against model-predicted values. Potentially influential observations were examined by reviewing individual longitudinal trajectories and residual distributions, as well as by identifying values that exerted disproportionate influence on fixed-effect estimates.

Results

Sample characteristics

The study cohort comprised 28 patients aged 19–59 years with severe acute pancreatitis complicated by infected necrosis who underwent surgical intervention during hospitalization. Surgical treatment was performed during the interval between the second and third ultrasound assessment time points. The median time from hospital admission to the first ultrasound examination was 8 days (IQR 6–10), and to the second examination was 29 days (IQR 26–31).

Preliminary results

A statistically significant progressive decrease in rectus femoris cross-sectional area was observed over time (Type III fixed-effects test: $F(2, 31.06) = 87.90$; $p < 0.001$). The estimated marginal means (EMMs) of CSA were 4.825 cm^2 (95 % CI 4.399–5.251) at T1, 4.196 cm^2 (95 % CI 3.770–4.623) at T2, and 3.836 cm^2 (95 % CI 3.409–4.263) at T3.

The absolute difference was –0.629 cm^2 (95 % CI –0.732 to –0.526; $p < 0.001$) between T1 and T2, –0.360 cm^2 (95 % CI –0.467 to –0.253; $p < 0.001$) between T2 and T3, and –0.989 cm^2 (95 % CI –1.150 to –0.828; $p < 0.001$) between T1 and T3. The relative reduction in CSA was 13.0 % between T1 and T2 and 8.6 % between T2 and T3, resulting in a total reduction of 20.5 % between T1 and T3.

Sensitivity analysis of results

Additional modeling of time from hospital admission as a continuous variable confirmed an independent association between duration of hospitalization and a decrease in rectus femoris CSA ($\beta = -0.025$ cm^2/day; 95 % CI –0.030 to –0.020; $p < 0.001$).

Secondary outcomes

A statistically significant effect of time on handgrip strength was observed (Type III fixed-effects test: $F(2, 29.96) = 445.01$; $p < 0.001$). Estimated marginal means were 24.5 kg (95 % CI 21.1–27.8) at T1, 20.0 kg (95 % CI 16.6–23.4) at T2, and 15.5 kg (95 % CI 12.1–18.9) at T3.

The absolute difference in handgrip strength was –4.5 kg between T1 and T2, –4.5 kg between T2 and T3, and –9.0 kg between T1 and T3 (all $p < 0.001$). The relative reduction was 18.4 % between T1 and T2 and 22.5 % between T2 and T3, resulting in a total reduction of 36.7 % between T1 and T3.

Association between ultrasound and CT parameters

In the subgroup of patients with paired CT examinations ($n = 17$), ultrasound-derived changes in rectus femoris CSA showed a moderate positive correlation with CT-derived changes in skeletal muscle area at the L3 vertebral level ($\rho = 0.65$; $p = 0.005$). The median relative reduction in CSA was 14.8 % (IQR 8.9–17.4 %), whereas the median relative reduction in SMA was 18.7 % (IQR 14.1–20.8 %).

Discussion

This study demonstrated a significant reduction in rectus femoris cross-sectional area, assessed by ultrasound, in patients who underwent surgical treatment for severe acute pancreatitis complicated by infected necrosis. During hospitalization, rectus femoris CSA decreased by 20.5 % from baseline, whereas handgrip strength showed a more pronounced decline of 36.7 %.

Considering the magnitude of these changes, the findings should be interpreted in the context of established mechanisms of muscle catabolism in critically ill patients. The results suggest the persistence of a hypercatabolic state despite individualized nutritional support based on patient tolerance throughout the perioperative period, with no evidence of stabilization by the time of hospital discharge. Such progressive reductions in muscle mass and strength may reflect the sustained impact of systemic inflammation, prolonged immobilization, and postoperative metabolic stress.

Comparable patterns have been reported in patients with sepsis and multiple organ dysfunction, in whom rapid declines in muscle thickness or cross-sectional area occur from the early days of intensive care unit admission [19, 22]. However, most available studies involve heterogeneous critically ill populations and do not specifically address the contribution of surgical intervention. In contrast, perioperative changes in skeletal muscle status among patients with severe acute pancreatitis complicated by infected necrosis remain insufficiently investigated.

The discrepancy between the magnitude of structural and functional changes warrants particular attention. These findings suggest that functional impairment is not solely attributable to reductions in muscle mass but may also reflect additional pathophysiological mechanisms. A similar dissociation between morphological and functional parameters has been described in critically ill patients and has been linked to the development of intensive care unit–acquired myopathy and polyneuropathy [9].

In this context, declines in muscle strength may also reflect alterations in muscle quality, impaired neuromuscular transmission, and reduced contractile function of muscle fibers. In the present cohort, further deterioration in handgrip strength was observed at later stages of follow-up, despite less pronounced changes in morphological parameters. This pattern may indicate a dynamic interplay between catabolic processes, neuromuscular dysfunction, and immobilization across different clinical phases of severe acute pancreatitis.

It is important to emphasize that the observed structural and functional changes developed over a relatively short period of hospitalization (median 49 [39–59] days), which is consistent with current understanding of the potential for rapid-onset acute secondary sarcopenia in the context of severe acute illness. Notably, there is currently no consensus in the literature regarding the time frame within which sarcopenia can be attributed to an acute event; reported intervals range from 28 days to 6 months from the onset of the acute pathological process [5].

A distinctive finding in the present cohort of patients with infected necrotizing pancreatitis was that substantial muscle mass loss had already occurred prior to surgical intervention, indicating that surgery was performed in the setting of an established muscle deficit. Subsequent assessments demonstrated further deterioration of these parameters during the postoperative period. Thus, the perioperative course in patients with infected necrotizing pancreatitis appears to be characterized by the combined impact of surgical stress and a persistent hypercatabolic state, which may adversely affect recovery of functional capacity and prolong the rehabilitation process.

In cohorts of patients with acute pancreatitis, most studies have focused on assessing nutritional status and CT-derived indicators of sarcopenia as predictors of disease severity and clinical outcomes [10, 12, 14]. In contrast, the present study employed serial ultrasound assessment of rectus femoris cross-sectional area during hospitalization in the perioperative period among patients with severe acute pancreatitis complicated by infected necrosis.

Unlike previous investigations, this study was designed prospectively, with measurements performed at clinically defined time points. It combined morphological evaluation of skeletal muscle mass using ultrasound with analysis of its association with CT-derived skeletal muscle parameters at the L3 vertebral level and with functional strength measures. This comprehensive approach enhances the robustness of the findings and allows a more detailed characterization of muscle deficit severity in this clinical population.

These observations also highlight the importance of opportunistic screening for reduced muscle mass using existing computed tomography examinations performed for the primary disease [10], which may facilitate early identification of patients at increased risk of developing sarcopenia.

The present findings highlight the importance of early assessment of muscle status as soon as the patient's clinical condition allows. Ultrasound examination enables effective serial bedside monitoring without additional radiation exposure or substantial resource utilization. At the same time,

although several studies have proposed cutoff values for ultrasound-derived muscle mass parameters in specific patient populations [2, 13, 24], their validity and reproducibility in surgical cohorts remain insufficiently established. This limitation complicates the diagnosis of acute secondary sarcopenia, its early detection during hospitalization, and the estimation of its prevalence among critically ill patients with acute pancreatitis.

Despite being conducted at two centers, this study has several limitations, including a relatively small sample size and a clinically homogeneous cohort. The absence of post-discharge functional status assessment precludes evaluation of the long-term clinical impact of the observed muscle deficit, particularly regarding functional recovery, rehabilitation needs, and quality of life.

A formal assessment of intra- and inter-observer reproducibility of ultrasound measurements, including calculation of concordance coefficients, was not performed. In addition, the influence of the volume and composition of nutritional support on muscle mass dynamics was not analyzed, which limits the interpretation of the potential therapeutic effect. These limitations highlight important directions for future research in this clinical population.

Future research should include larger multicenter cohorts to confirm the reproducibility of these findings and improve their external validity. An important direction for further investigation is to evaluate the association between the rate of muscle mass loss and clinically relevant outcomes, such as length of hospital stay, complication rates, need for repeat interventions, and recovery of functional capacity.

Particular attention should be given to determining whether serial ultrasound monitoring of skeletal muscles can be incorporated into risk stratification strategies, individualized nutritional support, and postoperative rehabilitation within existing clinical care pathways. In addition, long-term functional and metabolic consequences of the observed muscle deficits should be investigated, including their impact on quality of life and the risk of recurrent acute pancreatitis.

Conclusions

In this prospective cohort of patients who underwent surgical treatment for severe acute pancreatitis complicated by infected necrosis, serial ultrasound measurements demonstrated a progressive decrease in rectus femoris cross-sectional area during hospitalization. Overall, CSA declined by approximately 20 % from baseline, whereas handgrip strength decreased by nearly 37 %.

The more pronounced reduction in muscle strength may reflect the progression of skeletal muscle dysfunction alongside structural muscle loss or may precede detectable morphological changes. Adverse trends in both functional and morphological parameters were evident prior to surgical intervention and persisted during the postoperative period, suggesting sustained systemic hypercatabolism throughout the clinical course of severe acute pancreatitis.

The findings demonstrated a statistically significant correlation between ultrasound-derived measures of muscle mass and computed tomography–derived skeletal muscle area parameters, supporting the potential feasibility, accessibility, and clinical utility of ultrasound for longitudinal monitoring of muscle status in this clinical population.

Overall, the observed combination of skeletal muscle atrophy and reduced functional capacity may be consistent with the development of acute secondary sarcopenia in the context of severe systemic illness; however, the absence of validated diagnostic cut-off values for this surgical cohort necessitates cautious interpretation of the results. Further investigation of this approach may enable a more precise evaluation of the clinical relevance of serial muscle mass assessment and its potential to optimize nutritional support and rehabilitation strategies.

Declaration of interests

The authors declare that they have no conflicts of interest related to this study, its authorship, or the publication of this article.

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

Ethics approval and written informed consent statements

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment in the study.

References

1. Banks PA, Bollen TL, Dervenis C, Gooszen HG, Johnson CD, Sarr MG, Tsiotos GG, Vege SS; Acute Pancreatitis Classification Working Group. Classification of acute pancreatitis-2012: revision of the Atlanta classification and definitions by international consensus. Gut. 2013 Jan;62(1):102-11. doi: 10.1136/gutjnl-2012-302779. Epub 2012 Oct 25. PMID: 23100216.

2. Baş S, Çoban HH, Doğan A, Erölmez HN, Mutlu HH, İlhan N. Towards Rapid Bedside Detection of Sarcopenia in Cancer Patients: The Role of Rectus Femoris Muscle Ultrasonography-A Prospective Cross-Sectional Study. Medicina (Kaunas). 2026 Feb 21;62(2):413. doi: 10.3390/medicina62020413. PMID: 41752811; PMCID: PMC12941887.
3. Bender F, Marzeion L, Liese J, Hecker M, Wolff M, König T, Willis F, Thevenet IP, Tuffs C, Brose A, Pons-Kühnemann J, Padberg W, Hecker A, Strowitzki MJ. Sarcopenia is associated with an unfavorable outcome in patients with acute pancreatitis: A propensity score analysis. Dig Liver Dis. 2026 Jan;58(1):96-103. doi: 10.1016/j.dld.2025.10.013. Epub 2025 Nov 4. PMID: 41193276.
4. Boxhoorn L, Voermans RP, Bouwense SA, Bruno MJ, Verdonk RC, Boermeester MA, van Santvoort HC, Besselink MG. Acute pancreatitis. Lancet. 2020 Sep 5;396(10252):726-734. doi: 10.1016/S0140-6736(20)31310-6. Erratum in: Lancet. 2021 Nov 6;398(10312):1686. doi: 10.1016/S0140-6736(21)02377-1. PMID: 32891214.
5. Damanti S, Senini E, De Lorenzo R, Merolla A, Santoro S, Festorazzi C, Messina M, Vitali G, Sciorati C, Rovere-Querini P. Acute Sarcopenia: Mechanisms and Management. Nutrients. 2024 Oct 10;16(20):3428. doi: 10.3390/nu16203428. PMID: 39458423; PMCID: PMC11510680.
6. E Lima KM, da Matta TT, de Oliveira LF. Reliability of the rectus femoris muscle cross-sectional area measurements by ultrasonography. Clin Physiol Funct Imaging. 2012 May;32(3):221-6. doi: 10.1111/j.1475-097X.2011.01115.x. Epub 2012 Jan 24. PMID: 22487157.
7. Farquhar R, Matthews S, Baxter N, Rayers G, Ratnayake CBB, Robertson FP, Nandhra S, Lim WB, Witham M, Pandanaboyana S. Sarcopenia and Sarcopenic Obesity on Body Composition Analysis is a Significant Predictor of Mortality in Severe Acute Pancreatitis: A Longitudinal Observational Study. World J Surg. 2023 Nov;47(11):2825-2833. doi: 10.1007/s00268-023-07122-1. Epub 2023 Aug 4. PMID: 37541981; PMCID: PMC10545625.
8. Fazzini B, Märkl T, Costas C, Blobner M, Schaller SJ, Prowle J, Puthucheary Z, Wackerhage H. The rate and assessment of muscle wasting during critical illness: a systematic review and meta-analysis. Crit Care. 2023 Jan 3;27(1):2. doi: 10.1186/s13054-022-04253-0. PMID: 36597123; PMCID: PMC9808763.
9. Hermans G, Van den Berghe G. Clinical review: intensive care unit acquired weakness. Crit Care. 2015 Aug 5;19(1):274. doi: 10.1186/s13054-015-0993-7. PMID: 26242743; PMCID: PMC4526175.
10. Kolck J, Hosse C, Leimbach A, Beetz NL, Auer TA, Collettini F, Fehrenbach U, Pille C, Geisel D. Opportunistic screening for long-term muscle wasting in critically ill patients: insights from an acute pancreatitis cohort. Eur J Med Res. 2024 May 22;29(1):294. doi: 10.1186/s40001-024-01884-7. PMID: 38778361; PMCID: PMC11110383.
11. Leppäniemi A, Tolonen M, Tarasconi A, Segovia-Lohse H, Gamberini E, Kirkpatrick AW, Ball CG, Parry N, Sartelli M, Wolbrink D, van Goor H, Baiocchi G, Ansaloni L, Biffl W, Coccolini F, Di Saverio S, Kluger Y, Moore E, Catena F. 2019 WSES guidelines for the management of severe acute pancreatitis. World J Emerg Surg. 2019 Jun 13;14:27. doi: 10.1186/s13017-019-0247-0. PMID: 31210778; PMCID: PMC6567462.
12. Li P, Xing Q, Wang L, Shi J, Zhang YX, Fu H. The Individual and Joint Associations of Sarcopenic Obesity and Malnutrition on Predicting the Severity of Acute Pancreatitis. Int J Gen Med. 2025 Aug 30;18:4941-4955. doi: 10.2147/IJGM.S540037. PMID: 40909911; PMCID: PMC12407009.
13. Li S, Xu K, Wang A, Qin C, Hua N, Ling X, Xu L, He C, Zhou S, Chen J, Zhang Q, Yang Y. Determination of Ultrasound Reference Values for Diagnosing Low Muscle Mass in Older Chinese Adults. J Cachexia Sarcopenia Muscle. 2025 Dec;16(6):e70155. doi: 10.1002/jcsm.70155. Erratum in: J Cachexia Sarcopenia Muscle. 2026;17(1):e20012. doi: 10.1002/jcsm.70224. PMID: 41362106; PMCID: PMC12686591.
14. Lin C, Zhang J, Wang C, Lian W, Liu Y. The impact of skeletal muscle index at the third lumbar spine on nosocomial deterioration and short-term prognosis in acute pancreatitis: a retrospective observational study. PeerJ. 2024 Apr 30;12:e17283. doi: 10.7717/peerj.17283. PMID: 38708354; PMCID: PMC11067894.
15. Mourtzakis M, Prado CM, Lieffers JR, Reiman T, McCargar LJ, Baracos VE. A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care. Appl Physiol Nutr Metab. 2008 Oct;33(5):997-1006. doi: 10.1139/H08-075. PMID: 18923576.
16. Mourtzakis M, Wischmeyer P. Bedside ultrasound measurement of skeletal muscle. Curr Opin Clin Nutr Metab Care. 2014 Sep;17(5):389-95. doi: 10.1097/MCO.0000000000000088. PMID: 25023190.
17. Nagae M, Umegaki H, Yoshiko A, Fujita K. Muscle ultrasound and its application to point-of-care ultrasonography: a narrative review. Ann Med. 2023 Dec;55(1):190-197. doi: 10.1080/07853890.2022.2157871. PMID: 36538042; PMCID: PMC9788691.
18. Prado CM, Lieffers JR, McCargar LJ, Reiman T, Sawyer MB, Martin L, Baracos VE. Prevalence and clinical implications of sarcopenic obesity in patients with solid tumours of the respiratory and gastrointestinal tracts: a population-based study. Lancet Oncol. 2008 Jul;9(7):629-35. doi: 10.1016/S1470-2045(08)70153-0. Epub 2008 Jun 6. PMID: 18539529.
19. Puthucheary ZA, Rawal J, McPhail M, Connolly B, Ratnayake G, Chan P, Hopkinson NS, Phadke R, Dew T, Sidhu PS, Velloso C, Seymour J, Agley CC, Selby A, Limb M, Edwards LM, Smith K, Rowlerson A, Rennie MJ, Moxham J, Harridge SD, Hart N, Montgomery HE. Acute skeletal muscle wasting in critical illness. JAMA. 2013 Oct 16;310(15):1591-600. doi: 10.1001/jama.2013.278481. Erratum in: JAMA. 2014 Feb 12;311(6):625. Padhke, Rahul [corrected to Phadke, Rahul]. PMID: 24108501.
20. Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H, Cooper C, Sayer AA. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. Age Ageing. 2011 Jul;40(4):423-9. doi: 10.1093/ageing/afr051. Epub 2011 May 30. PMID: 21624928.
21. Tillquist M, Kutsogiannis DJ, Wischmeyer PE, Kummerlen C, Leung R, Stollery D, Karvellas CJ, Preiser JC, Bird N, Kozar R, Heyland DK. Bedside ultrasound is a practical and reliable measurement tool for assessing quadriceps muscle layer thickness. JPEN J Parenter Enteral Nutr. 2014 Sep;38(7):886-90. doi: 10.1177/0148607113501327. Epub 2013 Aug 26. PMID: 23980134; PMCID: PMC4502435.
22. Turton P, Hay R, Taylor J, McPhee J, Welters I. Human limb skeletal muscle wasting and architectural remodeling during five to ten days intubation and ventilation in critical care – an observational study using ultrasound. BMC Anesthesiol. 2016 Nov 29;16(1):119. doi: 10.1186/s12871-016-0269-z. PMID: 27894277; PMCID: PMC5127036.
23. Van Santvoort HC, Besselink MG, Bakker OJ, Hofker HS, Boermeester MA, Dejong CH, van Goor H, Schaapherder AF, van Eijck CH, Bollen TL, van Ramshorst B, Nieuwenhuijs VB, Timmer R, Laméris JS, Kruyt PM, Manusama ER, van der Harst E, van der Schelling GP, Karsten T, Hesselink EJ, van Laarhoven CJ, Rosman C, Bosscha K, de Wit RJ, Houdijk AP, van Leeuwen MS, Buskens E, Gooszen HG; Dutch Pancreatitis Study Group. A step-up approach or open necrosectomy for necrotizing pancreatitis. N Engl J Med. 2010 Apr 22;362(16):1491-502. doi: 10.1056/NEJMoa0908821. PMID: 20410514.
24. Yik V, Kok SSX, Chean E, Lam YE, Chua WT, Tan WJ, Foo FJ, Ng JL, Su SS, Chong CX, Aw DK, Khoo NAX, Wischmeyer PE, Molinger J, Wong S, Ong LW, Koh FH. Diagnosing Sarcopenia with AI-Aided Ultrasound (DINOSAUR)-A Pilot Study. Nutrients. 2024 Aug 20;16(16):2768. doi: 10.3390/nu16162768. PMID: 39203903; PMCID: PMC11357450.

Гостра втрата скелетної м'язової маси в пацієнтів, прооперованих із приводу тяжкого інфікованого некротичного панкреатиту: поздовжнє ультразвукове дослідження

В. Тетеріна

Національний медичний університет імені О. О. Богомольця, Київ

Мета — оцінити періопераційну динаміку ультразвукових показників м'язової маси на прикладі площі поперечного перерізу m. rectus femoris у пацієнтів, яким виконано хірургічне лікування з приводу тяжкого гострого панкреатиту, ускладненого інфікованим некрозом, а також дослідити супутні функціональні зміни та взаємозв'язок ультразвукових показників із параметрами м'язової маси за даними комп'ютерної томографії.

Матеріали та методи. У проспективне обсерваційне дослідження в двох клінічних центрах було залучено 28 пацієнтів віком 19—59 років, прооперованих з приводу інфікованого некротичного панкреатиту. Медіана тривалості госпіталізації становила 49 (39—59) днів. Виконано серійну оцінку площі поперечного перерізу (CSA) m. rectus femoris із використанням портативного ультразвукового пристрою з бездротовим високочастотним лінійним датчиком, а також оцінку сили стискання кисті методом динамометрії в трьох клінічно визначених часових точках (T1, T2, T3). Серійні вимірювання проводили в клінічно визначені часові точки, що відображували динаміку періопераційного перебігу тяжкого гострого панкреатиту: перше обстеження виконували на 8-й (6—10-й) день госпіталізації, друге — на 29-й (26—31-й) день. У підгрупі з 17 пацієнтів із наявними парними комп'ютерними томограмами оцінювали площу скелетних м'язів (SMA) на рівні L3 та проаналізували асоціацію змін ультразвукових параметрів і результатів комп'ютерної томографії за допомогою коефіцієнта кореляції Спірмена. Для оцінки динаміки показників скелетних м'язів використовували лінійні моделі змішаних ефектів.

Результати. Установлено статистично значуще ($p < 0{,}001$) прогресивне зменшення CSA m. rectus femoris протягом періоду спостереження. Сумарне відносне зниження CSA між T1 і T3 становило 20,5 %. Моделювання тривалості госпіталізації як безперервної змінної підтвердило незалежну асоціацію зменшення CSA з часом ($\beta = -0{,}025$ см^2/добу, $p < 0{,}001$). Зниження сили стискання кисті було виразнішим ($p < 0{,}001$), із сумарним відносним зменшенням 36,7 % між T1 і T3. У підгрупі пацієнтів із парними комп'ютерними томограмами зміни CSA за даними ультразвукового дослідження демонстрували помірну позитивну кореляцію зі змінами SMA на рівні L3 ($\rho = 0{,}65$; $p = 0{,}005$), що підтверджує узгодженість результатів обох методів.

Висновки. У пацієнтів, прооперованих з приводу інфікованого некротичного панкреатиту, спостерігалося прогресивне погіршення морфологічних і функціональних показників скелетних м'язів протягом періоду госпіталізації. Виразніше зниження показників м'язової сили порівняно зі змінами ультразвукових параметрів м'язової маси може відображувати асинхронну динаміку функціональних і морфологічних змін скелетних м'язів при тяжкому гострому панкреатиті, ускладненому інфікованим некрозом. Отримані результати обґрунтовують клінічну доцільність поєднаної морфологічної та функціональної оцінки м'язового статусу для своєчасного виявлення гострої вторинної саркопенії та оптимізації нутритивних і реабілітаційних втручань у цій популяції.

Ключові слова: виснаження скелетних м'язів, гостра саркопенія, ультразвукове дослідження м'язів, тяжкий гострий панкреатит, інфікований панкреонекроз, критичний стан, катаболізм.

FOR CITATION

Teterina V. Acute skeletal muscle loss in surgically treated patients with severe infected necrotizing pancreatitis: a longitudinal ultrasound study. General Surgery (Ukraine). 2026;(1);16-24. http://doi.org/10.30978/GS-2026-1-16.