Measuring visceral fat, subcutaneous fat and skeletal muscle area changes by computed tomography in acute pancreatitis: a retrospective, single-centre study

David J Brewster, Boyd J G Strauss and Timothy M Crozier

ABSTRACT

Objective: To show that body composition of intensive care unit patients can be analysed with existing computed tomography (CT) images. We planned to describe changes in visceral fat area (VFA), subcutaneous fat area (SFA) and muscle area (MA) on analysis of specific CT images during acute pancreatitis requiring an ICU admission.

Design, setting and participants: Retrospective analysis of body composition using existing CT images, in an ICU of a tertiary university-affiliated hospital 2005–2010, examining 21 patients with acute pancreatitis and CT imaging on two separate occasions within their hospital admission.

Main outcome measures: VFA, SFA, VFA:SFA ratio and MA. Medical records were hand searched to identify ICU and hospital mortalities and other clinical outcomes.

Results: Three women and 18 men had 84 CT scans analysed, from the level of the right renal hilum and L3 vertebra. The median patient age was 52 years. The median time between CT scans was 9.4 days and the mean Acute Physiology and Chronic Health Evaluation II score was 20.2. ICU mortality was 9%. Analysis showed a decrease in VFA from a median of 229.2 cm^2 to 202.1 cm^2 ($P < 0.01$) and a decrease in VFA:SFA ratio from a median of 1.20 to 1.05 ($P < 0.01$) during the acute illness. MA did not change significantly.

Conclusions: The body composition of ICU patients can be analysed through existing CT images. Pancreatitis requiring ICU admission causes a 12% decrease in VFA.

Crit Care Resusc 2014; 16: 42–47

We aimed to show that body composition of intensive care unit patients can be analysed through the use of existing computed tomography (CT) images. There has been much recent interest in body composition changes that occur in patients requiring ICU admission.[1,2] Long-stay ICU patients are known to develop muscle weakness and wasting,[2-4] and recent articles show that efforts are being made to preserve muscle mass in ICU patients.[5] Loss of weight, from catabolic illnesses and interrupted feeding practices,[6] can lead to added morbidity and mortality in many illnesses.[7,8] Visceral fat has been shown to be a strong predictor of mortality.[9] A reliable method for measuring changes in body composition may be able to effectively guide future research, looking at interventions that may affect clinical end points and thus patient care.

It has recently been reported that ultrasound can be used for bedside analysis of visceral and subcutaneous fat in patients with abdominal obesity,[10] highlighting that interest in radiological quantification of body composition changes in hospital patients may be growing. Recent articles have suggested that measuring body composition in ICU patients may help guide their treatment.[1]

Measurement of body composition in the critically unwell patient population has rarely been reported. Traditionally, technology for measuring body composition has not been widely used in intensive care medicine. Bioelectrical impedance may be too water dependent,[11] anthropometry (skinfold measurements) is often not reproducible and does not accurately estimate change in muscle mass,[12] and dual energy x-ray absorbtiometry scans would require difficult transportation of acutely unwell patients.

The development of reliable software, such as SliceOmatic 4.3 (Tomovision), means that single cross-sectional images from CT scans can be used to analyse a patient's body composition.[13] SliceOmatic software analysis of a single slice image at 10 cm above the L4–L5 vertebral level has been shown to best correlate with accurate measurement of visceral fat. Sex, age, body mass index and body position have little effect on accuracy.[13]

Measurement of muscle mass has been shown to be possible in a non-intensive care cohort of patients using the same software technology and CT imaging we used for our study.[14] Measurements for that study occurred in cancer patients, for whom the catabolic state may induce similar body composition changes to that of severe acute illnesses, such as pancreatitis. The authors showed skeletal muscle wasting is a prominent feature of patients with lung cancer, despite normal or heavy body weights.[14]

Ovid and Medline searches of "visceral fat" and "body composition", paired with "acute illness", "acute pancreatitis" or "intensive care", failed to reveal any previously published studies on body composition changes in the ICU population.

Table 1. Inclusion criteria for analysis of patients with acute pancreatitis

- Admission to the intensive care unit between 2005 and 2010 with a primary diagnosis of pancreatitis
- Serum lipase level > 160 U/L clinically attributed to pancreatitis, or computed tomography (CT) changes reported as consistent with pancreatitis
- CT imaging on two separate occasions from ICU admission

We investigated the hypothesis that the body composition of ICU patients can be analysed using existing CT images. In doing so, we also aimed to describe the changes in visceral fat area (VFA), subcutaneous fat area (SFA) and muscle area (MA) on analysis of specific CT images. This study was recognised as a project of quality assurance by the Southern Health Human Research Ethics Committee. This waived the requirement for informed consent.

Methods

We performed a retrospective analysis of 21 patients admitted to the Monash Medical Centre ICU with the diagnosis of acute pancreatitis between 2005 and 2010. These patients were identified through the ICU admissions database. We analysed CT images from studies that had already been performed during each patient's acute illness, as deemed appropriate for their clinical care.

For inclusion, each patient required two separate abdominal CT scans during their acute illness, and a diagnosis of pancreatitis (Table 1). These CT images were de-identified for an observer-blinded analysis of VFA, SFA, VFA:SFA ratios and MA.

A radiologist identified the CT slice through the right renal hilum. This image was chosen from each scan to be analysed for VFA, SFA and VFA:SFA ratios. This was in keeping with recent evidence for the most accurate level for analysis of VFA.[13] This led to 42 images being analysed at this level (a pair of images for each of 21 patients).

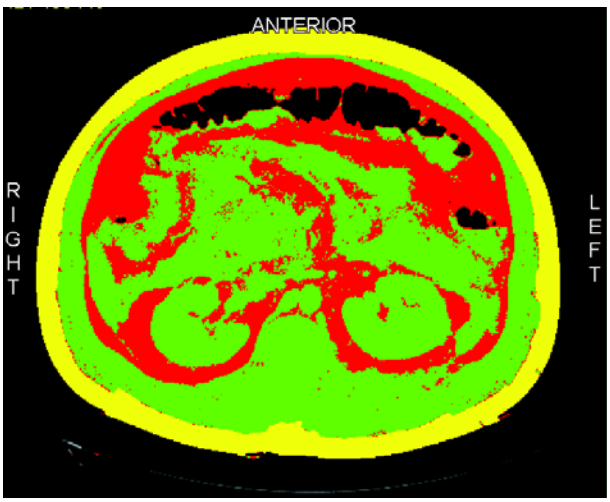
In addition, 42 different cross-sectional CT slices through the L3 vertebra were chosen to analyse the MA, consistent with other recent publications of CT analysis of MA.[15,16] Analysis at this level has been shown to correlate well with total body fat-free mass (FFM), calculated from a previously published formula:[16]

FFM (in kg) = 0.3 x (MA at L3) + 6.06; $r = 0.94$, $P < 0.001$

Digital Imaging and Communications in Medicine images from Centricity RA1000 were imported and analysed for body composition using SliceOmatic 4.3. Hounsfield unit (HU) ranges were used to differentiate between components of body composition on the images. Tissue from – 30 to – 190 HU was segmented as fat, and tissue from – 30 to 150 HU was segmented as muscle. This was in keeping with previously published articles.[16,17]

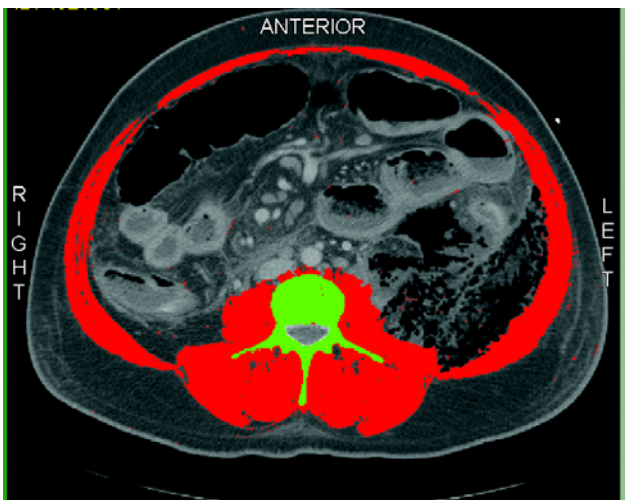
As with previous studies, fat inside the abdominal muscle layer was then differently segmented as visceral fat, and fat outside the abdominal muscle wall was considered as subcutaneous fat. Any fat inside muscle was segmented as muscle. VFA, SFA and MA were then calculated from the sum of pixel areas for the relevant segments (Figure 1 and Figure 2). A single, experienced observer (B S) performed all SliceOmatic segmentations. The intraobserver coefficient of variance, performed on 10 randomly selected images, was 0.2% for SFA and 0.7% for VFA.

Figure 1. Visceral and subcutaneous fat area analysis



Red = visceral fat area. Yellow = subcutaneous fat area.

Figure 2. Muscle area analysis



Red = muscle area.

Table 2. Clinical definitions of complications in patients with acute pancreatitis

- Acute renal injury: an acute rise in serum creatinine to > double the patient's baseline result[18]
- Acute lung injury: PaO_2:FiO_2 < 300, where PaO_2 is measured in mmHg and FiO_2 is in the range 0.21–1
- Sepsis and systemic inflammatory response syndrome, two of the following criteria:
  - leukocytes > 11 x 10^9 cells/L or < 4 x 10^9 cells/L
  - temperature > 38°C or < 36°C
  - heart rate > 90 beats per minute
  - respiratory rate > 20 breaths per minute[19]
- Anaemia: Haemoglobin < 90 g/L or clinical need for blood transfusion

Table 3. Demographics of patients with acute pancreatitis (*N* = 21)

Characteristic	Data
Men, *n* (%)	18 (86%)
Women, *n* (%)	3 (14%)
Median age, years (IQR)	52 (47–68)
Alcohol aetiology of pancreatitis, *n* (%)	6 (29%)
Other aetiology of pancreatitis, *n* (%)	15 (71%)
Mean APACHE II score	20.2
Mean APACHE III score	76.1
Mean peak lipase level, U/L	4840.3
Median time between CT scans, days (IQR)	9.4 (7–19.2)
Median time in ICU, days (IQR)	7 (4–23)
ICU mortality, *n* (%)	2 (9%)
Hospital mortality, *n* (%)	5 (24%)
Need for mechanical ventilation, *n* (%)	16 (76%)
Acute renal injury, *n* (%)	11 (52%)
Need for insulin, *n* (%)	15 (71%)
Supplementary EN between CT scans, *n* (%)	3 (14%)
Supplementary PN between CT scans, *n* (%)	13 (62%)
Nil feeding between CT scans, *n* (%)	1 (5%)
Need for laparotomy, *n* (%)	7 (33%)
Acute lung injury, *n* (%)	12 (57%)
Episode of sepsis, *n* (%)	19 (86%)
Episode of anaemia, *n* (%)	14 (67%)
History of alcohol misuse, *n* (%)	6 (29%)
History of obesity, *n* (%)	4 (19%)
History of hyperlipidaemia, *n* (%)	4 (19%)

IQR = interquartile range. APACHE = Acute Physiology and Chronic Health Evaluation. ICU = intensive care unit. CT = computed tomography. EN = enteral nutrition. PN = parenteral nutrition.

Table 4. Body composition of patients with acute pancreatitis

Body composition variable	Initial measure (IQR)	Final measure (IQR)	Change in measure*	*P*
Median VFA, cm^2	229.2 (136.5–276.7)	202.1 (132.5–276)	0.88	< 0.01
Median SFA, cm^2	172.7 (110.7–246.3)	163.5 (116.5–254.2)	0.95	0.81
Median VFA:SFA ratio	1.20 (0.86–1.86)	1.05 (0.88–1.62)	0.88	< 0.01
Median MA, cm^2	167.8 (144.2–203.7)	167.5 (130.5–188.7)	1	0.19

VFA = visceral fat area. IQR = interquartile range. SFA = subcutaneous fat area. MA = muscle area. * Final measure ÷ initial measure.

Each patient's medical record was hand-searched by one of us (D B) and the following data extracted: ICU and hospital mortality, need for mechanical ventilation, acute renal injury, the need for supplementary intravenous insulin and laparotomy, acute lung injury, systemic inflammatory response syndrome and sepsis, type of feeding between CT scans, episodes of anaemia, and history of alcohol misuse, hypercholesterolaemia and obesity. Table 2 shows our definitions for these complications of acute pancreatitis.

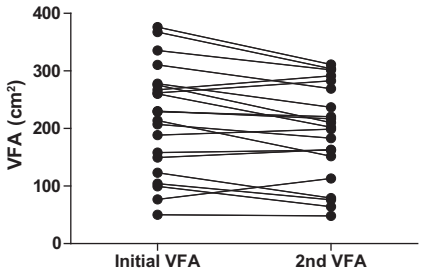
Statistical analysis

Descriptive statistics (medians and interquartile ranges [IQRs]) were generated for each body composition variable. A power calculation was performed to determine the number of patients needed to find a statistically significant change in VFA of 10%, with 80% power at $P < 0.05$. This showed a need to study 18 patients. Each patient had initial and final body composition parameters measured. This allowed us to compare changes in the body composition variables during their acute illness, using a Wilcoxon matched-pairs signed rank analysis. Patients were divided into two groups: those for whom VFA decreased versus those for whom VFA did not. These data were analysed using the Fisher exact test to see if VFA decrease was associated with a clinical outcome based on mortality and morbidity end points. Prism version 5.04 (GraphPad) software was used for all statistical calculations.

Results

Twenty-seven patients were screened for inclusion in the study, based on their ICU admission diagnosis of "pancreatitis" between 2005 and 2010. Six patients were excluded as their images were obtained from older software and were not able to be imported successfully into the SliceOmatic 4.3 program for analysis.

Figure 3. Change in visceral fat area (VFA) in intensive care unit patients with acute pancreatitis, from computed tomography (CT) (*n* = 21)

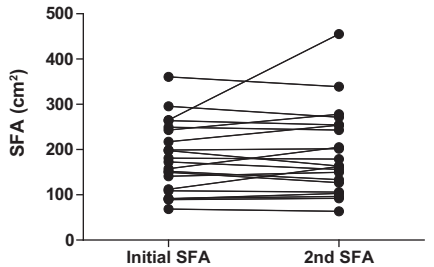


	Initial VFA	2nd VFA
25% percentile	136.5	132.5
Median	229.2	202.1
75% percentile	276.7	276.0

Wilcoxon matched-pairs signed rank test	
P	0.0101
Exact or approximate *P*-value?	Gaussian approximation
P-value summary	*

* A significant reduction in VFA is shown from the initial CT image to the subsequent CT image.

Figure 4. Change in subcutaneous fat area (SFA) in intensive care unit patients with acute pancreatitis, from computed tomography (*n* = 21)

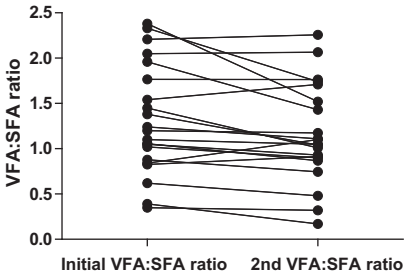


	Initial SFA	2nd SFA
25% percentile	110.7	116.5
Median	172.7	163.5
75% percentile	246.3	254.2

Wilcoxon matched-pairs signed rank test	
P	0.8078
Exact or approximate *P*-value?	Gaussian approximation
P-value summary	ns

ns = not significant.

Figure 5. Change in visceral fat area: subcutaneous fat area (VFA:SFA) ratio in intensive care unit patients with acute pancreatitis, from computed tomography (CT) (*n* = 21)

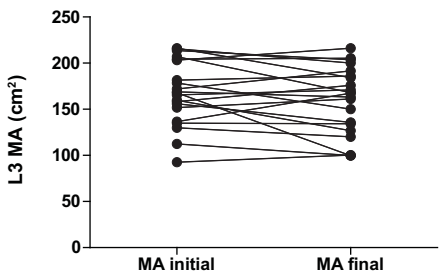


	Initial VFA:SFA ratio	2nd VFA:SFA ratio
25% percentile	0.8595	0.8840
Median	1.199	1.050
75% percentile	1.863	1.615

Wilcoxon matched-pairs signed rank test	
P	0.0136
Exact or approximate *P*-value?	Gaussian approximation
P-value summary	*

* A significant reduction in VFA:SFA ratio is shown from the initial CT image to the subsequent CT image.

Figure 6. Change in muscle area (MA), at level of L3 vertebra, in intensive care unit patients with acute pancreatitis, from computed tomography (CT) (*n* = 21)



	MA initial	MA final
25% percentile	144.2	130.5
Median	167.8	167.5
75% percentile	203.7	188.7

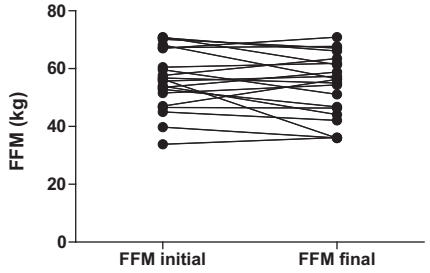
Wilcoxon matched-pairs signed rank test	
P	0.1866
Exact or approximate *P*-value?	Gaussian approximation
P-value summary	ns

ns = not significant.

Analysis of the medical records allowed us to describe pre-existing patient demographics and mortality and morbidity end points of illnesses (Table 3).

Twenty-one patients (three women and 18 men) had a total of 42 CT scans analysed at two body levels (the right renal hilum and L3 vertebra), resulting in 84 images to be analysed. There was a statistically significant decrease of 12% in VFA ($P < 0.01$) and VFA:SFA ratio ($P < 0.01$) (Table 4, Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7). There were no significant clinical outcomes associated with a VFA decrease, as shown in Table 5.

Figure 7. Change in fat-free mass (FFM) in intensive care unit patients with acute pancreatitis ($n = 21$)



	FFM initial	FFM final
25% percentile	49.32	45.21
Median	56.40	56.31
75% percentile	67.16	62.68

Wilcoxon matched-pairs signed rank test	
P	0.1866
Exact or approximate *P*-value?	Gaussian approximation
P-value summary	ns

ns = not significant.

Discussion

Our methodology was an opportunity to describe body composition changes in ICU patients without additional transportation or imaging. We showed a significant reduction in visceral fat of 12% over 9 days between CT scans during the first 2 weeks of acute pancreatitis requiring an ICU admission. These were substantial changes, although their overall significance is unknown. This methodology currently merely offers a more accurate and quantitative method for body composition analysis than the alternative of bedside clinical examination. However, having an accurate measure of body composition may benefit ICU doctors in the future. Access to a reliable, non-invasive and accessible tool for measuring these changes may guide future research into the significance of our findings. Further research is also needed to demonstrate that body composition analysis itself can provide benefit in guiding clinical interventions such as nutritional support within the ICU.

Pancreatitis is known to lead to prolonged ICU admission[20] and patients who have long ICU admissions often require multiple CT scans. Patients with pancreatitis were chosen for this study as they were likely to have had multiple CT scans available for our analysis. A similar analysis could be done on other ICU patient groups, such as trauma patients. It would be interesting to compare two or more different diagnostic groups.

Changes in MA are of interest during prolonged hospital and/or ICU admission. MA diminishes in patients with chronic cancer and cachexia,[14] but did not change in our retrospective analysis of patients with acute pancreatitis.

Table 5. Change in VFA and clinical outcome for acute pancreatitis (χ^2 analysis between outcomes) ($N = 15$)

End point	VFA decrease	VFA stable	*P*
ICU mortality	1 (7%)	1 (17%)	ns
Hospital mortality	3 (20%)	2 (33%)	ns
Mechanical ventilation	12 (80%)	4 (67%)	ns
Acute renal injury	8 (53%)	2 (50%)	ns
Insulin	11 (73%)	4 (67%)	ns
Laparotomy	4 (27%)	3 (50%)	ns
Acute lung injury	8 (53%)	4 (67%)	ns
Sepsis	14 (93%)	5 (83%)	ns
Anaemia	10 (67%)	5 (83%)	ns

VFA = visceral fat area. ICU = intensive care unit. ns = not significant.

Patients with chronic cancer may have already lost visceral fat in an earlier attempt to spare muscle loss. Within our study population, excessive visceral fat may have been protective. Our study included four patients with a documented history of obesity. They all demonstrated a loss of visceral fat and survived to hospital discharge.

We were unable to show a loss of MA in our patients, which may have been due to limitations in our study. For instance, loss of muscle would likely take longer than the median of 9.4 days between the CT scans performed for our patients. A prospective study of patients who have longer acute illnesses may show this change in body composition. Imaging 2 to 3 months from admission may show a significant loss of MA. A larger study may also help answer some of our questions.

We did not show a change in morbidity or mortality as a result of visceral fat loss. It is currently unclear whether this process is protective or detrimental to a patient's clinical course. We showed an accurate method to describe body composition changes in an acutely unwell ICU patient population. Further work should focus on expanding this application to other groups of critically ill patients, as well as looking at larger patient numbers and longer time frames.

Conclusions

Body composition of an ICU patient can be analysed through the use of existing CT images. We studied a group of patients requiring ICU admission for acute pancreatitis. There was a statistically significant decrease in VFA, with a median reduction of 12% ($P < 0.01$) over the initial 2 weeks of illness. There was no significant loss of MA. The change in VFA:SFA ratio did not have an effect on the clinical outcomes measured in our study, and further research is required.

Competing interests

None declared.

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