

CT of Hip Fracture Patients:

Muscle Size and Attenuation Helps Predict Mortality

Abstract

OBJECTIVE. Our objective was to determine the association between muscle cross-sectional area and attenuation, measured on routine CT scans, and mortality in older hip fracture patients.

MATERIALS AND METHODS. Retrospective 10-year study of hip fracture patients with the following inclusion criteria: age \geq 65 years, first-time hip fracture treated with surgery, and CT of the chest, abdomen, or pelvis. This yielded 274 patients (70% women; age 81.3 ± 8.3 years). On each CT scan, two readers independently measured the size (cross-sectional area, indexed for patient height) and attenuation of the paravertebral muscle at T12 and the psoas muscle at L4. We then determined the association between overall mortality and the muscle size and muscle attenuation, while adjusting for demographic variables (age, gender, ethnicity, body mass index), American Society of Anesthesiologists (ASA) classification, and Charlson Comorbidity Index (CCI).

RESULTS. Overall mortality increased from 28% at 1 year to 80% at 5 years. Mortality was associated with decreased thoracic muscle size (OR, 0.66; 95% CI, 0.49-0.87). This association persisted after adjusting for demographic variables (OR, 0.69; CI, 0.50-0.95), the ASA classification (OR, 0.70; CI, 0.51-0.97), and the CCI (OR, 0.72; CI, 0.52-1.00). Similarly, decreased survival was associated with decreased thoracic muscle attenuation after adjusting for all of these combinations of covariates (OR, 0.67-0.72; CI, 0.49-0.99). Decreased lumbar muscle size and attenuation trended with decreased survival, but did not reach statistical significance.

CONCLUSION. In older adults with hip fractures, CT findings of decreased thoracic paravertebral muscle size and attenuation are associated with decreased overall survival.

Keywords: computed tomography, hip fracture, mortality, muscle, sarcopenia

Sarcopenia – broadly defined as significant loss of muscle mass and function [1] – is recognized as a growing epidemic in rapidly aging populations worldwide [2]. The public health implications of sarcopenia include physical disability [3], falls [4], prolonged hospitalization [5], and the associated health care costs [6]. Various approaches to diagnosing sarcopenia have included functional muscle testing and imaging, including dual x-ray absorptiometry (DXA), ultrasound, magnetic resonance imaging (MRI), and computed tomography (CT) [1]. In non-orthopaedic patients, CT measurements of muscle size and attenuation have been associated with post-operative complications and premature death [7-10].

The association between sarcopenia and decreased survival has been studied most extensively in patients with various forms of cancer, who may be uniquely affected by cancer cachexia and toxicity from chemotherapy [1,11]. However, little is known about any association between sarcopenia and overall survival in patients with osteoporotic hip fractures – even though the mortality rates among elderly patients with hip fractures are higher than for many forms of cancer (e.g., breast cancer) [12]. After hip fracture, the 1-year mortality rates are generally 20% to 30% [13-15], but reportedly can range widely from 14% to 36% [16]. In hip fracture patients, increased mortality has been associated with increased age, male gender, and increased number of comorbidities [15-16].

Importantly, patient prognosis may influence surgical decision making. For example, in patients with a favorable life expectancy, treatment of displaced femoral neck fractures with total hip arthroplasty rather than hemiarthroplasty may be indicated, resulting in lower reoperation rates, better hip function, and better quality of life [8]. Unfortunately, there are currently no accepted objective CT findings that would help the orthopaedic surgeon assess frailty and determine prognosis. Although physicians have traditionally assessed prognosis subjectively based on their clinical experience, such an assessment may be subject to personal biases, lack scientifically proven methodology, and have low

reproducibility [9-10]. Furthermore, risk stratification has become a major priority in medicine because of the growing emphasis on healthcare safety, quality, and cost effectiveness (e.g., pay-for-performance models of reimbursement) [17]. Mortality rates associated with hip fractures are now widely tracked as an important indicator of inpatient quality of care [18].

More than 78 million CT scans are performed annually in the USA alone [19]. In elderly patients after a ground level fall, CT examinations are sometimes obtained to evaluate for radiographically-occult fracture, assess a fracture for pre-operative planning, or evaluate for other contemporaneous conditions that commonly occur with various medical comorbidities. Previous studies have validated CT measurement of muscle size as a biomarker for muscle atrophy [20] and muscle attenuation as a biomarker for muscle fatty infiltration [21] which could be useful in diagnosing sarcopenia. However, these CT measurements have not been used in hip fracture patients to opportunistically evaluate for sarcopenia.

We hypothesized that CT findings of sarcopenia are associated with increased mortality in older patients with hip fracture. Our specific objectives were to determine (1) whether muscle cross-sectional area and muscle attenuation are associated with clinical outcomes and (2) whether CT measurements are associated with survival, beyond established risk factors such as patient demographics, the American Society of Anesthesiologists (ASA) classification, and the Charlson Comorbidity Index (CCI).

MATERIALS AND METHODS

Patients and Study Design

After institutional review board approval with waiver of informed consent, we performed a retrospective study at a large academic medical center by searching both the electronic medical record and the picture archiving and communication system (PACS) for all patients who met the following three inclusion criteria: (a) patient age \geq 65 years with a low-energy injury (e.g., fall from standing position) between March 1, 2005 and February 28, 2015; (b) first-time hip fracture treated with surgery by one of four board-certified orthopaedic surgeons; and (c) diagnostic CT examination of the chest, abdomen, or pelvis. This yielded 274 patients. (In 258 of the 274 patients, surgery was performed in < 3 days, with surgery delayed for up to one week in the remaining 16 patients owing to comorbidities requiring medical optimization.) No cases met our pre-defined exclusion criteria of belonging to a vulnerable population (e.g., imprisoned) or exhibiting postoperative changes at the regions of interest (e.g., metallic artifact from spinal instrumentation).

Using the electronic medical record entry at the time of hospitalization, three categories of medical data were collected: (1) demographics (gender, age, ethnicity, body mass index (BMI), ASA physical status classification [22], and CCI score [23]); (2) proximal femoral fracture location (neck, intertrochanteric, subtrochanteric); and (3) fracture treatment (internal fixation, hemiarthroplasty, total hip arthroplasty). (The CCI is a measure of aggregate chronic disease burden that has been validated for predicting mortality as well as high health care costs.[23] The CCI is a weighted sum of numerous diagnoses [e.g., 1 point for congestive heart failure or diabetes without complications, 2 points for moderate or severe renal disease, 3 points for moderate or severe liver disease]. The CCI is used extensively in the medical literature for comorbidity adjustment.)

Annual subject enrollment was as follows: year 1 (n=16), year 2 (n=17), year 3 (n=20), year 4 (n=17), year 5 (n=33), year 6 (n=30), year 7 (n=30), year 8 (n=28), year 9 (n=26), year 10 (n=48), and year 11 (n=9). CT examinations were performed within 3 months of the hip fracture in 239/274 patients (87%), 3-12 months in 23/274 (8%), and more than 12 months in 12/274 (4%). The primary clinical indications for CT were to evaluate for fracture (157/274, 57%), vascular disorder (42/274, 15%), tumor (27/274, 10%), infection (24/274, 9%), or other conditions (e.g., abdominal pain) (24/274, 9%). For these patients, the primary diagnostic conclusions given in the CT reports were fracture (156/274, 57%), no acute derangement (63/274, 23%), active infection (18/274, 7%), active tumor (22/274, 8%), and vascular disorder (15/274, 6%). Scoliosis was incidentally observed in 41 of 274 patients (15%).

Mortality was determined using the National Death Index (NDI), which is a centralized database of death record information available from the National Center for Health Statistics at the United States Centers for Disease Control and Prevention. The NDI is updated annually, is considered a robust information source available to investigators (but not the general public), and is widely accepted as the reference standard for studies of mortality outcomes. In cross-checking NDI data with our hospital electronic medical records, we found that NDI data provided a more comprehensive accounting of mortality events, presumably because death often occurs outside the hospital.

CT Examination Protocol

Patients were scanned on one of five multidetector CT scanners (one 16-slice GE scanner, one 64-slice GE scanner, two 64-slice Siemens scanner, and one 128-slice Siemens scanner) that completed regular daily calibration using manufacturer supplied phantoms to ensure consistency in attenuation measurements. Detailed cross-evaluation of contemporaneous scanner records showed only slight systematic variance between vendors for water (HU = 0) and poly-methyl methacrylate (HU = 120) phantoms that bracket the normal attenuation of muscle. (For water, the average values recorded were

HU=3 for GE scanners versus HU = 1 for Siemens scanners. For poly-methyl methacrylate, the values recorded were HU = 123 for GE scanners versus HU = 124 for Siemens scanners. Of the 274 exams, 263 were performed on GE scanners.) An audit of the ACR phantom results recorded for all CT scanners used in this study showed consistent, close calibration (variability < 5%). Scans were performed routinely at 120 kV with a reference effective tube current of 220 to 260 mA. Beam collimation ranged from 20 to 40 mm, with all region-of-interest measurements made on 5-mm thick axial images windowed for soft tissue and using standard reconstruction kernels (standard body filter for the GE scanners and B40 for the Siemens scanners).. Intravenous contrast material was administered in 184 of 274 (67%), which resulted in enhancement of approximately 11 HU in the portal phase. We conducted sensitivity analyses, where all statistical models were stratified by administration of contrast material, and saw no significant alterations in the results (data not shown). No examinations were performed with orally-ingested contrast agents.

CT Image Measurements

Measurements were made independently on every CT scan by two readers (one faculty radiologist with 3 years of practice after fellowship training in musculoskeletal radiology and one fellow in musculoskeletal radiology) who were blinded to clinical data. Measurements were made with the routine clinical PACS software (iSite version 3.6, Philips Healthcare) used by all physicians at our institution.

Muscle cross-sectional area and attenuation were measured on axial images by outlining a free-hand region of interest around the circumference of the paravertebral muscles at the T12 pedicle level (on CT scans of the chest and abdomen) (**Fig. 1**) and at the L4 pedicle level (on CT scans of the abdomen and pelvis) (**Fig. 2**), using similar methodology as previously reported in liver transplant recipients [9] and patients with pancreatic adenocarcinoma [24]. This methodology involves measuring muscles

bilaterally which helps account for any muscle asymmetry associated with scoliosis. These measurements were used to calculate the following variables:

- *Thoracic muscle index* (TMI): the sum of left and right paravertebral muscle area (cm^2) divided by patient height (m^2).
- *Thoracic muscle density* (TMD): the average attenuation of the left and right paravertebral muscles, measured in Hounsfield units (HU).
- *Lumbar muscle index* (LMI): the total psoas muscle area (cm^2) divided by patient height (m^2).
- *Lumbar muscle density* (LMD): the average of left and right psoas muscle attenuation (HU).

Statistical Analysis

The measurements by the two readers were averaged for the purposes of the outcome analyses. Interreader reliability for TMI, TMD, LMI, and LMD were analyzed by calculating intraclass correlation coefficients and coefficients of variation.

Baseline clinical and demographic characteristics were summarized using descriptive measures, and comparisons of characteristics across genders were performed using t-tests for continuous variables and chi-square tests for categorical variables. The association of patient mortality versus baseline muscle metrics was performed using logistic regression and Cox proportional hazards models fitting each of the four muscle metrics standardized by gender as linear predictors. Each association was presented unadjusted; adjusted for age, gender, ethnicity, and BMI (Model 1); Model 1 plus ASA risk classification score (Model 2); and Model 1 plus CCI score (Model 3). Kaplan-Meier survival plots were produced using TMI and TMD stratified into standardized score categories: $Z \leq -1$; $-1 < Z \leq 1$; and $Z > 1$. All analyses were conducted using SAS v9.4 (SAS Institute, Cary, NC), and statistical estimates were

produced using confidence intervals. $p < 0.05$ was set as the definition of statistical significance. A non-significant trend was defined as p between 0.05 and 0.10.

RESULTS

Patient Characteristics

Of 274 patients, 193 (70.4%) were women. With respect to clinical features, women and men were similar in age, ethnicity, BMI, ASA classification, CCI score, fracture location, and fracture treatment (**Table 1**).

CT measurements of muscle *attenuation* (TMD and LMD) also were similar in women and men, but the muscle *size* metrics (TMI and LMI) were significantly lower in women than men ($p < 0.0001$).

Mortality

The overall mortality observed during this study was 55.1% (151/274 patients). This was not significantly different in men (55.6%; 45/81) compared to women (54.9%; 106/193) ($p = 0.9234$).

Table 2 shows cumulative mortality at time points ranging from 1 week to 8 years. The mean survival time was 21.2 months (SD 22.9), with a median survival time of 13.2 months (interquartile range, 3.1 to 31.8 months).

Mortality & CT Muscle Metrics

Kaplan-Meier survival analysis for TMI is shown in **Fig. 3**. Comparing patients at least 1 SD above and below the cohort median TMI, the patients with more muscle (higher TMI) had more favorable overall survival at each time point after hip fracture up through 7 years. Similarly, comparing patients with TMD measurements < 1 SD from the cohort median (indicative of fatty muscle) versus patients with TMD measurements > 1 SD (indicative of denser muscle), the overall survival was more favorable for patients with denser muscle at each time point (**Fig. 4**). Similar survival analysis for LMI and LMD are shown in **Fig. 5** and **Fig. 6**, respectively.

Table 3 shows the unadjusted and adjusted associations between baseline CT muscle metrics and mortality. The odds ratio for death was 0.66 (95% confidence interval [95% CI], 0.49 to 0.87) for each gender-specific standard deviation increase in TMI. For both men and women, a TMI increase of 2.0 cm²/m² was associated with the odds of death decreasing by 34% (unadjusted for comorbidities). Similarly, with each SD increase in TMI, the odds of death was significantly decreased even after adjusting for age, gender, ethnicity, and BMI (model 1 odds ratio, 0.69 [95% CI, 0.50 to 0.95]). This association between the TMI and decreased mortality also persisted after adjusting for the ASA classification (model 2 odds ratio, 0.70 [95% CI, 0.51 to 0.97]) and the CCI (model 3 odds ratio, 0.72 [95% CI, 0.52 to 1.00]).

The TMD also was an independently associated with the odds of death after adjusting for comorbidities. For example, for each gender-specific increase in the TMD (8.1 HU for women and 7.1 HU for men), the odds of death decreased by 31%, after controlling for age, gender, ethnicity, BMI, and ASA classification.

Correlation Between CT Metrics

Correlations between the four different CT-based muscle metrics were analyzed. The muscle cross-sectional *area* indexed for patient height had a moderate correlation (0.44; $p \leq 0.0001$) between the thoracic and lumbar spine. In comparing the *attenuation* of muscle in the thoracic and lumbar spine, there was also a moderate correlation (0.53; $p \leq 0.0001$). There was a small, but significant, correlation between the thoracic paravertebral muscle size and attenuation metrics (0.16; $p = 0.0170$). There was no correlation between the psoas muscle size and attenuation metrics (0.02; $p = 0.7579$). Interreader reliability was very good for all muscle metrics using intraclass correlation coefficients: TMI (0.85), TMD (0.93), LMI (0.90), and LMD (0.84).

DISCUSSION

Although sarcopenia commonly accompanies aging, disuse, and numerous diseases, the presence of muscle atrophy and fatty infiltration may be clinically occult [11]. The major findings in this study are that CT can be used to make muscle measurements (TMI and TMD) that are independently associated with future mortality in both men and women. These previously unused CT measurements therefore may have implications when planning surgery (e.g., deciding on pinning versus arthroplasty) and when determining expectations about outcomes with patients. To our knowledge, no prior studies have used CT to evaluate survival using muscle size and attenuation in elderly patients with hip fractures.

Patient Characteristics & Sarcopenia

The characteristics of patients in this study are similar to other studies of mortality in elderly hip fracture patients with respect to gender [13-15], age [13-15], BMI [13,14], ASA classification [13,15], CCI score [15], fracture location [13,15,16], and fracture treatment [13].

We chose to use CT to evaluate the T12 and L4 levels because this technique has been validated as prognostically significant for evaluation of the body “core” musculature in non-orthopaedic patients [9,25,26] and because these areas are commonly visualized on CT scans of the chest, abdomen, pelvis, and thoracolumbar spine. Although sarcopenia is considered an independent and potentially treatable risk factor for adverse outcomes [27], there is no universal agreement on diagnostic criteria [28]. Indeed, since the term was first introduced in 1989 [29], numerous different definitions for the diagnosis of sarcopenia have been proposed [30-32]. Not surprisingly, the prevalence of the sarcopenia varies widely, depending on the diagnostic criteria and patient population.

In elderly hip fracture patients, sarcopenia reportedly varies from 17% [33] to 71% [34] using bioelectrical impedance analysis (BIA) and from 22% to 95% [35] using DXA. Drawbacks of BIA as a diagnostic technique include that it is not specific to muscle and that alterations in body water (overhydration or dehydration) can lead to substantial errors [36]. While DXA is widely used for evaluating whole body lean mass, its use is not practical in acute hip fracture patients. In contrast, CT has been validated for the measurement of muscle size and attenuation [21], is widely available [19], and may be obtained in older patients presenting with hip fractures, often due to comorbid medical conditions. Although CT measurements of muscle size and attenuation have not been studied as risk factors for mortality in hip fracture patients, lower psoas cross-sectional area measured by CT has been associated with loss of independence upon discharge from the hospital (e.g., discharge to skilled-nursing facility or nursing home) [37].

Mortality & CT Muscle Metrics

The causes of death in older hip fracture patients are known to be multifactorial [14,38,39]. Our study showed increased mortality rates in patients with decreased muscle size and increased fatty infiltration at the T12 level. At the L4 level, psoas muscle fatty infiltration also showed a trend in predicting mortality. This difference may be related to the posterior paravertebral muscles being composed primarily of type I (slow-twitch) fibers which can undergo preferential atrophy with disuse, whereas the psoas muscle possesses a higher proportion of type II (fast-twitch) fibers.

Fatty infiltration in muscle can be quantified accurately by CT; an increase in lipid concentration of 1 g per 100 mL causes decreased CT attenuation by approximately 1 HU [40]. Previous investigators have suggested a threshold of \leq 30 HU for diagnosing fatty infiltration on CT after post-processing data using specialized thresholding software that requires additional time and training [21]. For our measurements, we used the routine PACS viewing software available to all the healthcare providers at

our hospital, and found muscle attenuation values in line with those expected for older patients. In our study population, the muscle attenuation measured in the thoracic and lumbar regions averaged 19 (\pm 8) HU and 22 (\pm 6) HU.

In addition to healthy muscle decreasing the risk of falls and fractures in the elderly [41], muscle may be an important indicator of physiologic reserve (“frailty”), given that muscle is the principal reservoir for amino acids to maintain protein synthesis and is normally the largest tissue in the human body [42]. Healthy muscle also is thought to play an important role in decreasing the risk of premature mortality by promoting insulin sensitivity and has systemic affects as an endocrine organ (e.g., anti-inflammatory roles) [42,43]. In light of these observations, numerous targeted therapies for sarcopenia are under investigation, including nutritional supplementation (e.g., vitamin D, branched chain amino acids) [44-46], physical activity (e.g., resistance exercise) [44, 47], and pharmacologic treatment [48] (e.g., androgen therapy [49], myostatin antibodies [50]).

The findings of this study must be interpreted in light of several limitations. First, no conclusion can be made about causality or generalizability to other clinical contexts from a retrospective investigation at a single institution. Second, we only studied hip fracture patients who had CT scans, which may have resulted in some unknown selection bias. Our cohort is a convenience sample of hip fracture patients, intended to mirror the real-world workflow and utilization of CT examinations of the chest, abdomen, and pelvis. Our approach is supported by the available literature that indicates that muscle measurements at T12 and L4 are valid proxies for assessment of generalized muscle loss in sarcopenic patients [1, 9, 10]. However, while body composition information on CT scans being obtained in our patients showed prognostic significance, we are not proposing routine CT scans on all hip fracture patients. Third, owing to our use of routine PACS viewing software, no post-processing of the CT data was performed. Without this additional thresholding step performed in other studies, our

investigation may have been less sensitive to changes in muscle size and attenuation. This is a possible reason that psoas size metrics were not a statistically significantly associated with survival. However, motivated by the desire to investigate a practical clinical tool, we used a methodology that did not rely on image post-processing by trained personnel on a separate workstation. Fourth, although there are numerous variables that can reduce the accuracy of quantitative evaluation based on HU (e.g., reconstruction kernel, scatter correction algorithms, tube voltage, patient girth), all CT scanners used in this study showed consistent, close calibration (variability < 5%), which compares favorably with the 4-5 HU variability reported for rigorously calibrated equipment [21]. Such “asynchronous calibration” enables the increasingly accepted “opportunistic” use of CT for measuring quantitative body composition phenotypes that may have diagnostic, prognostic, and therapeutic implications.

This study also has several strengths. First, in a relatively large pilot study of elderly patients with hip fractures, we have investigated both short-term and long-term mortality outcomes confirmed using the National Death Index, the most complete and reliable measure for this outcome. Second, we employed a widely utilized technique, CT, which has been validated for quantifying muscle atrophy and fatty infiltration, and applied it to older hip fracture patients. Most importantly, we established that muscle size and attenuation are independently associated with all-cause mortality in orthopaedic patients, even after accounting for the influence of age, gender, BMI, ethnicity, ASA classification, and CCI score. All-cause mortality is a widely accepted endpoint, is commonly regarded as a better measure than disease-specific mortality, and was intentionally selected as the outcome measure for this study. In our cohort of elderly hip fracture patients, the strength of association between sarcopenia and all-cause mortality is similar to that observed in previous studies of patients with cancer and liver disease [1, 25].

In conclusion, although not routinely analyzed in patients with hip fractures, CT examinations include core muscles on every scan. Using routine CT, simple quantitative measures of muscle -- size

and attenuation -- are feasible with routine PACS viewing software. We found muscle atrophy and fatty infiltration on CT of older patients with hip fractures are significantly associated with mortality in both men and women.

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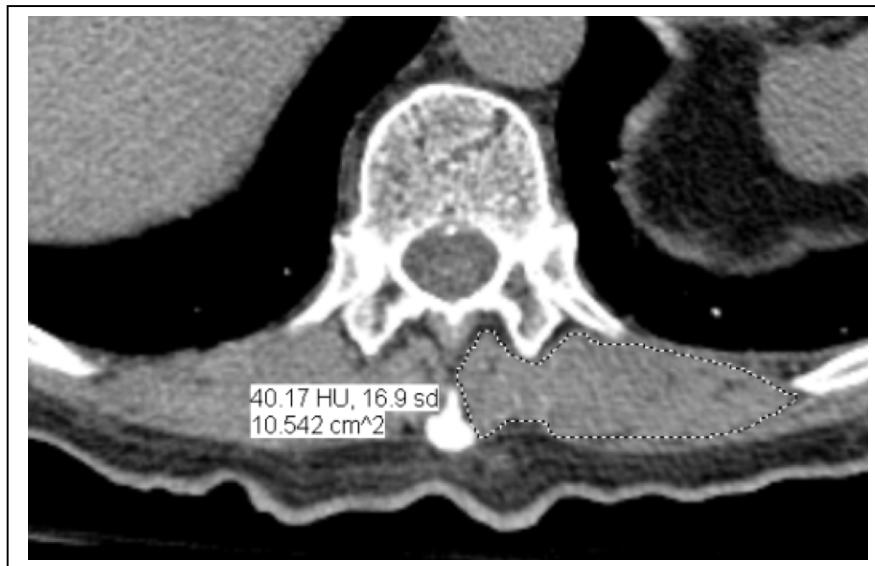
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FIGURES

Fig. 1. Axial CT image outlining the paravertebral muscles unilaterally at the T12 level in two 81 year-old women. **(A)** shows the cross-sectional area measuring 10.542 cm^2 and the average muscle attenuation measuring 40.17 Hounsfield units (HU). **(B)** shows the cross-sectional area measuring 6.7809 cm^2 and the average muscle attenuation measuring -4.25 HU. Although only left-sided measurements are shown, all study subjects had bilateral measurements that were then averaged.

(A)



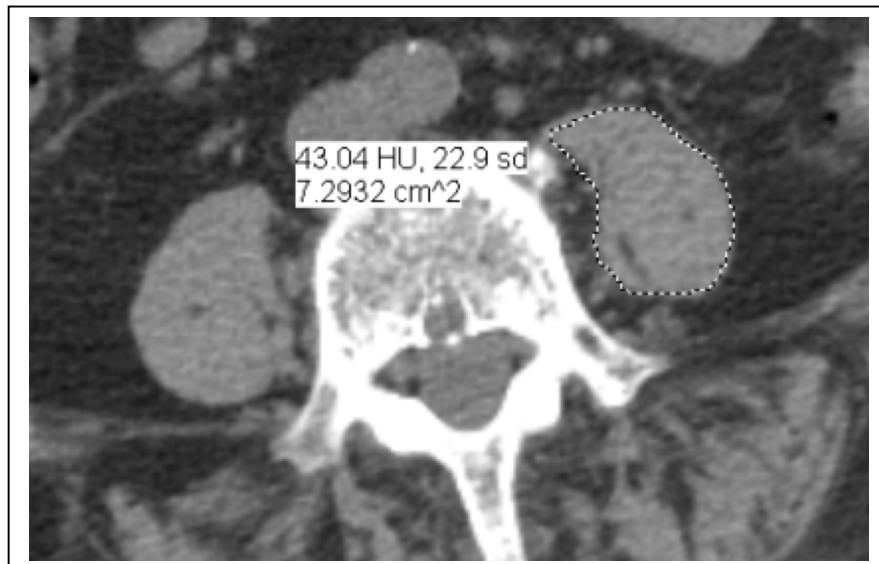
(B)



Fig. 2. Axial CT image outlining the psoas muscles unilaterally at the L4 level in two 74 year-old women.

(A) shows the cross-sectional area measuring 7.2932 cm^2 and the average muscle attenuation measuring 43.04 Hounsfield units (HU). **(B)** shows the cross-sectional area measuring 5.0935 cm^2 and the average muscle attenuation measuring 24.57 HU. Although only left-sided measurements are shown, all study subjects had bilateral measurements that were then averaged.

(A)



(B)

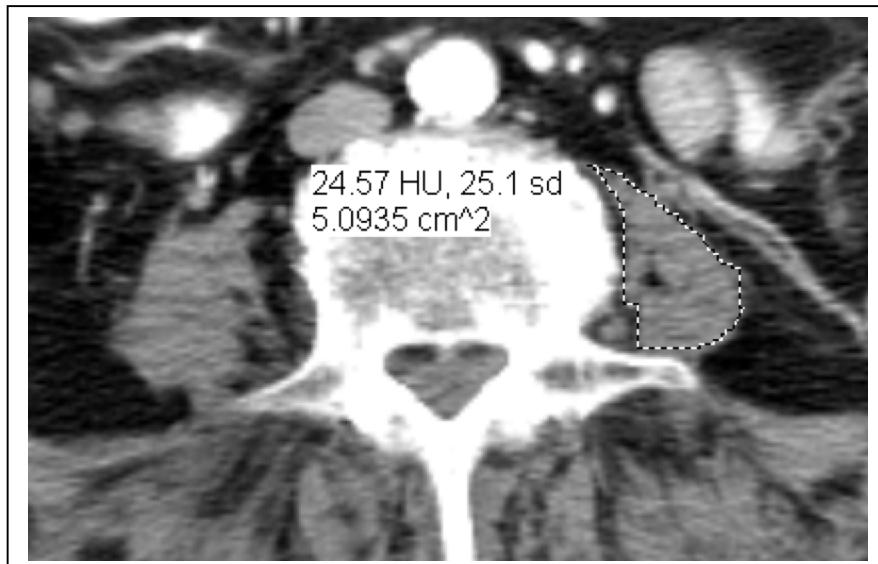


Fig. 3. Kaplan-Meier plot for patients stratified by thoracic muscle index measurements. Patient survival is compared among three groups, ranging from at least one standard deviation below the cohort median ($Z \leq -1$) to more than one standard deviation above the cohort median ($Z > 1$).

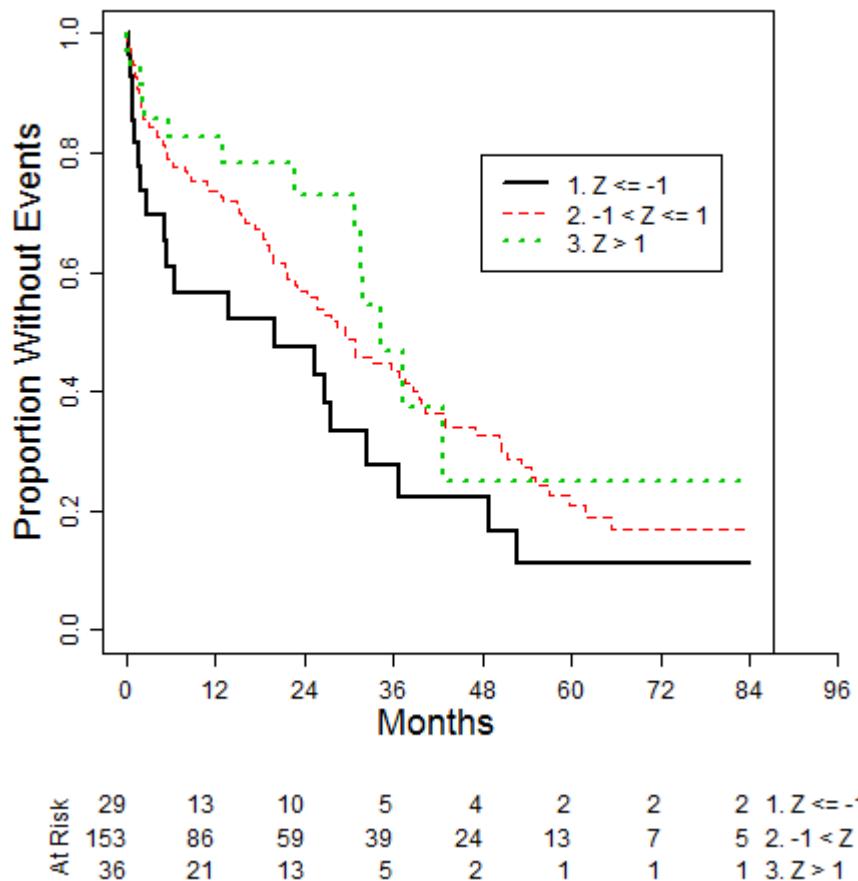
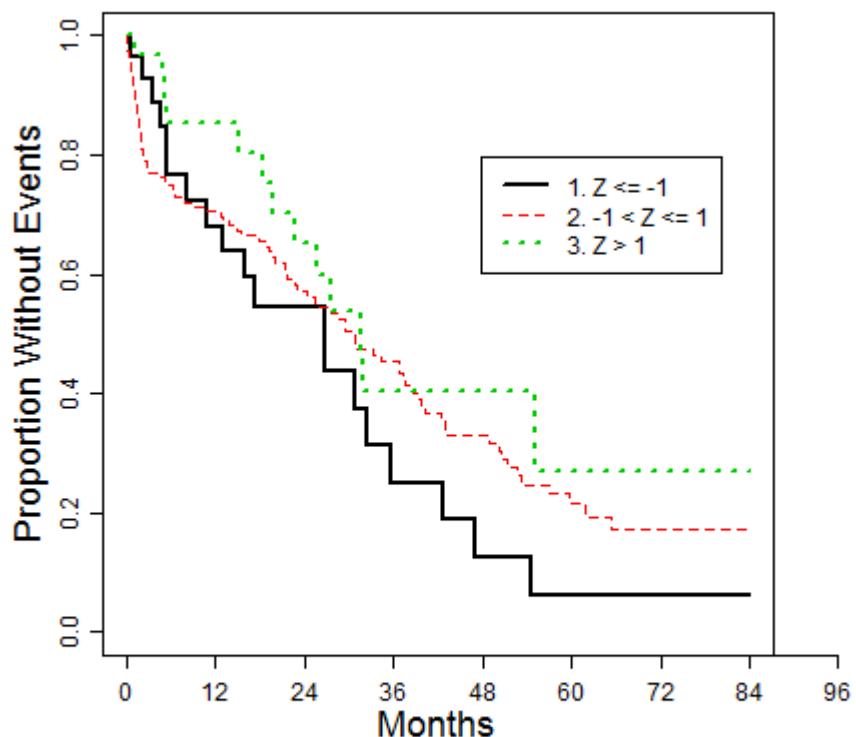


Fig. 4. Kaplan-Meier plots for patients stratified by thoracic muscle attenuation measurements. Patient survival is compared among three groups, ranging from at least one standard deviation below the cohort median ($Z \leq -1$) to more than one standard deviation above the cohort median ($Z > 1$).



	29	16	10	4	2	1	1	1	1. $Z \leq -1$
At Risk	158	88	61	43	24	13	7	5	2. $-1 < Z \leq 1$
	35	18	13	4	4	2	2	2	3. $Z > 1$

Fig. 5. Kaplan-Meier plots for patients stratified by lumbar muscle index measurements. Patient survival is compared among three groups, ranging from at least one standard deviation below the cohort median ($Z \leq -1$) to more than one standard deviation above the cohort median ($Z > 1$).

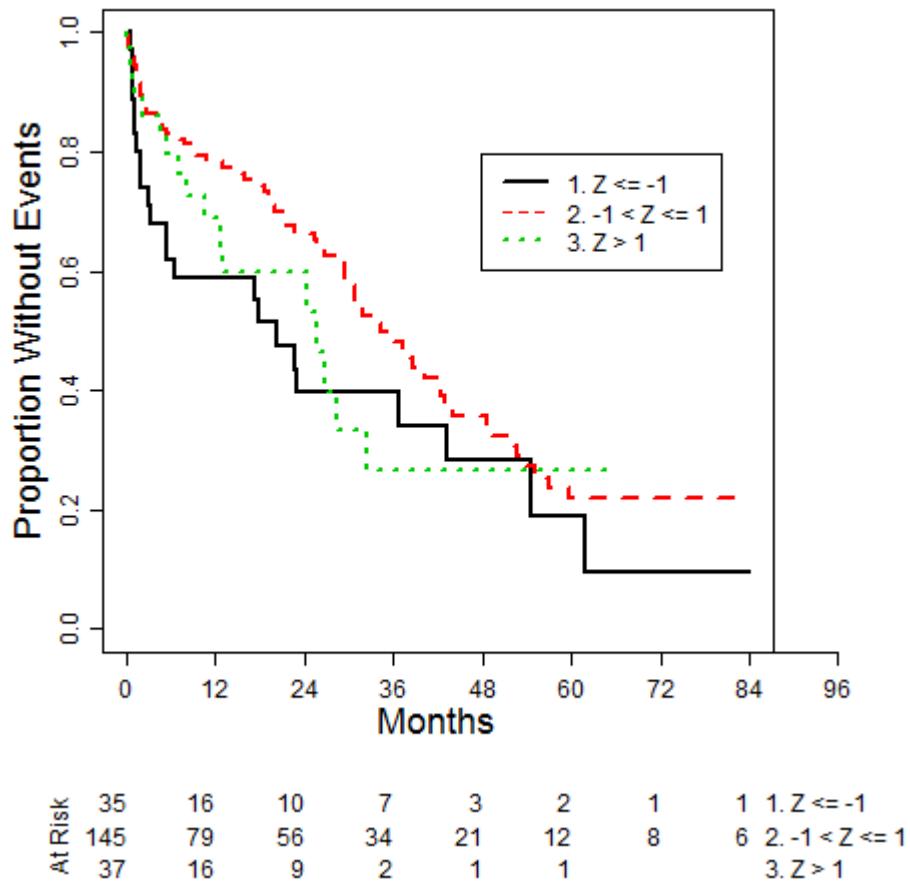
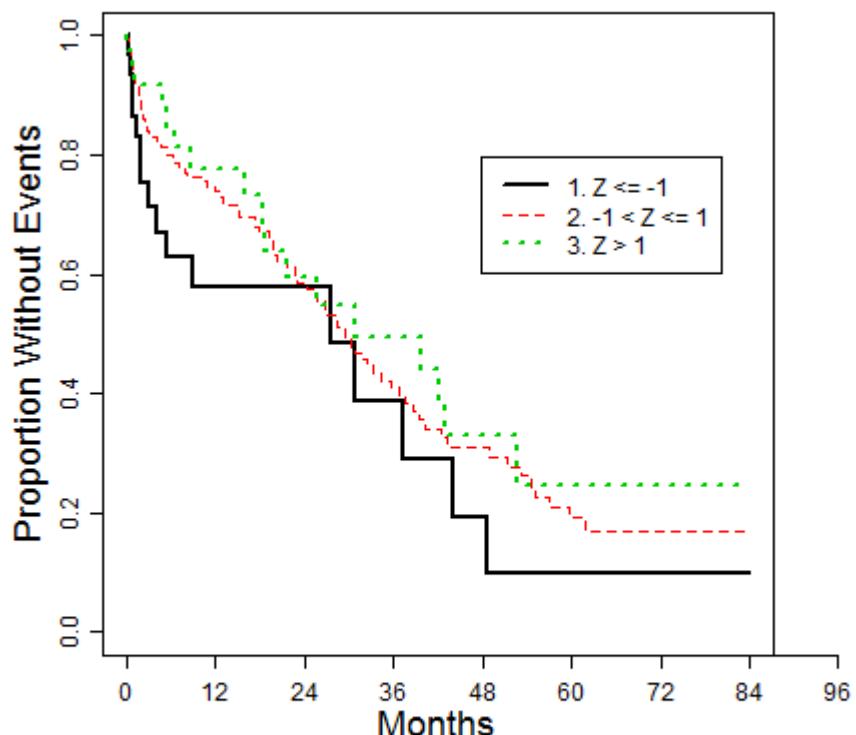


Fig. 6. Kaplan-Meier plots for patients stratified by lumbar muscle attenuation measurements. Patient survival is compared among three groups, ranging from at least one standard deviation below the cohort median ($Z \leq -1$) to more than one standard deviation above the cohort median ($Z > 1$).



	1. $Z \leq -1$	2. $-1 < Z \leq 1$	3. $Z > 1$
At Risk	31	10	6
	162	89	60
	38	19	13
	4	32	9
	2	19	4
	1	11	3
	1	5	3
	1	3	3
	1	1	1

TABLE 1. Patient characteristics

	Men	Women	All	
	n=81	n=193	n=274	P-value
<u>Demographics</u>				
Age (years)	80.5 ± 9.0	81.7 ± 8.0	81.3 ± 8.3	0.2587
Race/Ethnicity, n (%)				
White	57 (70.4)	129 (66.8)	186 (67.9)	0.7686
Hispanic	7 (8.6)	12 (6.2)	19 (6.9)	
Black	2 (2.5)	6 (3.1)	8 (2.9)	
Asian	5 (6.2)	20 (10.4)	25 (9.1)	
Other	10 (12.3)	26 (13.5)	36 (13.1)	
Body Mass Index (kg/m ²)	24.6 ± 4.7	24.1 ± 5.6	24.3 ± 5.3	0.4584
American Society of Anesthesiologists Score (1-6)	3.0 ± 0.6	3.1 ± 0.6	3.1 ± 0.6	0.4863
Charlson Comorbidity Index	3.0 ± 2.2	2.5 ± 2.0	2.6 ± 2.1	0.0507
<u>Fracture Location</u>				
Neck (%)	41 (50.6)	84 (43.5)	125 (45.6)	0.5501
Intertrochanteric (%)	35 (43.2)	94 (48.7)	129 (47.1)	
Subtrochanteric (%)	5 (6.2)	15 (7.8)	20 (7.3)	
<u>Fracture Treatment</u>				
Total Hip Arthroplasty (%)	3 (3.7)	8 (4.1)	11 (4.0)	0.3881
Hemiarthroplasty (%)	29 (35.8)	53 (27.5)	82 (29.9)	
Internal Fixation (%)	49 (60.5)	132 (68.4)	181 (66.1)	
<u>CT Muscle Metrics</u>				
Thoracic Muscle Index (cm ² /m ²)	8.6 ± 2.0	6.9 ± 2.1	7.4 ± 2.2	<.0001*
Lumbar Muscle Index (cm ² /m ²)	7.2 ± 1.9	5.4 ± 1.4	5.9 ± 1.7	<.0001*
Thoracic Muscle Attenuation (HU)	20.3 ± 7.1	18.1 ± 8.1	18.8 ± 7.9	0.0599
Lumbar Muscle Attenuation (HU)	21.6 ± 5.6	21.9 ± 6.5	21.8 ± 6.2	0.7990
Intravenous Contrast Material (%)	55 (67.9)	129 (66.8)	184 (67.2)	0.8644

Data are presented as means ± SD or n (%).

* p < 0.05

TABLE 2. Cumulative mortality over time in 274 geriatric hip fracture patients*

Follow-up Time	Cumulative Number of Deaths	Cumulative Number of At-Risk	Cumulative Mortality
1 week	6	266	2.2%
1 month	18	245	6.7%
3 months	45	206	17.2%
6 months	58	181	22.7%
1 year	70	142	28.3%
2 years	94	96	41.8%
3 years	117	59	56.9%
4 years	133	34	68.4%
5 years	144	20	79.5%
6 years	146	12	82.1%
7 years	146	9	82.1%
8 years	151	3	92.6%

* 151 deaths, 123 censored. Cumulative mortality rates estimated using the Kaplan-Meier product limit method.

TABLE 3. Unadjusted and adjusted* associations between baseline CT muscle metrics and mortality

	Thoracic Muscle Index	Thoracic Muscle Attenuation	Lumbar Muscle Index	Lumbar Muscle Attenuation
<i>Odds Ratios (95% Confidence Interval)**</i>				
Unadjusted	0.66 (0.49, 0.87)	0.77 (0.58, 1.01)	0.74 (0.56, 0.97)	0.92 (0.71, 1.20)
Model 1	0.69 (0.50, 0.95)	0.67 (0.49, 0.91)	0.98 (0.71, 1.34)	0.83 (0.63, 1.10)
Model 2	0.70 (0.51, 0.97)	0.69 (0.50, 0.94)	0.94 (0.68, 1.30)	0.85 (0.64, 1.12)
Model 3	0.72 (0.52, 1.00)	0.72 (0.53, 0.99)	1.00 (0.71, 1.39)	0.94 (0.70, 1.26)
<i>Hazard Ratios (95% Confidence Interval)**</i>				
Unadjusted	0.83 (0.70, 1.00)	0.82 (0.68, 0.98)	0.93 (0.75, 1.14)	0.84 (0.69, 1.02)
Model 1	0.82 (0.67, 1.00)	0.80 (0.65, 0.97)	1.03 (0.81, 1.31)	0.82 (0.67, 0.99)
Model 2	0.85 (0.70, 1.04)	0.82 (0.67, 1.00)	1.01 (0.79, 1.28)	0.84 (0.69, 1.01)
Model 3	0.86 (0.70, 1.04)	0.82 (0.67, 1.00)	1.01 (0.80, 1.29)	0.84 (0.69, 1.02)

* Model 1 adjustments made for age, gender, ethnicity, and baseline body mass index. Model 2 adjusted for all covariates in Model 1 plus the American Society of Anesthesiologists classification. Model 3 adjusted for all covariates in Model 1 plus the Charlson Comorbidity Index.

** Odds ratios and hazard ratios are presented per gender-specific standard deviation of each muscle metric.