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Association of Radiologic Indicators of Frailty With 1-Year Mortality in Older Trauma Patients

Opportunistic Screening for Sarcopenia and Osteopenia

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IMPORTANCE Assessment of physical frailty in older trauma patients admitted to the intensive care unit is often not feasible using traditional frailty assessment instruments. The use of opportunistic computed tomography (CT) scans to assess sarcopenia and osteopenia as indicators of underlying frailty may provide complementary prognostic information on long-term outcomes.

OBJECTIVE To determine whether sarcopenia and/or osteopenia are associated with 1-year mortality in an older trauma patient population.

DESIGN, SETTING, AND PARTICIPANTS A retrospective cohort constructed from a state trauma registry was linked to the statewide death registry and Comprehensive Hospital Abstract Reporting System for readmission data analyses. Admission abdominopelvic CT scans from patients 65 years and older admitted to the intensive care unit of a single level I trauma center between January 2011 and May 2014 were analyzed to identify patients with sarcopenia and/or osteopenia. Patients with a head Injury Severity Score of 3 or greater, an out-of-state address, or inadequate CT imaging or who died within 24 hours of admission were excluded.

EXPOSURES Sarcopenia and/or osteopenia, assessed via total cross-sectional muscle area and bone density at the L3 vertebral level, compared with a group with no sarcopenia or osteopenia.

MAIN OUTCOMES AND MEASURES One-year all-cause mortality. Secondary outcomes included 30-day all-cause mortality, 30-day readmission, hospital length of stay, hospital cost, and discharge disposition.

RESULTS Of the 450 patients included in the study, 269 (59.8%) were male and 394 (87.6%) were white. The cohort was split into 4 groups: 74 were retrospectively diagnosed with both sarcopenia and osteopenia, 167 with sarcopenia only, 48 with osteopenia only, and 161 with no radiologic indicators. Among the 408 who survived to discharge, sarcopenia and osteopenia were associated with higher risks of 1-year mortality alone and in combination. After adjustment, the hazard ratio was 9.4 (95% CI, 1.2-75.4; $P = .03$) for sarcopenia and osteopenia, 10.3 (95% CI, 1.3-78.8; $P = .03$) for sarcopenia, and 11.9 (95% CI, 1.3-107.4; $P = .03$) for osteopenia.

CONCLUSIONS AND RELEVANCE More than half of older trauma patients in this study had sarcopenia, osteopenia, or both. Each factor was independently associated with increased 1-year mortality. Given the prevalent use of abdominopelvic CT in trauma centers, opportunistic screening for radiologic indicators of frailty provides an additional tool for early identification of older trauma patients at high risk for poor outcomes, with the potential for targeted interventions.

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Invited Commentary

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In 2015, older adults accounted for nearly 30% of all trauma incidents, with accompanying case fatality rates ranging from 5.04 to 8.73 per 100—the highest among all age groups.[1] Risk of readmission and 1-year mortality among older trauma patients who survive to hospital discharge is independently associated with age.[2] Worse short-term and long-term outcomes in older trauma patients combined with the growing older adult population has spurred recent efforts to improve care for this population.[3-5] Indeed, care of older trauma patients is of great importance with national-level prioritization.

Frailty, defined as a gradual, age-related decline in function across multiple domains that increases susceptibility to disease and death, may be an important contributor to poor outcomes.[6] Distinct from age, disability, and comorbidity, frailty is a prevalent syndrome that independently confers worse outcomes across several medical and surgical populations, including the trauma population.[7,8] However, current frailty assessment instruments have notable limitations in the trauma population, owing to some patients' inability to complete functional testing or accurately answer medical history questions. Recent studies of frailty in trauma patients have relied on family or other surrogates to complete frailty assessment instruments on behalf of severely ill or injured patients.[8,9] Maxwell et al[8] note that "[s]creening for preinjury frailty…is feasible yet highly dependent on the presence of a surrogate respondent."

These limitations have led us to search for surrogate markers with comparable prognostic value, such as sarcopenia, defined by low muscle mass and impaired muscle function.[10-17] Sarcopenia is an independent predictor of ventilator-free days, intensive care unit (ICU)-free days, discharge disposition, and mortality among older high-acuity patients.[18-20] Like sarcopenia, osteopenia is intertwined in the pathophysiology of frailty and is associated with poor outcomes.[21-25] Frailty is associated with multiple falls and multiple fractures.[26] Low bone density greatly increases the risk of hip, spine, and extremity fractures,[27] the risk of subsequent fractures, and mortality.[28] Recent studies have repurposed cross-sectional imaging obtained for other reasons to retrospectively screen for sarcopenia or osteoporosis.[19,29] Thus, opportunistic use of imaging, specifically computed tomography (CT), can be applied in the trauma setting, where a large proportion of patients undergo CT evaluation as part of their routine trauma evaluation.

Given that radiologic evidence of sarcopenia and osteopenia are associated with underlying physical frailty through shared pathologic pathways and that CT imaging in the trauma setting is prevalent, opportunistic screening for sarcopenia and osteopenia is poised to fill a gap in frailty assessment. We hypothesize that sarcopenia and osteopenia will predict 1-year mortality in older trauma patients.

Key Points

Question Is opportunistic assessment of sarcopenia and osteopenia as radiologic indicators of frailty in the trauma population predictive of 1-year mortality?

Findings In this cohort study of 450 adults 65 years and older, sarcopenia, osteopenia, or both were present in more than half the cohort and were strongly associated with 1-year mortality, even after adjustment for other factors.

Meaning Screening for radiologic indicators of frailty may improve prognostic ability, which may help early risk stratification and the design of tailored interventions for this subset of older trauma patients.

Methods

Study Design, Setting, and Participants

In this retrospective cohort study, we queried the Washington State trauma registry for patients 65 years and older who were admitted to the ICU of Harborview Medical Center, a level I trauma center, from January 2011 to May 2014 following traumatic injury. Patients with abdominopelvic CT imaging obtained within 48 hours of admission were included. Patients with out-of-state addresses, with maximum head Abbreviated Injury Scale (AIS) scores of 3 or greater, or who died within 24 hours of admission were excluded. Additionally, patients with inadequate CT images were also excluded. Harborview Medical Center, an affiliate hospital of the University of Washington, is a county teaching hospital with 413 beds, including 89 ICU beds. Harborview Medical Center serves as the only level I trauma center in the state of Washington and is a regional trauma and burn referral center for the states of Alaska, Montana, and Idaho. The institutional review board for the University of Washington approved the study and provided a waiver of consent.

Exposure Variables

The primary exposure variables were sarcopenia and osteopenia. For sarcopenia, we used previously described skeletal muscle index thresholds of 52.4 cm^2/m^2 for men and 38.5 cm^2/m^2 for women, which are calculated from total cross-sectional muscle area at the L3 vertebral level.[30] Although other measures of sarcopenia have been described, such as psoas-only skeletal muscle index or muscle density, we chose this skeletal muscle index measure based on its well-established use throughout the literature.[31] Osteopenia was defined as an average Hounsfield units below 100.0 of the L3 vertebral body trabecular bone, a level selected based on previous work describing diagnosis of osteoporosis at L3.[29,32] Based on these thresholds, the cohort was divided into 4 frailty indicator groups: those with both sarcopenia and osteopenia (SR+OS), those with sarcopenia only (SR), those with osteopenia only (OS), and those with no sarcopenia or osteopenia (neither).

Image Analysis Protocol

Computed tomographic imaging was screened for adequacy using the hospital's native clinical radiology picture archiving and communication system. Images with capture windows that cut off any muscle, low-quality image, or images with any anatomical distortion (eg, abdominal wall hematoma, avulsion, foreign body, grade II or III L3 compression fracture, or the presence of hardware) were excluded. A single axial CT slice

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at the most superior L3 vertebral level, where trabecular bone fills the vertebral body, was selected and exported for further analysis using SliceOmatic version 5.0 (TomoVision).

For sarcopenia, total muscle cross-sectional area of skeletal muscle was measured as centimeters squared and based on muscle selection using a Hounsfield units threshold from −29.0 to 150.0. The rectus abdominis, internal and external obliques, transversus abdominis, quadratus lumborum, psoas major and minor, erector spinae, and latissimus dorsi (if present) were examined. Skeletal muscle index was calculated by dividing the total muscle cross-sectional area by height squared (cm^2/m^2).

For osteopenia, a 1.5-2-cm^2 region of interest was drawn over the trabecular bone of the L3 vertebral body, avoiding the sclerotic bone, fracture lines, hemangiomas, and traversing vessels, to calculate average Hounsfield units.

The 2 authors who conducted the image analysis (S.J.K. and M.D.) were blinded to patient outcomes during the analysis period. Absolute agreement between raters was confirmed via intraclass correlation coefficient calculations (mean coefficient, 0.996; 95% CI, 0.992-0.998; individual coefficient, 0.992; 95% CI, 0.984-0.996; $F = 266.51$; $P < .001$). An additional author (J.A.G.), who is an expert in emergency and trauma radiology, developed the image analysis protocol and verified accuracy and agreement.

Covariates

Patient demographic information (age, sex, race/ethnicity, and state of residence), injury characteristics (mechanism of injury, Injury Severity Score, and head, chest, and spine AIS scores), and clinical data (body mass index [BMI, calculated as weight in kilograms divided by height in meters squared] and ventilator requirement) were obtained from the trauma registry. Updated Charlson Comorbidity Index scores[33] were abstracted from patient medical records. Age was categorized into 3 groups: age 65 to 74 years, 75 to 84 years, and 85 years and older.[34] Race/ethnicity categories with less than 5 observations were combined into a single "other" category. Mechanism of injury was divided into 4 groups: penetrating, blunt-fall related, blunt-nonfall related, and other (eg, burn or bite). Injury Severity Score and maximum head AIS were treated as ordinal variables. Charlson Comorbidity Index scores were categorized into 3 groups: 0, 1, and 2 or more.

Outcome Measures

The primary outcome measure was all-cause 1-year mortality following hospital discharge. Death data were obtained from the Washington State Death Registry in October 2015 and censored at 1 year from hospital discharge date. Secondary outcome measures included hospital and ICU lengths of stay, discharge disposition, inpatient hospital cost (combined direct and indirect), 30-day readmission, and 30-day mortality. Length of stay and discharge disposition were obtained from the trauma registry. Cost data were obtained from the institution's finance office. Readmission data were obtained from the Washington State Comprehensive Hospital Abstract Reporting System.

Statistical Analysis

Data are reported as medians with interquartile range for continuous and discrete variables or as counts with frequencies for categorical variables. The Kruskal-Wallis test with Dunn post hoc test and Šídák correction were used for univariate noncategorical comparisons. Pearson χ^2 test or Fisher exact test were used for categorical comparisons, as appropriate. Tests for trends in outcomes among groups were conducted using Cuzick nonparametric method. Kaplan-Meier survival curves were constructed using 1-year survival after discharge as the dependent variable, then compared with the log-rank test with correction for multiple-group comparisons. Unadjusted and adjusted Cox proportional hazards regression models were constructed to assess the association of frailty indicators with 1-year mortality. Inclusion of variables in the adjusted model was performed in a purposeful fashion, selecting variables with known clinical influence, as well as those variables that approached significance ($P \le .20$). Interaction variables were tested based on bivariate correlations. We used variate P values and both Akaike and Bayesian information criteria to guide model optimization. Postestimation diagnostic tests were performed to confirm model fit and assumption adherence. Injury mechanism and discharge disposition were dichotomized into fall vs all other mechanisms and skilled-nursing facility/long-term acute care vs other disposition, respectively, for inclusion in the models. Post hoc sensitivity analysis was performed for age and Charlson Comorbidity Index scores to ensure variable categorization did not alter overall findings or interpretation. Patients with missing data were excluded from analysis. All statistical analyses were conducted with Stata/SE version 14.1 (StataCorp) using an a priori 2-sided significance level of $P < .05$.

Results

Between January 2011 and May 2014, 554 in-state residents 65 years and older were admitted to the ICU of Harborview Medical Center following traumatic injury who had head AIS scores of 2 or less and abdominopelvic CT imaging performed within 48 hours of admission. A total of 104 patients (18.8%) were excluded (57 [54.8%] because of muscle distortion on CT, 15 [14.4%] because of missing data, 14 [13.5%] because of low-quality CT images, 10 [9.6%] because of L3 fracture, and 8 [7.7%] because of other anatomical abnormality). Among the 450 patients included in this study, 289 (64%) had at least 1 radiologic indicator of frailty, including 74 (16.4%) in the SR+OS group, 167 (37.1%) in the SR group, 48 (10.7%) in the OS group, and 161 (35.8%) in the neither group. **Figure 1** shows the flow diagram of patient selection, exclusion, and exposure assignment. Patient and injury characteristics are listed in **Table 1**.

Short-term Outcomes

Comparisons among the 4 groups over 6 short-term outcomes are listed in **Table 2**. Although the initial comparison test for 30-day mortality was significant ($P = .05$), subsequent pairwise comparisons with correction for multiple comparisons did not reveal statistically significant differences

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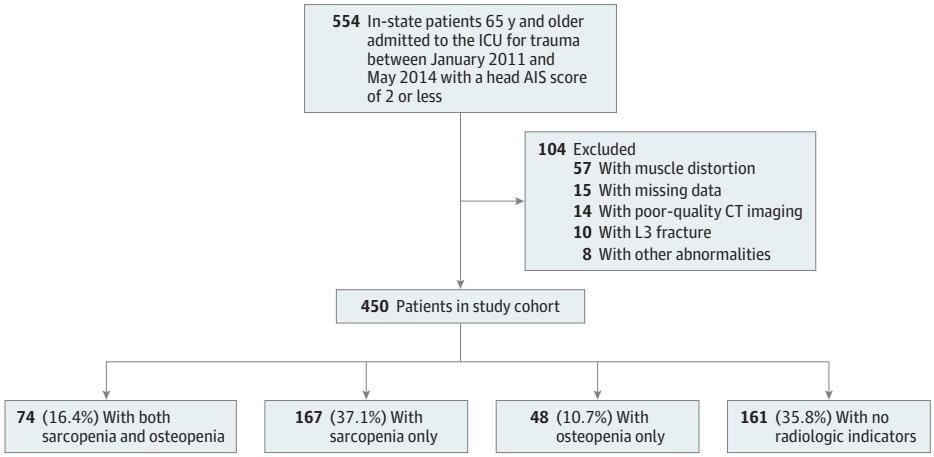
among the groups. However, a significant trend of increasing 30-day mortality was observed ($z = 2.2$; $P = .03$). Intensive care unit and hospital lengths of stay, discharge disposition, inpatient hospital costs (both direct and indirect), and 30-day readmission did not differ among the groups, nor were any significant trends observed. Because 42 patients died in the hospital and 3 patients could not be linked with the Washington State Comprehensive Hospital Abstract Reporting Sys-

Figure 1. Study Participant Flow Diagram.



AIS indicates Abbreviated Injury Scale; CT, computed tomography; ICU, intensive care unit.

Table 1. Baseline Patient and Injury Characteristics

Characteristic	No. (%)			
	Both Sarcopenia and Osteopenia (n = 74)	Sarcopenia (n = 167)	Osteopenia (n = 48)	No Sarcopenia or Osteopenia (n = 161)
Age, median (IQR), y	83 (75-89)	75 (69-83)	78.5 (72-83)	72 (68-78)
65-74	17 (23.0)	74 (44.3)	20 (41.7)	104 (64.6)
75-84	26 (35.1)	57 (34.1)	19 (39.6)	45 (28.0)
≥85	31 (41.9)	36 (21.6)	9 (18.8)	12 (7.5)
Female	27 (36.5)	51 (30.5)	34 (70.8)	69 (42.9)
Race				
White	69 (93.2)	142 (85.0)	41 (85.4)	142 (88.2)
Asian	5 (6.8)	14 (8.4)	2 (4.2)	10 (6.2)
Other	0	11 (6.6)	5 (10.4)	9 (5.6)
Hispanic ethnicity	0	1 (0.6)	3 (6.3)	3 (1.7)
BMI, median (IQR), y	25 (22-29)	25 (22-28)	27 (25-30.5)	29 (26-32)
Charlson Comorbidity Index score				
0	31 (41.9)	109 (65.3)	28 (58.3)	111 (68.9)
1	11 (14.9)	19 (11.4)	7 (14.6)	24 (14.9)
≥2	32 (43.2)	39 (23.4)	13 (27.1)	26 (16.2)
Type of injury				
Fall	48 (64.7)	86 (61.5)	19 (39.6)	68 (42.2)
Blunt, other than fall	26 (35.1)	79 (47.3)	29 (60.4)	81 (50.3)
Other	0	1 (0.6)	0	9 (5.6)
Penetrating	0	1 (0.6)	0	3 (1.9)
ISS, median (IQR), score	10 (6-17)	14 (10-20)	17 (11.5-22)	17 (12-22)
Maximum AIS score, median (IQR), score				
Head	0 (0-0)	0 (0-2)	0 (0-0)	0 (0-2)
Chest	1 (0-3)	2 (0-3)	3 (0-3)	2 (0-3)
Spine	0 (0-2)	2 (0-3)	0 (0-2)	2 (0-3)
Ever ventilated	23 (31.1)	42 (25.2)	18 (37.5)	58 (36.0)
Operative management	27 (36.5)	82 (49.1)	21 (43.8)	87 (54.0)

Abbreviations: AIS, Abbreviated Injury Scale; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); IQR, interquartile range; ISS, Injury Severity Score.

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Table 2. Short-term and Long-term Outcomes

Outcome	No. (%)				*P* Value	Test for Trend *P* Value
	Both Sarcopenia and Osteopenia (n = 74)	Sarcopenia (n = 167)	Osteopenia (n = 48)	No Sarcopenia or Osteopenia (n = 161)		
Any in-hospital complication	11 (14.9)	31 (18.6)	10 (20.8)	30 (18.6)	.85	.58
ICU LOS, median (IQR), d	3.2 (1.6-5.3)	2.5 (1.4-5.0)	2.7 (1.6-5.7)	2.7 (1.5-4.8)	.45	.63
Hospital LOS, median (IQR), d	7 (5-11)	7 (4-12)	6 (5-10)	7 (5-11)	.99	.99
Disposition						
Home	21 (28.4)	52 (31.1)	15 (31.3)	61 (37.9)	.61	NA
Home with home health	3 (4.0)	5 (3.0)	2 (4.2)	7 (4.4)		
Rehabilitation facility	1 (1.4)	9 (5.4)	0	7 (4.4)		
SNF/LTAC	43 (58.1)	79 (47.3)	26 (54.2)	73 (45.3)		
In-hospital death	6 (8.1)	19 (11.4)	5 (10.4)	12 (7.5)		
Other	0	3 (1.8)	0	1 (0.6)		
Unfavorable disposition[a]	49 (66.2)	98 (58.7)	31 (64.6)	85 (52.8)	.20	.10
Inpatient costs, median (IQR), US$ in thousands	32.4 (17.4-52.1)	31.6 (17.1-57.1)	30.3 (20.3-56.0)	33.6 (18.5-62.6)	.82	.25
Readmission within 30 d[b]	18 (26.5)	32 (21.8)	6 (14.0)	24 (16.3)	.23	.06
30-d mortality[c]	3 (4.4)	2 (1.4)	1 (2.3)	0	.05[d]	.03
1-y mortality[c]	11 (16.2)	17 (11.5)	4 (9.3)	1 (0.7)	<.001[e]	<.001

Abbreviations: ICU, intensive care unit; IQR, interquartile range; LOS, length of stay; LTAC, long-term acute care facility; NA, not applicable; SNF, skilled nursing facility.

[a] Defined as SNF, LTAC, or death.

[b] Among the 405 patients who survived to discharge and had readmission data available.

[c] Among the 408 patients who survived to discharge.

[d] After correction for multiple comparisons, no pairwise comparisons are significant.

[e] Only pairwise comparisons between the group with no sarcopenia or osteopenia and the other 3 groups are significant.

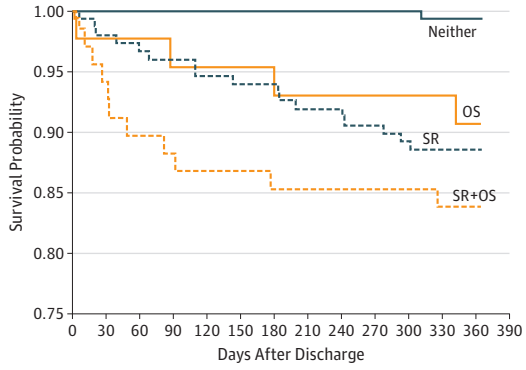
tem readmission database, only 405 patients (90.0%) were included in readmissions analysis.

One-Year Mortality

Among the 408 patients who survived to discharge, 33 (8.1%) died within 1 year. The frequency of 1-year mortality differed significantly among the groups (Table 2). Pairwise comparisons between groups revealed significant differences only when comparing the group without sarcopenia or osteopenia (1 death [0.7%]) with any of the remaining 3 groups (SR+OS, 11 [16.2%]; SR, 17 [11.5%]; and OS, 4 [9.3%]) (all $P < .001$). The trend toward higher mortality was also significant ($z = 4.33$; $P < .001$). Univariate Kaplan-Meier survival curves corroborated these observed differences (**Figure 2**; log-rank $\chi^2 = 19.6$; $P < .001$). Pairwise comparisons between groups again only revealed significant differences when comparing the curve of the group without sarcopenia or osteopenia with any of the remaining 3 curves.

Unadjusted Cox proportional hazards regression modeling revealed several patient and injury characteristics associated with 1-year mortality (**Table 3**). Notably, the risk of mortality was increased among patients with radiologic indicators of frailty compared with those patients without either indicator; this increased risk was observed in a gradated fashion (SR+OS: hazard ratio [HR], 26.7; 95% CI, 3.4-206.7; $P = .002$; SR: HR, 17.9; 95% CI, 2.4-134.4; $P = .005$; and OS: HR, 14.4; 95% CI, 1.6-128.7; $P = .02$). This trend of increasing risk was also seen with older age and higher Charlson Comorbidity Index scores. Fall-related injury was also associated with increased risk (HR, 2.1; 95% CI, 1.0-4.3; $P = .04$). Body mass index appeared to be mildly protective (HR, 0.9; 95% CI, 0.8-0.9; $P = .001$). None of the short-term outcomes were associated with increased risk of 1-year mortality.

Figure 2. Kaplan-Meier Survival Estimates Stratified by Radiologic Indicators of Frailty



Patients were divided into groups with both sarcopenia and osteopenia (SR+OS), with sarcopenia only (SR), with osteopenia only (OS), and with no radiologic indicators (neither), which were significantly different (log-rank $\chi^2 = 19.6$; $P < .001$). Pairwise comparisons with adjustment for multiple comparisons demonstrated significant differences between the neither group and each of the other 3 groups (SR+OS: $\chi^2 = 22.23$; $P < .001$; SR: $\chi^2 = 15.33$; $P < .001$; and OS: $\chi^2 = 10.02$; $P = .01$).

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Table 3. Unadjusted and Adjusted Survival Models for Risk of 1-Year Mortality

Characteristic	Unadjusted		Adjusted	
	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
Frailty criteria				
No osteopenia or sarcopenia	1 [Reference]	NA	1 [Reference]	NA
Sarcopenia and osteopenia	26.7 (3.4-206.7)	.002	9.4 (1.2-75.4)	.03
Sarcopenia only	17.9 (2.4-134.4)	.005	10.3 (1.3-78.8)	.03
Osteopenia only	14.4 (1.6-128.7)	.02	11.9 (1.3-107.4)	.03
Age, y				
65-74	1 [Reference]	NA	1 [Reference]	NA
75-84	4.2 (1.5-11.8)	.006	2.1 (0.7-5.9)	.17
≥85	8.6 (3.1-23.8)	<.001	2.9 (1.0-8.6)	.06
Male sex	1.3 (0.7-2.8)	.42	2.1 (1.0-4.7)	.06
BMI	0.9 (0.8-0.9)	.001	0.9 (0.8-1.0)	.003
Updated Charlson Comorbidity Index score				
0	1 [Reference]	NA	1 [Reference]	NA
1	3.0 (1.0-9.1)	.06	3.2 (1.0-10.0)	.05
≥2	8.1 (3.6-18.4)	<.001	6.0 (2.5-14.2)	<.001
Fall injury mechanism	2.1 (1.0-4.3)	.04	NA	NA
ISS	1.0 (0.9-1.0)	.32	NA	NA
Maximum AIS score				
Head	0.9 (0.6-1.4)	.72	NA	NA
Chest	0.8 (0.6-1.0)	.03	NA	NA
Spine	1.0 (0.8-1.2)	.83	NA	NA
Ever ventilated	1.2 (0.6-2.5)	.62	NA	NA
Operative management	0.9 (0.4-1.8)	.72	NA	NA
Any in-hospital complication	2.3 (1.1-4.9)	.02	2.9 (1.3-6.5)	.01
ICU LOS	1.0 (1.0-1.1)	.37	NA	NA
Hospital LOS	1.0 (1.0-1.0)	.41	NA	NA
Discharge to SNF/LTAC	1.5 (0.7-3.0)	.26	NA	NA
Readmission within 30 d	0.9 (0.4-2.2)	.83	NA	NA

Abbreviations: AIS, Abbreviated Injury Scale; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); HR, hazard ratio; ICU, intensive care unit; ISS, injury severity score; LOS, length of stay; LTAC, long-term acute care facility; NA, not applicable; SNF, skilled nursing facility.

After adjustment for age, sex, and comorbidities, radiologic indicators of frailty remained significant predictors of 1-year mortality (SR+OS: HR, 9.4; 95% CI, 1.2-75.4; *P* = .03; SR: HR, 10.3; 95% CI, 1.3-78.8; *P* = .03; and OS: HR, 11.9; 95% CI, 1.3-107.4; *P* = .03) (Table 3). Increased Charlson Comorbidity Index scores (score of 1: HR, 3.2; 95% CI, 1.0-10.0; *P* = .05; score of 2 or greater: HR, 6.0; 95% CI, 2.5-14.2; *P* < .001) also remained predictive. No interaction variables were found to be significant, nor did their inclusion significantly improve model performance.

Discussion

Among older trauma patients admitted to the ICU who survived to discharge, radiologic indicators of frailty were strongly predictive of 1-year mortality even after adjustment for age, comorbidity, and other factors. To our knowledge, this is the first study to demonstrate an association between sarcopenia or osteopenia and 1-year mortality in trauma patients and the first study to combine radiologic quantitation of sarcopenia and osteopenia as indicators of underlying physical frailty syndrome in lieu of traditional frailty assessment instruments.

Physical frailty, sarcopenia, and osteopenia are intertwined on a pathophysiologic level.[6,10-17,21-25] Traditional frailty assessment instruments only include criteria for sarcopenia and osteopenia implicitly through shared characteristics, such as weakness, weight loss, or falls.[35] Acknowledging that physical frailty encompasses a wider band of physiologic deficits compared with either sarcopenia or osteopenia, it is important to avoid conflating the 3 distinct conditions. However, just as the prognostic values of frailty assessment instruments are hinged on the presence or absence of several nonspecific criteria (eg, weight loss)—many of which corroborate concurrent sarcopenia, osteopenia, or both—so too do the presence of these radiologic indicators corroborate concurrent physical frailty. This is not to suggest that radiologic indicators can or should be used as a substitute for traditional frailty instruments. Recent evidence suggests that the formal addition of a sarcopenia variable improves the prognostic accuracy of traditional instruments.[36]

The relationships among sarcopenia, osteopenia, frailty, age, and comorbidity are exemplified in this study through the attenuation of HRs for radiologic frailty indicators in the adjusted Cox model. Note that the adjusted HRs for the SR+OS, SR, and OS groups are reduced compared with the unadjusted HRs. We suspect this represents the well-described interaction between frailty, age, and comorbidity, where many frail patients are concurrently and comparatively older with more comorbidities.

In Table 3, the adjusted HRs demonstrated significant increased risk of 1-year mortality with either sarcopenia or

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osteopenia. Naturally, we had expected an even higher risk of death for patients with both osteopenia and sarcopenia. However, patients in that group had similar HRs and 95% CIs. This could be a result of the adjustment for comorbidity, which was higher in the SR+OS group, or an artifact of low precision in the point estimates and broadly overlapping 95% CIs. Regardless, sarcopenia and osteopenia remain predictive of mortality in all groups with substantive HRs, even after adjustment.

More than half of the patients in this cohort exhibited at least 1 radiologic indicator of frailty, which is concordant with previous investigators' findings.[7,37] This underscores recent discussions of frailty as an important predictor of outcomes, given its prevalence in the general population.[6]

Interestingly, we did not find an association between radiologic indicators of frailty and short-term outcomes, which contrasts with other studies in the trauma population.[7,9,19] One explanation is related to our patient selection being limited to ICU admissions only. Given the physiologic burden of trauma requiring ICU admission, the trauma itself may direct hospital course and short-term outcomes. This overriding effect of trauma on other contributing factors is the reason why we excluded patients with maximum head AIS scores of 3 or above, as devastating head injuries often dictate prognosis. Although we aimed for a homogenous cohort by limiting ourselves to patients from the ICU, it would be interesting to know how radiologic indicators of frailty are associated with short-term and long-term outcomes in patients with lower acuity.

We also investigated the association of fall-related mechanism of injury between radiologic indicators of frailty and our study outcomes. Although there was a higher proportion of fall-related injuries with increasing frailty, in adjusted analysis, this mechanism was not predictive of mortality. In other words, after adjustment for underlying frailty, fall-related injury was not predictive of mortality.

The void in frailty assessment of acutely injured patients is the reason why we chose the ICU population. Many patients in this setting are unable to participate in functional testing, unable to complete self-report of deficits, or do not have surrogates who are able to accurately answer personal deficit-related questions (eg, attitude toward health, loneliness, or sexual activity).[38] While we used a research-oriented software package for our image analysis, clinically practical radiologic protocols to calculate muscle cross-sectional area and vertebral body density can be developed. Although the usefulness of such implementations remains prognostic at present, it is easy to imagine a risk-based intervention that uses radiologic indicators of frailty to guide patient selection, track progress, and lend outcome measures.

The findings from this study demonstrate an objective method of identifying radiologic indicators of frailty, which can be used when traditional frailty assessment instruments cannot. Radiologic evidence of sarcopenia and osteopenia may not diagnose physical frailty but are useful screening tools that may indicate concomitant physical frailty. It is our hope the findings from this study will advance the discussion regarding opportunistic imaging and frailty assessment.

Limitations

There are several limitations that should be considered when interpreting this study. We did not directly assess frailty using any traditional frailty assessment instrument. While previous investigators have undoubtedly shown the relationships and interactions between sarcopenia, osteopenia, and frailty,[10-14,19,21-23] we could not exhibit these relationships. This is primarily because of the retrospective nature of the study, which itself confers the accordant biases associated with retrospective research. We also did not assess preinjury disability, which is another important concurrent condition among older patients with frailty and comorbidity.[21] Our study was limited to the trauma population at a single level I center, with predominately white, non-Hispanic representation, which reflects the overall population diversity of Washington. Although the use of a single institution and robust registries associated with trauma research–facilitated data acquisition and integrity in this study, the specific population limits generalizability. There is also a selection bias introduced by analyzing only patients with an available abdominopelvic CT scan, which may have selected for a study cohort who clinically appeared to have more severe injuries. Finally, as this study captured CT imaging performed within the first 48 hours of admission, it is possible that fluid resuscitation in some patients might have increased the total muscle cross-sectional area measured. However, very few patients without measured sarcopenia died within a year, which suggests that the sarcopenia muscle index threshold used in this study performed well regardless of fluid status.

Conclusions

In a retrospective cohort study of older ICU trauma patients who survived to hospital discharge, sarcopenia and osteopenia as radiologic indicators of frailty were predictive of 1-year mortality. More than half of older trauma patients have sarcopenia, osteopenia, or both. Screening for radiologic indicators of frailty augments our current prognostic ability, which may help early risk stratification and the design of tailored interventions for this subset of older trauma patients.

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