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Original Contribution

Comparison of bedside screening methods for frailty assessment in older adult trauma patients in the emergency department

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ABSTRACT

Background: Frailty is linked to poor outcomes in older patients. We prospectively compared the utility of the picture-based Clinical Frailty Scale (CFS9), clinical assessments, and ultrasound muscle measurements against the reference FRAIL scale in older adult trauma patients in the emergency department (ED).
Methods: We recruited a convenience sample of adults 65 yrs. or older with blunt trauma and injury severity scores <9. We queried subjects (or surrogates) on the FRAIL scale, and compared this to: physician-based and subject/surrogate-based CFS9; mid-upper arm circumference (MUAC) and grip strength; and ultrasound (US) measures of muscle thickness (limbs and abdominal wall). We derived optimal diagnostic thresholds and calculated performance metrics for each comparison using sensitivity, specificity, predictive values, and area under receiver operating characteristic curves (AUROC).
Results: Fifteen of 65 patients were frail by FRAIL scale (23%). CFS9 performed well when assessed by subject/surrogate (AUROC 0.91 [95% CI 0.84–0.98] or physician (AUROC 0.77 [95% CI 0.63–0.91]. Optimal thresholds for both physician and subject/surrogate were CFS9 of 4 or greater. If both physician and subject/surrogate provided scores <4, sensitivity and negative predictive value were 90.0% (54.1–99.5%) and 95.0% (73.1–99.7%). Grip strength and MUAC were not predictors. US measures that combined biceps and quadriceps thickness showed an AUROC of 0.75 compared to the reference standard.
Conclusion: The ED needs rapid, validated tools to screen for frailty. The CFS9 has excellent negative predictive value in ruling out frailty. Ultrasound of combined biceps and quadriceps has modest concordance as an alternative in trauma patients who cannot provide a history.

1. Introduction

Trauma in the geriatric population is a significant public health burden, with mortality due to injuries constituting the 3rd leading cause of death in older adults [1]. There is an expected decline in physical function during normal aging; however, the rate of this decline is multifactorial and highly variable among patients. A subset of older adults develop the syndrome of physical frailty, which is characterized by weakness, easy fatigability, and weight loss [2]. Evaluation for physical frailty typically involves measures of functional parameters (e.g. gait speed, muscle strength), but tools that do not require activity are useful in trauma patients who often have injuries that preclude participation in testing [2-4].

In addition to overlapping symptoms and signs such as weakness and weight loss, the condition of sarcopenia (loss of muscle mass) is associated with physical frailty [5,6]. Accordingly, radiologic indicators of frailty such as sarcopenia are increasingly described in older patients. As an example, CT-identified sarcopenia has been associated with poor short and long-term outcomes in the trauma population [7,8]. However, the latter are dependent on the opportunistic availability of CT imaging, which is not always obtained in this population. The utility of ultrasound for diagnosing sarcopenia has been shown in community-dwelling older adults [9]. In the ED, however, no prior studies have assessed the use of bedside ultrasound measures of sarcopenia as a predictor of frailty.

Frailty is an important prognostic indicator of morbidity and mortality in the older patient [10]. At present no rapid bedside screening tool is

Abbreviations: CFS9, Clinical Frailty Scale; ED, emergency department; MUAC, mid-upper arm circumference; US, ultrasound; AUROC, area under receiver operating characteristic; AIS, abbreviated injury scale.

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accepted as a gold standard to distinguish frail from non-frail elders presenting to the ED [11,12]. Furthermore, little consensus exists on the most accurate frailty assessment instrument among researchers and societies dedicated to geriatric care. A recent study of several emergency departments in Canada suggests modest performance of the Canadian Study of Health and Aging Clinical Frailty Scale (CSHA-CFS), as well as physician overall impression of frailty, for ED patients with AUROCs of 0.637 and 0.667 respectively [13]. However, a comparison of a rapid pictorial based clinical scale with other screening modalities has not yet been performed in the trauma ED setting. Routine screening for frailty in Emergency Departments across the nation is not the norm. This is despite guidelines from governing bodies such as the American College of Emergency Physicians (ACEP) that underscore the opportunities and challenges in caring for this population in the ED [14]. In the older trauma patient, a variety of assessment tools are needed to reflect their capabilities after incurring an injury.

To begin addressing these gaps in clinical frailty assessment, we performed a prospective study to determine the diagnostic performance of pictorial, clinical and sonographic predictors of frailty in older adult trauma patients against the reference standard of the FRAIL score. The latter was chosen as the reference standard due to its ease of use, validation in several studies for use by patients or their surrogates, and endorsement by the frailty consensus working group [15].

2. Methods

2.1. Study design and setting

This study was IRB approved by the University of Washington School of Medicine Human Subjects Division. The protocol was a prospective cross-sectional study conducted over a six-month period during 2016. Study staff recruited patients meeting the following inclusion criteria: trauma victims age 65 years and older, slated for hospital admission, with the ability to self-consent or with a surrogate for consent. Exclusion criteria included: any head injury with Abbreviated Injury Scale (AIS 2005©, update 2008) severity of 3 or greater [16], amputees, limb asymmetry such as those caused by prior hemiplegic stroke leading to unilateral muscle wasting, neuromuscular muscle-wasting disorder as a known pre-existing condition, and skin lacerations or open wounds in the areas selected for ultrasound assessment as part of the study. This study was conducted at Harborview Medical Center, the single designated level 1 trauma center for the States of Washington, Northern Idaho, Northern Montana (MT), and Alaska (AK) that also serves as the community safety-net hospital for King County, Washington. All trauma patients presenting to the ED are enrolled in the HMC trauma registry, which was queried for injury characteristics, demographic information, and outcomes.

During their ED stay or within 72 h of admission, study participants or their surrogates completed the simple FRAIL scale [reference scale] [17], the pictorial 9-point Clinical Frailty Scale [3,18], dominant hand grip strength, dominant arm MUAC (mid upper arm circumference measure) [19,20], and ultrasound measures of easily accessible areas of skeletal muscle. The treating physician (Emergency Medicine Attending, Trauma Surgery Attending, or Trauma Surgery Fellow) assigned a CFS9 rating after their initial history and physical was performed. The treating physician's impression was obtained during their shift and was blinded to the patient self-impression and other measures of frailty and sarcopenia.

2.2. Simple FRAIL Scale

The Simple FRAIL Scale served as the gold standard for this study [17]. There are 5 questions regarding Fatigue (tired "all" or "most" of the time is an affirmative), Resistance (inability to climb 10 stairs unassisted is an affirmative), Ambulation (inability to walk 100 yards unassisted is an affirmative), Illness (the presence of 5 or more illnesses from a list of 11 common diseases that includes heart failure, arthritis and stroke is an affirmative), and Loss of Weight (weight loss >5% baseline over the prior year is an affirmative). Simple FRAIL Scale scores of 3 or greater are considered frail [15].

2.3. Clinical Frailty Scale

The CFS is a 9-point pictorial scale ranging from level 1 (robust) to level 9 (end of life) that is a 2 point extension of the CSHA-CFS [3,13]. The CFS9 has been studied in many settings, but not previously compared to clinical and ultrasound modalities in an ED setting. CFS9 scores of 4 or greater are considered vulnerable to frailty (score of 4) or frail (score of greater than 4) [3].

Each scale was conducted by the research assistant with values recorded and entered into a locally-hosted secure online database (Research electronic data capture [REDCap]) [21]. The results and interpretation of each scale were not provided to the patient or treating clinician.

2.4. Clinical measures

Clinical measures of dominant mid-upper arm circumference (MUAC) and hand-grip strength were measured in patients able to participate. MUAC was measured in accordance with standard procedure described by Lohman et al. [19]. The patient's arm was bent at the elbow to 90 degrees of flexion, and the midpoint between the acromion and upper border of the olecranon was marked. At this midpoint, a circumference was obtained with a flexible measuring tape on the patient's dominant arm, or both arms if patient was unable to discern a dominant arm. Grip strength of the dominant hand was measured using age and gender adjusted hand-grip dynamometer [Camry Scale Store, City Industry, CA] in patients able to participate and discern their dominant hand.

2.5. Ultrasound screening measures

This was a study in trauma patients who might have injuries in multiple locations. Accordingly, spatially distinct body areas were assessed by US. Subjects were scanned using a portable Sonosite Edge Ultrasound system (Sonosite Inc., Fujifilm Inc., Bothell WA USA) with a linear probe placed exactly perpendicular to the skin surface with very little compression to distort soft tissue. The subjects were scanned in the supine position with arms/legs at rest and toes facing the ceiling in order to avoid external rotation at the hip joint. Measures of skin-to-bone [including muscle and subcutaneous fat], and superficial layer of muscle fascia-to-bone [to discern muscle thickness alone] were performed for the following muscles: 1) *biceps* [approximately 2/3 of the distance between the acromion and the upper border of the olecranon]; 2) *quadriceps* [half way between the distance from the anterior superior iliac crest and the superior border of the patella]; 3) *right rectus abdominis* muscle [to the right of the linea alba, one probe's width (1 cm) superior to the umbilicus during deep inspiration]; and 4) *thenar* and *hypothenar* muscles of dominant and non-dominant hands. Still images were saved and later reviewed by an ultrasound fellowship trained emergency physician in a blinded fashion. Images were assessed for quality assurance, accuracy of caliper placement, and qualitative features associated with aging muscle including whether muscle was hyperechoic compared with adjacent subcutaneous fat. A subset of 8 subjects underwent ultrasound measures by two different study investigators to determine inter-rater reliability (by intra-class correlation coefficient) for the ultrasound screening exams.

Scans were performed by study personnel, which included two senior medical students and a senior resident physician. All were provided with a minimum of 1-hour training that included a lecture and hands-on practice of the scanning protocol on at least 5 healthy volunteers. The healthy volunteers were scanned by at least 2 study personnel for establishment of the inter-observer correlation coefficient for each area of ultrasound measurement.

Medical records from the Trauma Registry were abstracted for injury severity index (ISS), hospital length of stay, ICU admission and number of days, and discharge disposition to home, skilled nursing facility or death in hospital.

2.6. Statistical analysis methods

Sample size calculations were performed to power the ultrasound portion of the study. We assumed a baseline prevalence of low muscle mass of 40% among older adult trauma patients putting them at risk for frailty, we calculated a required sample size of 35 patients to detect a 25% decrease in biceps thickness (power 80%, alpha 0.05).

For analyses, we used as a reference standard the simple FRAIL scale value of 3 or greater (of a possible 5 points) was = Frail and Not Frail if <3 points. A CFS9 score of 4 or greater (of a possible 9 points) was = Frail and Not Frail if <4 points.

We constructed area under receiver-operating characteristic (AUROC) curves to evaluate performance of the CFS9 performed by the patient and CFS9 impression by the treating physician compared with our clinical reference standard of the simple FRAIL scale. Test characteristics, including sensitivity and specificity, were obtained from our AUROC curve analysis. In determining the best cut points for the CFS9, clinical tests, and ultrasounds measures, we maximized sensitivity while still maintaining specificity above 50%.

For the statistical analysis of ultrasound results, measures of biceps and quadriceps were analyzed using Random forests modeling by WEKA (Waikato Environment for Analysis version 3.8.1.), an ensemble machine learning method, which uses multiple learning algorithms to optimize the predictive classifier (frail or not frail). Given the small sample size using this approach, we were unable to calculate confidence intervals around the AUROC, nor were we able to discern whether biceps or quadriceps measures alone would be sufficient.

To determine inter-rater reliability of the ultrasound measurements for sarcopenia in a previously unstudied ED setting, an intra-class correlation coefficient was calculated for the test-retest reliability of ultrasound measures of muscle thickness in the above-listed key locations. Qualitative muscle assessment of whether the muscle was hyperechoic compared to adjacent fat was measured as a binary variable against the Simple FRAIL scale using the Fischer's exact test.

Statistical analyses were performed using SPSS vs. 20.0 (IBM, Armonk NY), R version 3.2.3 (R Core Team, Vienna, Austria, 2015). Comparisons of baseline characteristics in sub-groups were conducted using the Mann-Whitney *U* test for continuous, non-parametric data, and the Fisher's exact test (given the small sample size) for categorical data. Standard algorithms from the statistical literature were used to calculate likelihood ratios and their confidence intervals.

3. Results

3.1. Study population

Of the 98 eligible patients who were approached during our study period, 65 agreed to participate and were enrolled in the study. The simple FRAIL scale and self-reported CFS9 was performed in all 65 subjects. Due to concerns regarding recall of specific patients in a busy ED setting, attending scores were noted only if they were documented during the same shift. Accordingly, 46 subjects had both attending and self-reported CFS9 scores. Clinical and ultrasound measures were performed in all 65 subjects.

Characteristics and demographics of subjects with and without frailty are shown in Table 1. Diagnosis of frailty by FRAIL scale was made in 15 of 65 subjects who had a FRAIL scale score of 3 or greater, comprising 23% of our population. The mean ± SD age of the subjects enrolled was 79.5 (±7.36) years in the frail group and 76.8 (±8.38) in the not frail group ($P = 0.2656$), and 47%/50% were female in the frail/not frail groups, respectively ($P = 0.2254$). In this population, subjects deemed frail by the FRAIL reference standard had longer total and ICU hospital length of stay, were more likely to be discharged to a skilled nursing facility (SNF), and less likely to be discharged to home (all $P < 0.05$).

3.2. Clinical Frailty Scale

Subjects deemed frail (CFS9 ≥ 4) by CFS9 self-report and CFS9 physician were older, had longer total lengths of stay, were more likely to be discharged to a skilled nursing facility (SNF), and less likely to be discharged to home (all $P < 0.05$) as shown in Table 1.

When compared to the reference FRAIL scale, the Clinical Frailty scale (CFS9) had an AUROC of 0.91 [95% CI 0.84–0.98] when performed by the subject/surrogate and an AUROC 0.77 [95% CI 0.63–0.91] for the physician performed CFS as shown in Figs. 1 and 2, respectively. If both physician and subject provided scores less than 4, considered not at risk for frailty, the sensitivity and negative predictive value were 90.0% (54.1–99.5%) and 95.0% (73.1–99.7%), respectively. Using optimal cut-off points on the AUROC curve, the CFS9 by self-report had sensitivity of 91% and specificity of 57%, while CFS9 by physician had sensitivity of 74% and specificity of 46% [Table 2].

3.3. Clinical measures

Morphometric measures of muscle function and size were utilized to supplement questionnaires, pictorial images and ultrasound. Based on their relationship to frailty and sarcopenia, respectively, age/gender adjusted dominant hand grip strength and MUAC were evaluated using the two sample *t*-test and two sample Wilcoxon Rank sum/Mann-Whitney test. Notably, neither of these clinical measures showed a correlation with the reference FRAIL scale.

3.4. Ultrasound measures of thickness and quality

Point of care US to assess sarcopenia and correlate with frailty has not been previously evaluated in the older trauma population. In addition, these patients might have injuries in multiple locations. Accordingly, multiple muscles: biceps, quadriceps, rectus abdominis and thenar/hypothenar were measured. Of note, measurements included in this analysis included muscle thickness alone and muscle thickness including subcutaneous fat.

Ultrasound thickness measures of combined biceps and quadriceps (with and without subcutaneous fat) demonstrated an AUROC of 0.75, with sensitivity of 0.67 and specificity of 0.80 to predict frailty with the FRAIL scale [Table 2]. Given the small sample size, when analyzed alone, biceps muscle thickness and quadriceps muscle thickness did not show a statistically significant ability to be used an as independent predictor of frailty.

Ultrasound measures of thenar, hypothenar and abdominal wall musculature were evaluated using the two sample *t*-test and two sample Wilcoxon Rank sum/Mann-Whitney test. None of these muscles (whether subcutaneous fat was included or not) showed a correlation with frailty as determined by the reference FRAIL scale.

The appearance of muscle on ultrasound might reflect age-related changes, such as fatty infiltration, that have been reported in clinical studies [22]. In normal healthy muscle, the gray-scale appearance of muscle tissue appears at an equal level of echogenicity or is relatively hypoechoic (darker) compared to adjacent fat. We postulated that in our study population, frail patients would have muscle that appears hyperechoic (brighter) compared to the adjacent fat as a visual, qualitative correlation with frailty. We included a blinded review of whether the muscle in each of the saved images appeared hyperechoic on ultrasound compared with the adjacent hypoechoic fat. Qualitative assessment of muscle appearance of the biceps and quadriceps were

Table 1
Patient characteristics and outcomes.

	Simple Frail Score							Clinical Frailty Scale - subject							Clinical Frailty Scale - physician						
	Frail			Not Frail			P-value	Frail			Not Frail			P-value	Frail			Not Frail			P-value
Patients N	15			50				21			44				23			23			
Age mean (sd)	79.5	7.36		76.8	8.38		0.2656	82.4	7.64		75	7.38		**0.0004**	81.2	8.69		72.2	6.47		**0.0003**
Age 65–74	4			22			0.1208	3			23			**0.0027**	5			16			**0.0012**
Age 75–84	7			18			0.1783	9			16			0.1880	9			6			0.1612
Age 85+	4			10			0.2299	9			5			**0.0052**	8			1			**0.0102**
Female N (%)	7	47%		25	50%		0.2254	12	57%		20	45%		0.1434	10	43%		9	39%		0.2251
Race [A/P/W][a] N (%)	A	2	13%	A	6	12%	0.3306	A	2	10%	A	6	14%	0.2937	A	2	9%	A	4	17%	0.2392
	P	0	0%	P	1	2%	0.7692	P	0	0%	P	1	2%	0.6769	P	0	0%	P	1	4%	0.5000
	W	13	87%	W	43	86%	0.3281	W	19	90%	W	37	84%	0.2517	W	21	91%	W	18	78%	0.1591
Ethnicity[b] [H/N] N (%)	H	1	7%	H	0	0%	0.2308	H	1	5%	H	0	0%	0.3231	H	0	0%	H	0	0%	1.0000
	N	14	93%	N	50	100%	0.2308	N	20	95%	N	44	100%	0.3231	N	23	100%	N	23	100%	1.0000
ISS mean (sd)	15.9	18.2		12.3	6.7		0.2449	15.4	15.9		12.2	6.6		0.2543	15	15.5		12.5	5.97		0.4742
LOS days (sd)	8.33	6.65		4.7	3.56		**0.0072**	7.76	6.36		4.47	3.17		**0.0069**	6.83	6.3		3.4	2.44		**0.0190**
ICU LOS hours (sd)	112.1	103		52.46	36		**0.0009**	75	81.7		61.5	45.2		0.3938	80.1	79.8		53.1	47.2		0.1695
Outcome [in hospital mortality] N (%)	1	7%		0	0%		0.2308	1	5%		0	0%		0.3231	1	4%		0	0%		0.5000
Hospital disposition [HH/HOME/MORGUE/	HH	2	13%	HH	4	8%	0.2928	HH	3	14%	HH	3	7%	0.2133	HH	1	4%	HH	1	4%	0.5111
NA/OACF/SNF] N (%)	HOME	2	13%	HOME	31	62%	**0.0009**	HOME	4	19%	HOME	29	66%	**0.0004**	HOME	8	35%	HOME	18	78%	**0.0029**
	MORGUE	1	7%	MORGUE	0	0%	0.2308	MORGUE	1	5%	MORGUE	0	0%	0.3231	MORGUE	1	4%	MORGUE	0	0%	0.5000
	NA	0	0%	NA	1	2%	0.7692	NA	1	5%	NA	0	0%	0.3231	NA	0	0%	NA	1	4%	0.5000
	OACF	0	0%	OACF	1	2%	0.7692	OACF	0	0%	OACF	1	2%	0.6769	OACF	1	4%	OACF	0	0%	0.5000
	SNF	10	67%	SNF	13	26%	**0.0047**	SNF	12	57%	SNF	11	25%	**0.0099**	SNF	12	52%	SNF	3	13%	**0.0047**

ISS = Injury Severity Score, LOS = length of stay, ICU = Intensive Care Unit. HH = home health, NA = died in ED or was discharged from ED and not admitted, OACF = transferred to another acute care facility, SNF = Skilled Nursing Facility. Bold = $p < 0.05$, frail versus not frail.

[a] Race: A = Asian, P = Pacific Islander, W = White; no Blacks participated in the study.

[b] Ethnicity: H = Hispanic, N = non-Hispanic.

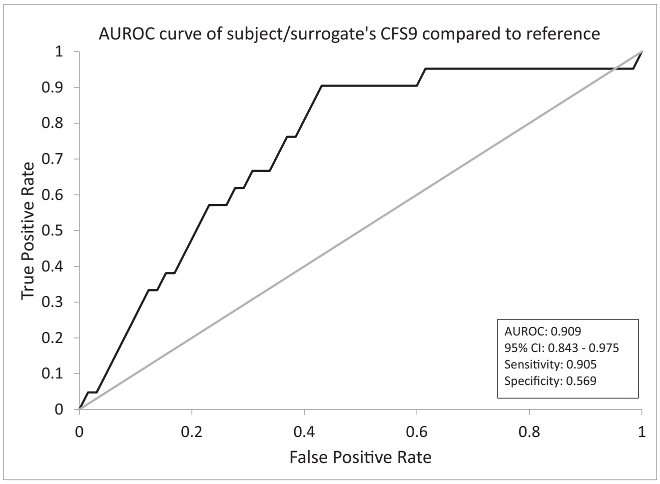

Fig. 1. AUROC curve of subject/surrogate's Clinical Frailty Score (CFS9) compared to reference. AUROC = area under receiver operating characteristic.

assessed as a binary variable (hyperechoic compared to adjacent fat, or not hyperechoic compared to adjacent fat). The appearance of muscle did not correlate with the reference FRAIL scale in either the biceps or the quadriceps as measured by the Fishers Exact test.

Average Intraclass correlation coefficients (ICC) were calculated for a subset of 8 subjects evaluated by 2 different investigators. Ultrasound measures of the bicep, anterior thigh/quadriceps muscle thickness were acceptable with ICC of the bicep as 0.946 [95% CI 0.755–0.989] and ICC of the thigh as 0.955 [95% CI 0.503–0.997]. ICC of the abdominal (rectus muscle thickness) musculature was possibly acceptable [ICC = 0.706, 95% CI −0.328–0.94] and the thenar/hypothenar measures were considered to have poor ICC [ICC = 0.403, 0.554 respectively].

4. Discussion

We sought to find a simple and rapid tool to identify frailty in older trauma patients in the ED. A pictorial tool, clinical measures, and point of care US measures of muscle thickness were correlated against a reference FRAIL scale. Examination of the study population, their age, total hospital and ICU length of stay and their discharge disposition indicated that those identified as frail by the FRAIL scale were indeed a subset of patients that could benefit from early identification in the ED. Instituting interventions, such as geriatrics consultation and multidisciplinary

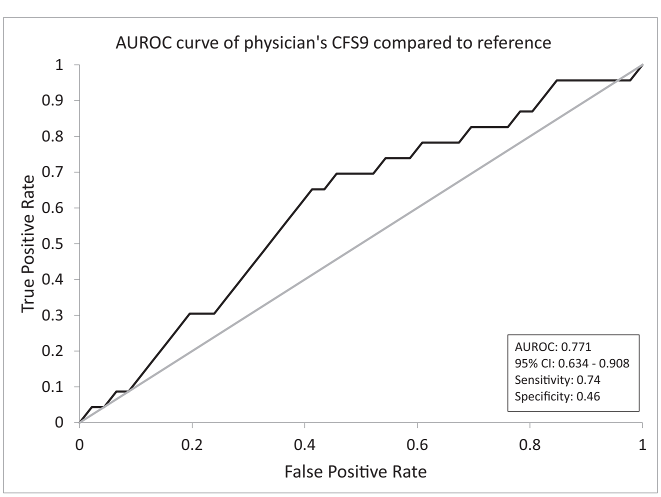

Fig. 2. AUROC curve of physician's Clinical Frailty Score (CFS9) compared to reference. AUROC = area under receiver operating characteristic.

Table 2
Diagnostic performance characteristics of the Clinical Frailty Scale (CFS9) and the combined ultrasound measure against reference standard.

	AUROC	95% confidence interval	Sensitivity	Specificity
CFS9 Subject	0.91	0.843–0.975	0.91	0.57
CFS9 Physician	0.77	0.634–0.908	0.74	0.46
Ultrasound (Bic/Quad)	0.75	*	0.67	0.80

CFS9 Subject was the subject/surrogate's self-assessed CFS9 score. CFS9 Physician is the physician's assessment of the patient on the CFS9 pictorial scale. Ultrasound (Bic/Quad) represents the analysis of the combined ultrasound measures for bicep and quadriceps. *We were unable to calculate CI for AUROC of ultrasound measures given random forest statistical model limitations.

evaluation including social work, at the point of triage in the ED is increasingly incorporated in patient centered care [23,24].

Of the assessments evaluated against the FRAIL scale, we found that the CFS9 score was a statistically significant and accurate predictor of frailty in our study population. In terms of patient characteristics, this pictorial test identified older patients who were more likely to have a long hospital stay and go on to skilled nursing home care. Moreover, the CFS9, which is sometimes equated to a "gestalt" tool, outperformed morphometric measures and bedside ultrasound screening for sarcopenia as correlates to the reference FRAIL scale. CFS9 performance in this study also had better sensitivity for frailty than the performance of the ISAR (Identification of Seniors at Risk) screening tool for adverse events, developed in 1999 as a self-report screening tool for health in older ED patients, and referenced in the ACEP Geriatric Emergency Guidelines [14,25].

Our findings also demonstrated that the ability of CFS9 to identify frailty is magnified when both the patient and the care provider provide a CFS9 score of 4 [vulnerable] or greater. The positive and negative predictive value in our older trauma population suggests that using the CFS9 in this fashion presents an exciting opportunity for additional avenues of study. A recent study utilizing the CFS9 in the ED showed correlation with future functional decline in community-dwelling seniors who present with minor injuries [13]. The CFS9 also predicts late mortality in older patients receiving transcatheter aortic valve replacement [26]. The data in this study complements these earlier works, as well as those utilizing the more detailed Trauma Specific Frailty Index (TSFI), in the older population presenting with acute injuries [27]. Taken together, these results indicate that screening for frailty among trauma patients in the ED is possible and desirable [28].

The key difference between our study and previous research on frailty screening in the ED is the comparison to a reference FRAIL scale of: a pictorial frailty scale, clinical measures, and ultrasound assessment of muscle thickness in target muscle groups at risk for sarcopenia. The addition of clinical measures, such as dominant hand grip strength and MUAC is warranted, but not always feasible in a trauma population. We note that these measures did not show correlation against the reference FRAIL scale. This is not surprising for grip strength given the dependence of this test on patient factors, such as awareness and motivation, which are difficult to incorporate consistently in the ED. Furthermore, MUAC measurements may have limited utility in this patient population. Whereas MUAC is a well-validated tool to assess undernutrition in children, especially in resource-limited environments such as Low and Middle-income countries (LMIC) [29], the high prevalence of obesity in the US population likely limits its utility in older adults.

In contrast to clinical studies, we found that US does provide an opportunity to correlate muscle thickness, a predictor of sarcopenia, with a reference FRAIL scale in patients for whom no history is available. Prior studies of ultrasound muscle mass [not thickness] have demonstrated correlation of muscle mass in quadriceps and biceps to frailty in community dwelling populations [30], but associations with muscle thickness as measured by non-radiology providers in the ED have not been previously performed. In our study, which was powered to find a 25% decrease in biceps thickness, the test characteristics for ultrasound measurement of combined biceps and quadriceps muscle thickness demonstrated a link between sarcopenia and frailty. The discriminatory power of the limb muscle thickness was not strong enough to displace the CFS9 in many patients, but US could have great utility in patients who cannot self-report or do not have a surrogate to report a CFS9. In this context, ultrasound assessment may play a larger role in frailty screening. Further studies with larger numbers of patients are warranted to evaluate whether alternative US measures such as muscle:fat ratio or cross-sectional area are more highly associated with frailty.

Our prospective study has several limitations. First, the study was performed at a single institution that serves as the county safety-net hospital and the region's only level 1 trauma center. In addition, the ethnicity and race reflected that of King County, which limits generalizability. We also note that the prevalence of frailty [23%] in our subject population was initially lower than we anticipated. We mitigated this result by enrolling patients above our initial required sample size to ensure power sufficient to perform data analysis. In addition, the ultrasound portion of our study had several limitations, which may have affected detection of subtle changes in muscle. Most subjects received intravenous fluids as we allowed up to 72 h for enrollment to improve recruitment. Fluids might have contributed to edema in some subjects, thereby potentially altering muscle thickness measures by US and MUAC. One statistical limitation may be the use of a random forests approach for analysis of the ultrasound measurement data. Given the small sample size, further study may be necessary for concrete conclusions. Lastly, the qualitative review of whether muscle appeared abnormally bright or hyperechoic on ultrasound was secondarily analyzed by an ultrasound expert on recorded images, not by study personnel at the bedside. Future studies of point of care sonography that focus on the quadriceps and biceps, and analyses of both muscle quality and area rather than thickness, are warranted.

In conclusion, our findings suggest the pictorial CFS9 is a superior screening tool compared with other clinical and sonographic measures of physical frailty in an older trauma population presenting to the ED. The predictive power of CFS9 for frailty is optimized when both patient and treating physician concur that the patient has a CFS ≥ 4. Conversely, if both physician and subject provided CFS scores <4 there is high sensitivity and negative predictive value for frailty. Ultrasound measures of muscle thickness in the biceps and quadriceps, when combined, are a modest predictor of frailty and might be of clinical utility in patients unable to provide any history. Future research should continue to identify optimal methods to rapidly identify frail older trauma patients and implement early interventions such as geriatrics and multidisciplinary consultation at the point of triage in the ED.

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Declaration of interest

The authors have no disclosures or conflicts of interest.

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